6.3 Human influence on climate

Naturally occurring factors can cause climates to change. World climates changed long before humans were around. However, scientific evidence suggests that human activities such as agriculture, urbanisation and industrialisation have influenced climate. Building cities and clearing land for agriculture change climate on a local scale. Increased use of fossil fuels, industrialisation and deforestation have had a more widespread effect on the world's climate.

INQUIRY science 4 fun

Melting icebergs

What effect do melting icebergs and glaciers have on sea levels?

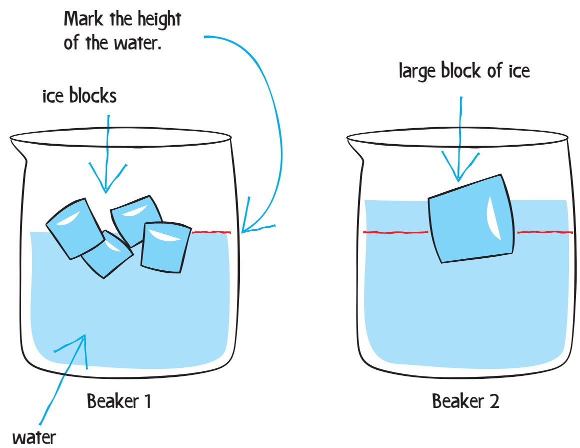
Yes

Collect this …

- 2 glasses or beakers of equal size and large enough to contain 300 mL of water each
- 4–6 small ice blocks that have been made using 100 mL of water
- large block of ice made from 100 mL of water
- yoghurt container or similar in which to create the block of ice
- measuring jug
- 400 mL water

Do this …

1. Place the small ice blocks in one of the empty beakers and half fill it with water. Mark the water level on the side, as shown in the diagram. This beaker represents the ocean in which icebergs are floating.
2. Pour water into the second beaker until it is at the same level as in beaker 1. Mark the water level on the side. This beaker represents the ocean into which a glacier is flowing.
3. Place the large block of ice into beaker 2. The ice block represents a large chunk of ice that has broken off a glacier in Antarctica.



4. When all the ice has melted, mark the new water levels on both beakers.

Record this …

Describe what happened.

Explain whether icebergs or the melting glaciers will contribute most to sea level rises.

Is the Earth warming?

All indications are that Earth is in a period of warming. According to the World Meteorological Organization (WMO), the decade of the 2000s (2000–09) is the warmest on record. This is shown in Figure 6.3.1.

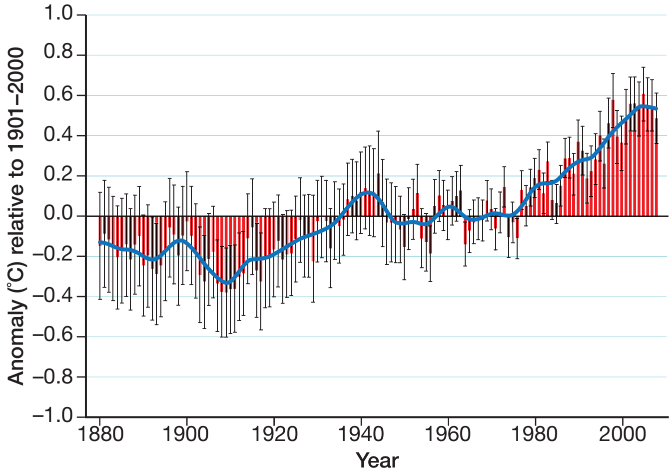


Figure 6.3.1 The zero line on this graph is the average global surface temperature for the years 1901–2000 which is 14°. The blue line indicates the number of degrees Celsius above or below that average, for the mean temperature in any year. For example, in 2000 the temperature was 0.4°C above the long-term average. In 2009, it was 0.44°C above the long-term average of 14°C.

The Intergovernmental Panel on Climate Change (IPCC) conducted a comprehensive review of the scientific evidence for climate change. In 2007, the IPCC reported:

- increases in global average air and ocean temperatures
- widespread melting of snow and ice (Figure 6.3.2)
- rising global average sea level (Figure 6.3.3).

Figure 6.3.2 A scientific study of more than 100 000 glaciers worldwide has found that most glaciers are shrinking. A significant retreat in the 1940s was followed by stability or growth in the 1970s. From 1980 onwards most glaciers have been in retreat.

Figure 6.3.3 At their highest point, the islands of Tuvalu (in the Pacific Ocean between Hawaii and Australia) are only 4.5 metres above sea level. Most of the land is less than 1 metre high. If there is a significant rise in sea level, then Tuvalu will experience severe flooding.

The enhanced greenhouse effect

Many scientists believe that human activities are having a significant effect on the rate and intensity of global warming, and that this is influencing climate change. However, measurement of climate variables on a worldwide scale has been occurring for little more than a century. Many of the trends that drive climate change occur over periods much longer than this—hundreds of thousands of years. Therefore it is difficult to identify the exact effect of changes caused by humans.

The IPCC report suggested that global warming is partly due to natural processes but is also caused by the **enhanced greenhouse effect**. The enhanced greenhouse effect is an increase in the natural greenhouse effect caused by human activity.

The major cause of the enhanced greenhouse effect is an increase in carbon dioxide, methane and nitrous oxide concentrations in the atmosphere.

Scientists have created computer models to try to forecast the effects of global warming on Earth's climate. Not all the computer models agree in specific details. However, there is agreement that if greenhouse gases continue to be produced at the same rate as in the year 2000, then there will be a 0.1°C increase in temperature per decade. What actually happens will depend on the actual carbon dioxide emissions that occur. As can be seen from Figure 6.3.4, Australia's emissions already exceed the 2000 levels.

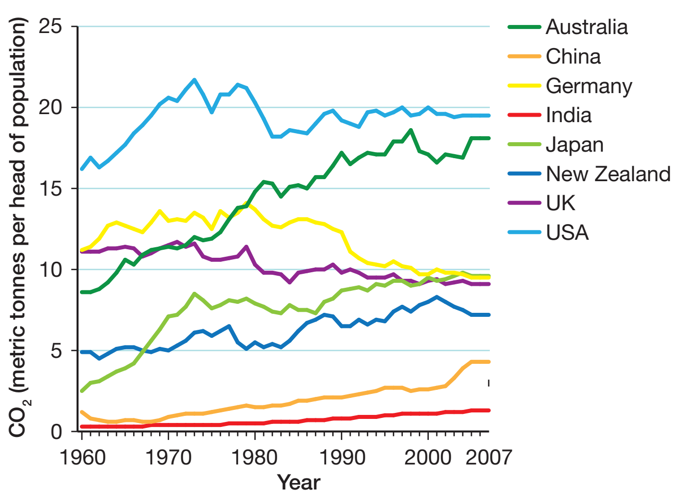


Figure 6.3.4 Australia's carbon dioxide emissions have risen since 2000. Other developed nations have reduced or stabilised their emissions per head of population.

Carbon dioxide in the atmosphere

Of all the carbon dioxide produced on Earth, 95% would be emitted whether humans were present or not. The largest source is natural decay of organic material in forests and grasslands. However, the carbon dioxide produced by natural means is balanced by natural carbon sinks—these are places and events that remove carbon dioxide from the atmosphere.

In 1957, measurements of carbon dioxide began at the Mauna Loa Observatory on Mauna Loa, Hawaii (USA), and in Antarctica. Figure 6.3.5 demonstrates the increase in atmospheric carbon dioxide over Mauna Loa in the past 50 years.

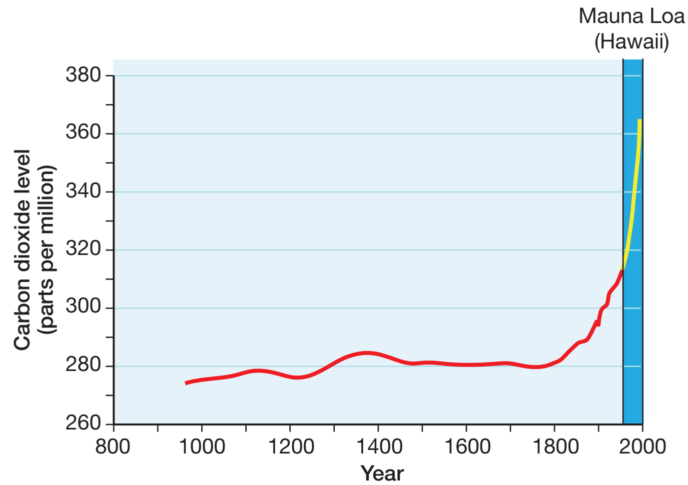


Figure 6.3.5 Ice core analysis provides information about carbon dioxide levels in the atmosphere before measurements were taken over Mauna Loa. The rapid increase in concentration coincides with the Industrial Revolution, which began around 1750.

The concentration of carbon dioxide in the atmosphere has increased from 280 parts per million (ppm) before the Industrial Revolution to 391 ppm in 2010. Compare this with an increase of only 20 ppm in the 8000 years before industrialisation.

Coal and gas are both major carbon sinks. Since the Industrial Revolution, humans have been extracting and burning coal and gas as a primary energy source, releasing carbon dioxide into the atmosphere.

In Australia most of the energy used in homes and by industry is produced by coal-fired power stations. Figure 6.3.6 shows the output of carbon dioxide in Australia per head of population compared with other nations.

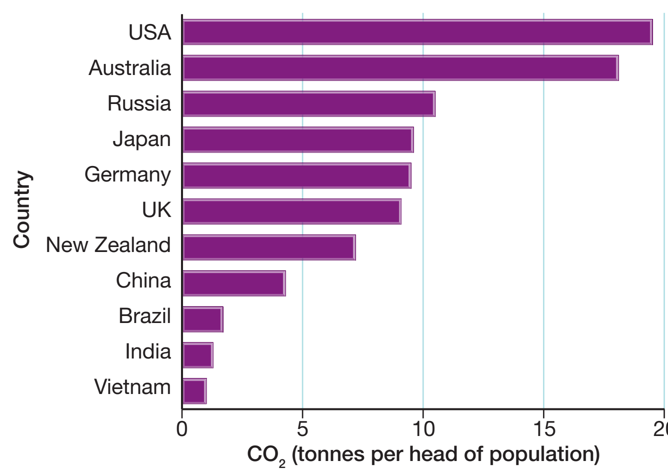


Figure 6.3.6 In 2007, Americans produced more carbon dioxide per head of population than any other nation, but Australians are not far behind.

India and China produce only a small amount of carbon dioxide per person when compared with Australia. However, when the population of these countries is taken into account, the picture is different. Table 6.3.1 compares the populations of these four countries.

Table 6.3.1 Comparing the populations of four countries

Country	Population (millions)	Total CO_2 output (millions of tonnes)
Australia	22.3	400
United States	307.0	5990
India	1140.0	1140
China	1325.0	5300

6.3
p201

Methane

Methane (CH_4) is able to trap more than 20 times the heat of carbon dioxide. It is formed from the breakdown of organic matter. Methane is produced in the stomachs of cows and sheep as bacteria digest the cellulose in the grass the animals eat (Figure 6.3.7). Rice paddies, garbage tips, coal mines and natural gas fields also release methane. The concentration of methane in the atmosphere in 2010 was 18.5 ppm, which is more than double the level before the Industrial Revolution.

Figure 6.3.7 Digestion of plant material releases methane. Livestock produce 11% of Australia's methane emissions.

SciFile

Gas emissions!

About 90% of New Zealand's methane emissions are produced as animals such as cows and sheep burp and break wind. The 45 million sheep and 10 million cattle in New Zealand make for a lot of methane!

On Earth, there are areas near the poles where the temperature in layers of soil or rock beneath the surface never rises above freezing point. These layers are known as **permafrost**. Vast areas of the Arctic are boggy wetlands of permafrost where the remains of plants and animals decompose, producing methane. Permafrost traps the methane (Figure 6.3.8). However, rising temperatures in the Arctic causes the boggy soils to melt and release the trapped methane. Estimates suggest that Arctic soils store billions of tonnes of methane.

Increased methane emissions may cause the temperature to rise further, melting more ice and releasing more methane in a process known as positive feedback.

Figure 6.3.8 Bubbles of methane are trapped in the ice of the permafrost. Between 2003 and 2007, methane emissions from the Arctic increased by 31%.

Nitrous oxide

Nitrous oxide (N_2O) is capable of trapping 300 times more heat than carbon dioxide. Its concentration in the atmosphere in 2010 was 3.19 ppm—this is about 18% higher than before the Industrial Revolution. Nitrous oxide is produced in car exhausts and through many industrial processes, as well as the burning of forests and the use of nitrogenous fertilisers.

Loss of ice

During winter, the amount of ice in the Antarctic doubles to cover an area of about 19 million square kilometres. That is an area about three times the size of Australia. Scientists are currently gathering information that seems to suggest that the extent and thickness of the ice has an effect on climate.

Figure 6.2.2 on page 184 shows that areas of the globe covered in ice reflect more of the Sun's rays and have a cooling effect on Earth. Any reduction in the area of Antarctic ice would reduce this cooling effect.

When it covers the ocean water, ice acts as a blanket. The amount of heat that moves from the ocean to the atmosphere is reduced. Less ice means that more heat will be added to the atmosphere.

Ice is fresh water. As salt water freezes, the salt remains in the ocean. The salinity increases and therefore the density of the water also increases. The dense water sinks, moving into the deep currents that circle the Earth as seen in Figure 6.2.7 on page 186.

The Antarctic Ocean is Earth's major source of the cold dense water that is the driving force for the global conveyor belt. Changes to the amount of Antarctic ice will cause changes in the amount of cold dense water entering the global conveyor belt. This in turn could cause changes in the currents and the global climate.

Carbon dioxide absorption

Water at the surface of the oceans absorbs carbon dioxide from the atmosphere. As the cold dense water of the Antarctic Ocean sinks, the carbon dioxide is carried with it. This has the effect of pumping carbon dioxide out of the atmosphere. Without this process, any build-up of carbon dioxide in the atmosphere would be faster.

Shrinking Antarctica

Scientists are carrying out research to answer the question of whether or not the Antarctic ice is melting. Satellites are used to measure the total mass of ice on Antarctica. Figure 6.3.9 represents the results collected so far. The results indicate that Antarctica is losing ice and that the rate of loss is increasing.

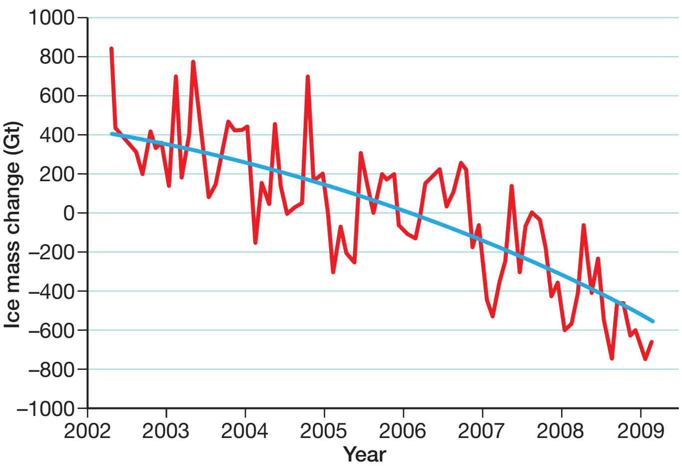


Figure 6.3.9

This graph shows that the amount of Antarctic ice increases in the middle of year (winter) and decreases in the summer. The actual amount of change varies from year to year. However, the general trend, shown by the blue line, is a decrease in the mass of ice for the years 2002–09.

Different things are happening in different parts of the continent of Antarctica. Under the ice of east Antarctica is a land mass about the size of Australia. In this part of the continent, there is a little loss of ice at the edges and an accumulation of snow in the interior. Therefore, there is not much change.

West Antarctica is more like a series of islands so a lot of the ice is sitting in water. Here the sea ice surrounding the islands is retreating. Loss of sea ice allows the glaciers to flow more rapidly, sending large amounts of ice into the ocean.

In February 2010, an iceberg 78 km long and 39 km wide broke off the tongue of the Mertz Glacier in East Antarctica. The tongue of the glacier was hit by an iceberg known as 'B9B' which is 97 kilometres long. Some scientists are concerned that this event may affect wildlife in the area. You can see this collision in Figure 6.3.10.

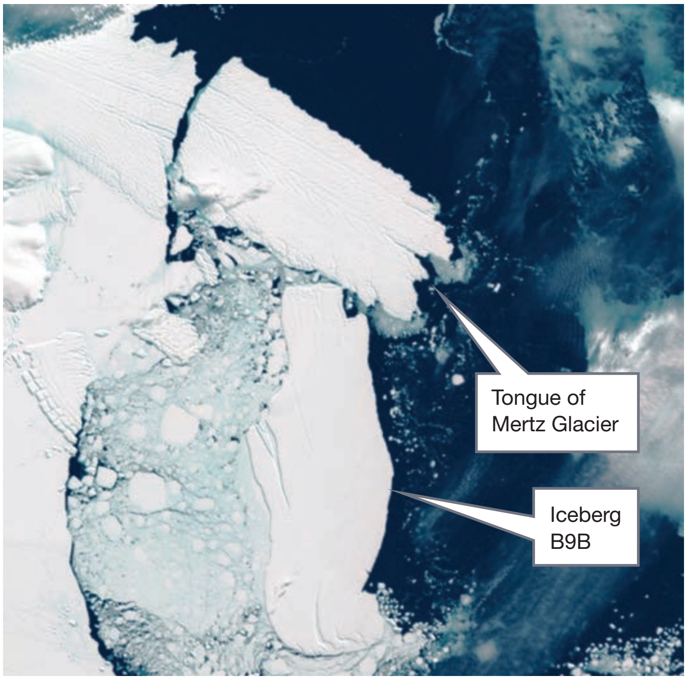


Figure 6.3.10 The tongue of the Mertz Glacier broke off when it was hit by Iceberg B9B.

SciFile

Ozone

Ozone reacts easily with organic molecules. These reactions can break down the walls surrounding the spores of fungi and bacteria, leaving behind only harmless wastes. Ozone can be used as an environmentally friendly alternative to chlorine in the purification of water.

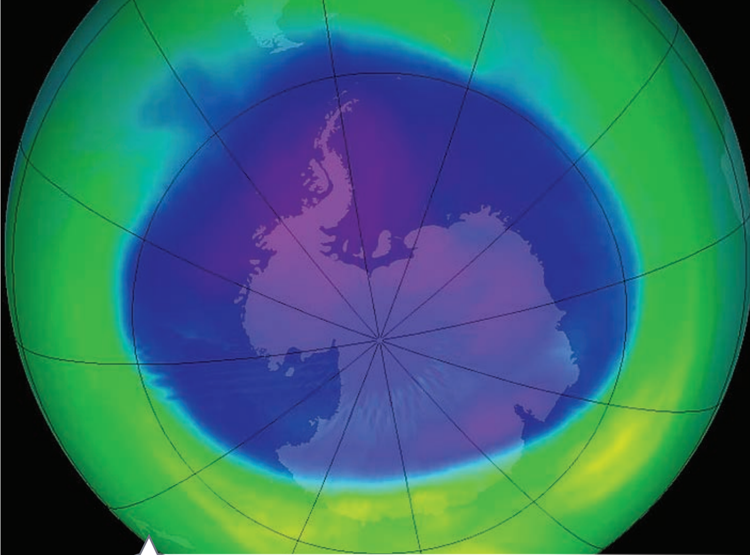


Figure 6.3.11 The hole in the ozone layer over Antarctica (shown in purple)

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Ozone

Ozone (O_3) occurs naturally in the atmosphere, mostly in the stratosphere. It is vitally important to life on Earth because it absorbs ultraviolet (UV) radiation emitted by the Sun (Figure 6.3.12). Too much exposure to UV radiation can cause skin cancers and eye disease.

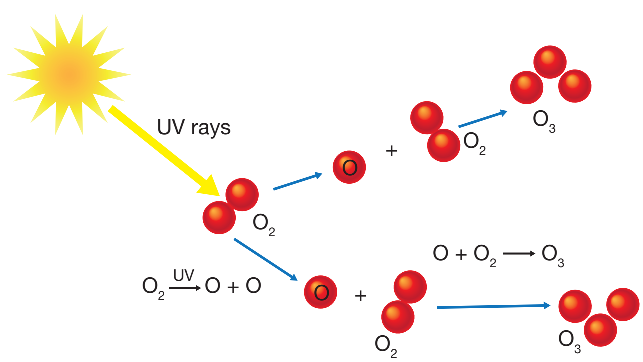


Figure 6.3.12 Ozone is formed when UV light strikes an oxygen molecule (O_2) and splits it into individual atoms, which then combine with O_2 molecules to form O_3 molecules.

The 'thickness' of the ozone layer is measured in Dobson units (DU). Ozone is spread throughout the stratosphere, so the term *thickness* is misleading. If all the ozone in the world could be concentrated into a pure layer at ground level, it would be 5 mm thick or 500 DU.

A value of less than 220 DU is considered a 'hole'.

The concentration of ozone in the atmosphere varies throughout the year and around the world. Measurements over Antarctica show that the values are lowest during September to October, when daylight returns after the long dark winter. At this time chlorine is most effective at breaking down ozone molecules. In November, prevailing winds carry ozone-rich air from other regions and repair the hole. But lower ozone levels still remain over Australia and New Zealand.

An increase in the rate of ozone destruction was linked to the release into the atmosphere of manufactured compounds such as chlorofluorocarbons (CFCs) (Figure 6.3.13) and halons. CFCs are very stable compounds that scientists now know react with UV radiation to release chlorine, which destroys ozone. Halons were developed to fight fire.

Figure 6.3.13 CFCs were developed in the 1920s as propellants in spray cans and coolants in refrigerators and air conditioners. They were used to make the bubbles in foam packaging and were included in industrial cleaners.

When the destructive powers of CFCs and halons were recognised in the 1970s, the use of CFCs was banned in the United States, Canada and Norway. However, it took until 1985 and the identification of a hole in the ozone layer over Antarctica, to convince the rest of the world that there was a serious problem. In 1987, 196 countries agreed to stop producing CFCs. This treaty (known as The Montreal Protocol) demonstrates the contribution that science can make to environmental protection agreements. Scientists predict that the ozone layer will recover to its pre-1980 concentrations by the middle of the 21st century.

6.4

6.3 Unit review

Remembering

1 **Name** two factors that influence world climate.

2 **Name** two aspects of climate that have been measured and have increased since the Industrial Revolution.

3 **State** the term used by scientists for the interconnected currents that influence world climate.

Understanding

4 **Explain** why melting icebergs will not affect sea levels but melting glaciers will.

5 **Explain** the term *carbon sink*.

6 **Explain** why nitrous oxide became more important as a greenhouse gas in the second half of the 1900s.

7 a **List** the sources of methane in the atmosphere.

b **Describe** the human actions that are increasing methane levels in the atmosphere, and explain how the increase is brought about.

8 **Explain** why there is so much concern about the increase in carbon dioxide in the atmosphere.

9 **Explain** how the amount of ice in polar regions can influence climate.

Applying

10 a **Calculate** the annual output of carbon dioxide in Australia, the United States, India and China from the data presented in Figure 6.3.6 on page 196 and Table 6.3.1 on page 197.

b **Identify** the country that is the highest emitter of carbon dioxide, then rank the others in order of decreasing production.

11 Use diagrams to **demonstrate** what happens as sea ice forms at the poles and water is added to a deep ocean current.

Analysing

12 **Compare** global warming and climate change.

13 a **Compare** carbon dioxide, methane and nitrous oxide as greenhouse gases.

b **Explain** why the focus of concern about greenhouse gases is on carbon dioxide, not on methane and nitrous oxide.

Evaluating

14 **Propose** reasons for why the data in Figure 6.3.6 are presented as carbon dioxide emissions per head of population, rather than for the total population.

15 It is over 100 years since people were made aware of the potential global warming effect of carbon dioxide. **Propose** reasons why people did not act earlier to reduce carbon dioxide emissions.

Creating

16 **Construct** a consequences wheel for global warming. Use Figure 6.3.14 as a guide to the layout. In the centre, write ‘global warming’. In the next layer record the immediate consequences of global warming such as a rise in average world temperature. In the second layer add the consequences of these changes.

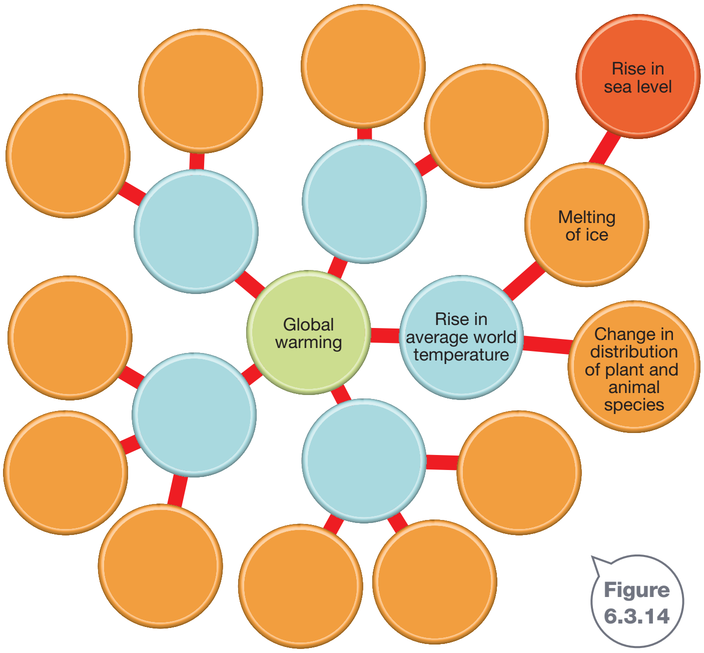


Figure 6.3.14

Inquiring

1 Research energy sources that are used as alternatives to fossil fuels. Discuss their efficiency as energy sources and the impact they have on the environment.

2 Investigate the scientific information used to demonstrate changes to the Earth’s atmosphere in the 20th century.

3 Some scientists are sceptical (not convinced) about the degree to which human activity is responsible for climate change. Research some of the alternative views on climate change and discuss the points of view.

4 Design an experiment that investigates the effect of carbon dioxide on air temperature.

6.3 Practical activities

1 Freezing and density

Purpose

To investigate the effect of freezing on the density of salt water.

Materials

- 6 L container (such as a bucket or watering can)
- 2 large transparent containers (pneumatic trough, pie dish or aquarium)
- 2 L container that can be placed in the freezer
- 1 L plastic container
- 6 L water
- 60 g salt (sodium chloride)
- food colouring
- access to a fridge and freezer
- stirrer

Procedure

1. Mix 6 L of water with 60 g of salt and stir until all the salt is dissolved.
2. Add 2 L of the salt solution to each of the large transparent containers. Place the containers in the fridge.
3. Add a few drops of food colouring to the remaining 2 L of salt solution.
4. Pour off the coloured salt solution into the 2 L container and place in the freezer.
5. Leave the coloured salt solution in the freezer until two-thirds of it is frozen.
6. Pour the liquid that has not frozen from step 5 into the 1 L container and place it in the fridge.
7. Save the ice from the coloured salt solution and allow it to thaw in the fridge. Add a few more drops of colouring if there is not an obvious tint to the water.
8. When the coloured solution and thawed ice are at the same temperature as the solution in the large containers, remove all containers from the fridge.
9. Allow the water in the large containers to settle.
10. Gently pour the coloured salty water in a slow steady stream into one end of one of the large containers as shown in Figure 6.3.15. Observe where the coloured water goes. Record your observations in your workbook.
11. Using the same technique as step 10, gently pour the thawed ice water in a slow steady stream into one end of the other large container. Observe where the coloured water goes. Record your observations in your notebook.

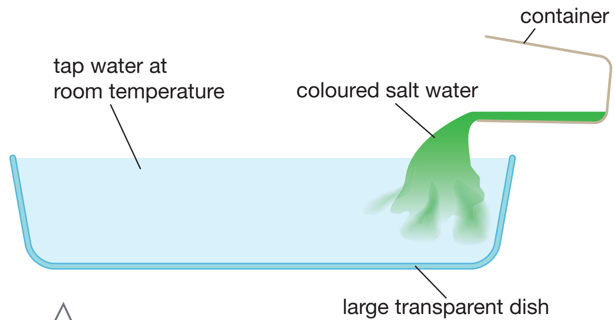
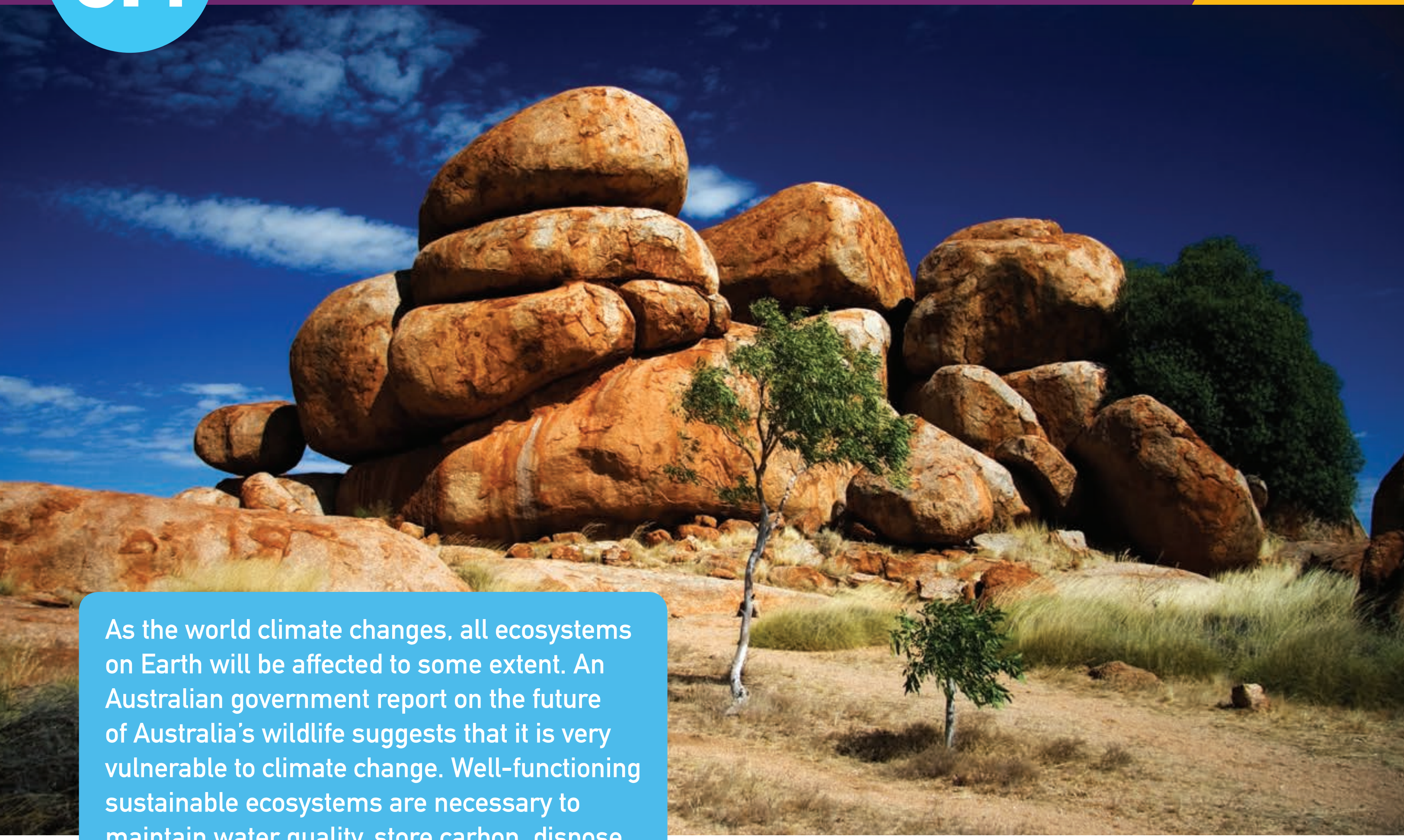


Figure 6.3.15

Discussion

1. **Describe** the behaviour of the coloured salt water when it was poured into the large container.
2. **Describe** the behaviour of the coloured water that came from thawing the ice when it was poured into the large container.
3. **Compare** ways that the solution and water from the ice behaved.
4. **Propose** why the two solutions behaved in this way.
5. **Explain** how this experiment is relevant to the effect of polar ice on the Arctic or Antarctic Oceans.

6.4 Changing environments



As the world climate changes, all ecosystems on Earth will be affected to some extent. An Australian government report on the future of Australia's wildlife suggests that it is very vulnerable to climate change. Well-functioning sustainable ecosystems are necessary to maintain water quality, store carbon, dispose of natural wastes, remove pollination and maintain genetic diversity.

Predictions

Many different computer models of climate change have been created. They produce different outcomes. However, they agree that not all parts of the world will be affected in the same way. The models predict that the oceans will not warm as much as land. The greatest increase in temperature will be in the northern parts of the northern hemisphere. Areas near the Antarctic and in the far north of the Atlantic Ocean are predicted to have the smallest temperature increase.

The area of land covered in snow will decrease and the amount of sea ice at both poles will be reduced. Satellite data have shown that the extent of Arctic sea ice has decreased by 2.7% each decade since 1978.

The number of extreme weather events such as heatwaves and tropical cyclones (such as the one in Figure 6.4.1) will increase.

Precipitation will increase towards the poles, but in subtropical areas such as the Mediterranean, parts of Queensland and Western Australia the rainfall will decrease.

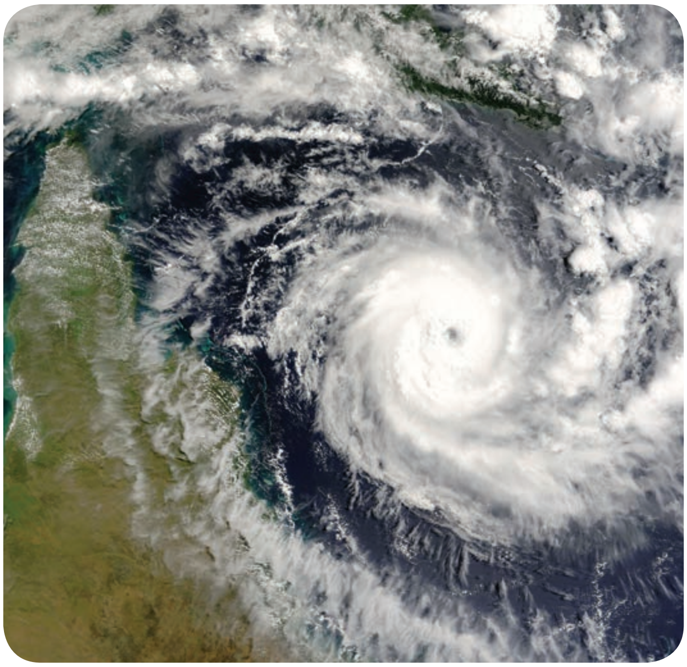


Figure 6.4.1 Computer modelling of climate change suggests that there will be more frequent cyclones in northern Australia.

6.5

Save the whales

A lack of iron in the waters of the Southern Ocean inhibits the growth of photosynthesising plankton. Twelve thousand sperm whales live there, releasing 50 tonnes of iron each year in their faeces. This iron means the plankton flourish and through photosynthesis use 400 000 tonnes of carbon dioxide—twice as much as the whales produce through respiration. The presence of the whales therefore helps take carbon dioxide out of the atmosphere.

SciFile

Who will survive?

The history of the Earth reveals that climate change in the past has caused many species and entire ecosystems to become extinct. About 14 700 years ago, Earth's temperature rose by 10°C. At that time, many of the mega-mammals of North America such as mammoths, mastodons and giant sloths (Figure 6.4.2) began to disappear. There is debate about whether climate alone caused those extinctions or whether hunting by early humans was a contributing factor.

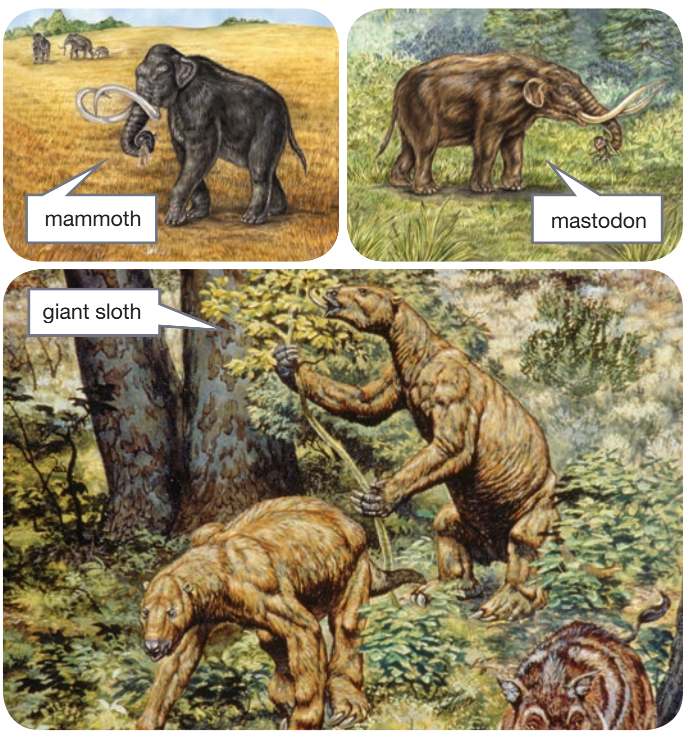


Figure 6.4.2 Extinction of the megafauna of North America may have been due to a rise in temperature as the last Ice Age came to an end.

Around 56 million years ago many large mammals disappeared due to a 7.2°C rise in temperature caused by a natural release of methane from marine sediments. Humans were not around at this time.

Not all plants and animals die out when the temperature changes. When the climate warms, species move towards the poles if they are able to. During a period of cooling, they move towards the equator.

Urban development and clearing land for agriculture have destroyed some natural ecosystems and divided others into small fragments. This makes it more difficult for organisms to move away from areas that are no longer suitable.

Climate change and the destruction of ecosystems by human activity has led to a decrease in biodiversity. **Biodiversity** is the variety of ecosystems in the biosphere, the variety of species within those ecosystems and the genetic variation within those species.

Australia is very biodiverse. It is one of 17 countries that together contain more than 70% of all species found on Earth. Many species found here are unique to Australia. About 85% of Australia's terrestrial mammals, 91% of flowering plants, and 90% of reptiles and frogs are found nowhere else in the world. More than 50% of the world's marsupial species occur only in Australia.

Great Barrier Reef

Corals are very sensitive to small changes in temperature. An increase in temperature of only 1–1.5°C above the summer average maximum can cause severe stress to the coral.

The health of coral reefs depends on the symbiotic relationship between the coral and unicellular, photosynthetic protists that live within their cells. As well as providing essential nutrition, these protozoans give corals their distinctive colour. An example is shown in Figure 6.4.3.

Figure 6.4.3 Healthy corals owe their colour to the protozoans that live within their cells.

When the coral is stressed, it expels the protists. The coral becomes lighter in colour—it is bleached. A bleached coral can be seen in Figure 6.4.4 on page 204. Once the bleaching has begun, it does not necessarily stop once the stress has reduced. Some corals take months to recover from a bleaching episode. Other corals never recover.

Bleached corals suffer from a lack of the nutrients that are normally provided by the protists. The corals can no longer compete with faster growing algae. The corals die and the reef is overtaken by algal growth.

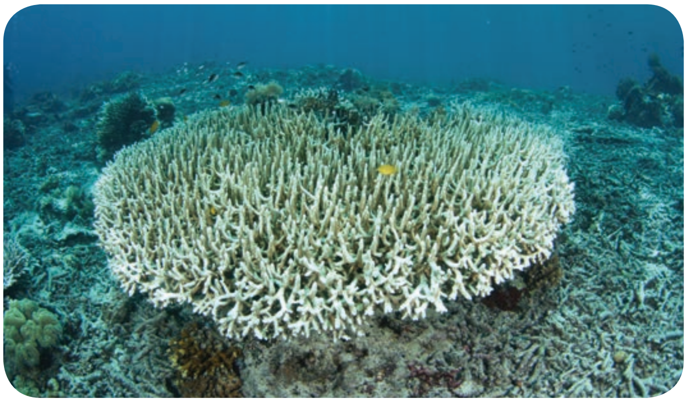


Figure 6.4.4 Coral bleaching is occurring in coral reefs throughout the world. Not only are natural ecosystems affected by coral bleaching, fishing and tourism industries are adversely affected as well.

A great variety of organisms depend on corals for food and shelter. These organisms will be affected directly by any change in the health of the coral reefs. Many other organisms further along the food chain will be affected indirectly.

Kakadu

Changes to fire regimes, rising sea levels and increased storm activity are results of climate change. These could impact on Kakadu National Park in the Northern Territory.

There are large areas of wetland in Kakadu National Park. These wetlands support a large variety of species including many migratory species of bird such as magpie geese (*Anseranas semipalmata*) seen in Figure 6.4.5.

Figure 6.4.5 Late in the dry season, millions of magpie geese flock to Kakadu to feed.

Human activity has significantly reduced many populations of this bird in southern and south-eastern Australia. Looking after the population in Kakadu is a good opportunity to conserve the species. Kakadu wetlands are fresh water. However, many areas are very low lying. A rise in sea level combined with increased storm activity would allow salt water to flood into the area. Organisms that cannot live in saline conditions will disappear from the area. Organisms tolerant of salt will flourish and the ecosystems will change.

Extensive flooding also allows weed species and feral animals from surrounding areas to invade the wetlands. Feral animals such as pigs, cane toads and water buffalo (Figure 6.4.6) already pose problems in Kakadu. Water buffalo damage river banks, causing erosion. The water becomes muddy and unsuitable for the water plants and fish that normally live there. Water buffalo also eat so much that they are in direct competition with native wildlife.

Figure 6.4.6 Water buffalo (*Bubalus bubalis*) wallow in shallow waterholes in Kakadu National Park.

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More spiders

In West Greenland, higher average temperatures have led to spring arriving more than 20 days earlier than usual, giving wolf spiders more time to hunt. The average size of female spiders has increased and it is likely they will lay more eggs, leading to an explosion in the spider population in Greenland.

Species on the move

The long-spined sea urchin *Centrostephanus rodgersii* is shown in Figure 6.4.7. It is a very common species in the temperate waters of southeastern Australia. It appears to be moving down to Tasmania, where it could damage shallow reef ecosystems and the commercial abalone and rock lobster industries. Scientists believe that a strengthening of the East Australian Current resulting from climate change is carrying the larvae south.

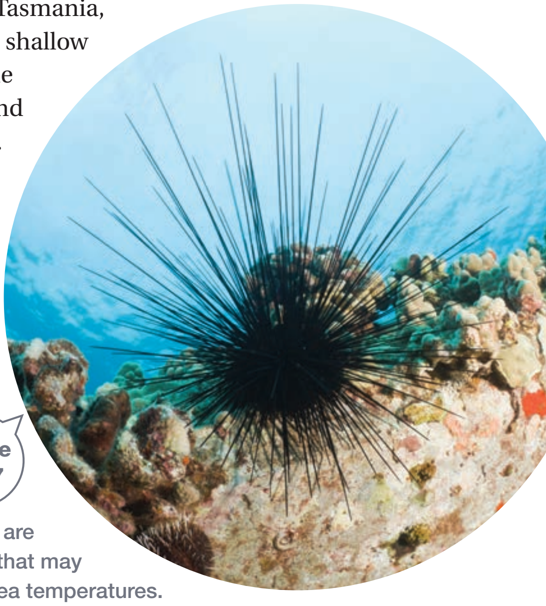


Figure 6.4.7 Long-spined sea urchins are moving south, a change that may be a response to rising sea temperatures.

In the Australian Alps kookaburras are hunting at higher altitudes and preying on alpine skinks. The alpine skinks do not recognise the kookaburras as predators and do nothing to avoid them. As a result, the alpine skink population will decrease.

Swamp wallabies and red-necked wallabies are also moving further up to graze on the herb fields high in the Australian Alps. Many plant species in the herb fields (Figure 6.4.8) will not survive continuous grazing, and biodiversity of the area will decrease.

Figure 6.4.8 Mountain ecosystems such as these herb fields survive under extreme conditions. They are very vulnerable to any added stress such as grazing.

SciFile

Early spring

A team of scientists in Europe's International Phenological Gardens records the date that each tree and shrub buds, blossoms and loses it leaves each year in the gardens. These data show that between 1959 and 1996 the growing season lengthened by eleven days with Spring coming earlier. Satellite tracking has confirmed this trend in other parts of the world. Changes to seasons could alter interactions between plants and animals in ecosystems.

In response to the earlier spring, some migratory birds are changing the time they start their migration.

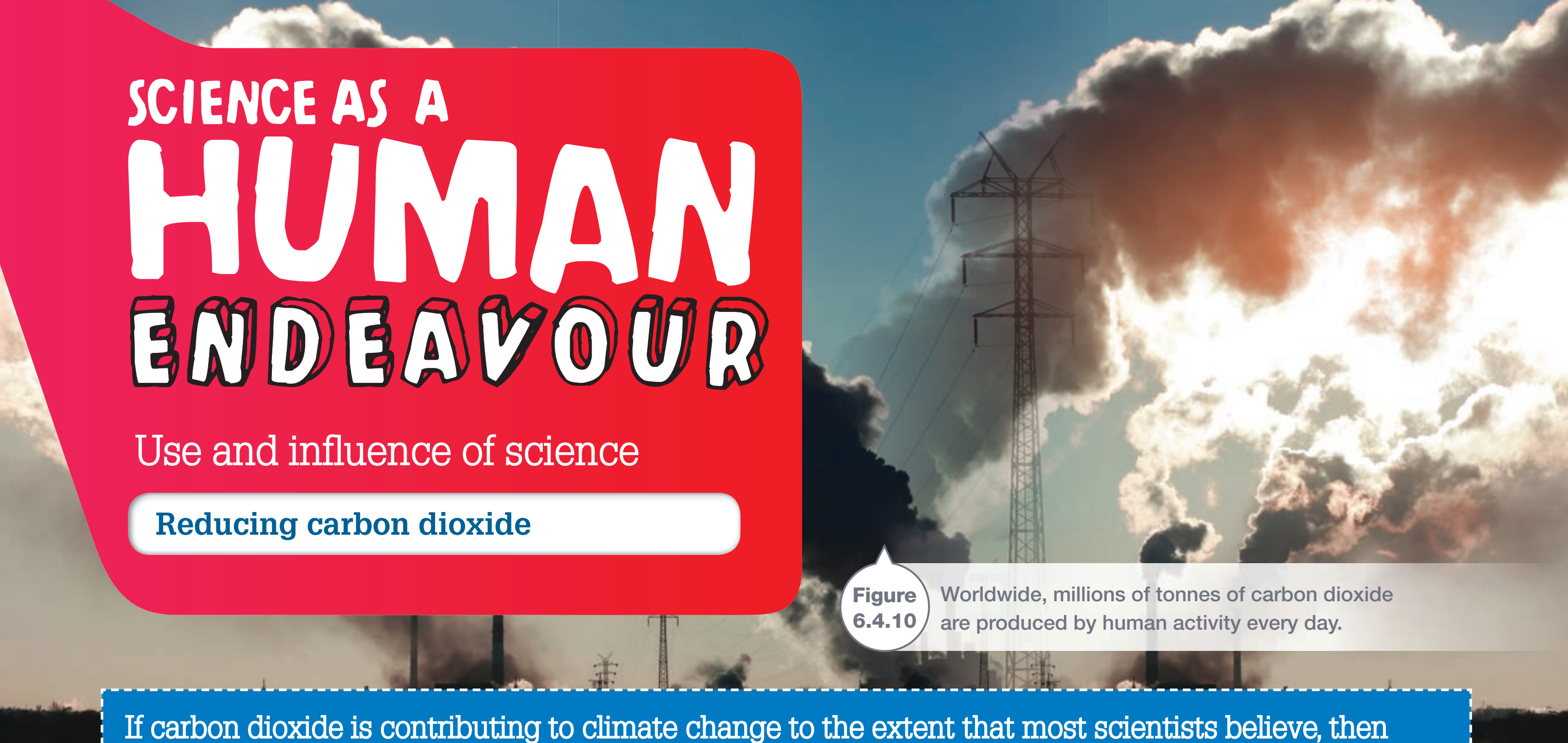
Change in sea level

Geological history shows that sea levels have been both higher and lower than they are today. About 18 000 years ago, sea levels were about 120 metres lower. In the past 7500 years, sea levels have risen about 5.8 metres—that is about 2.5 cm every 30 years. This is a natural part of being in an interglacial warming period.

If all the ice on land on Earth were to melt, the sea level would rise about 70 metres. However, no climate change model has suggested that this could happen. Most cities are on the coast and therefore any rise in sea level is of concern. When sea levels rose in the past, cities like Sydney and Melbourne, London and New York did not exist. The industry, roads, houses, apartments and businesses you can see in Figure 6.4.9 were not in place then. As the water rose, animals moved out of the way and any early humans went with them. As the sea level fell again, they moved back to the newly exposed land. Skyscrapers, homes and businesses will not be able to be moved out of the way of the sea, so the economic impact will be huge.

1 p208 6.6 6.7 6.8

Figure 6.4.9 When sea levels rose in the past, animals just moved to higher ground. Development in coastal areas means that any future change in sea level will have a significant economic impact. The Gold Coast is at particular risk.



SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Reducing carbon dioxide

Figure 6.4.10 Worldwide, millions of tonnes of carbon dioxide are produced by human activity every day.

If carbon dioxide is contributing to climate change to the extent that most scientists believe, then reducing the amount of carbon dioxide in the atmosphere should be a priority.

The direct approach to reducing carbon dioxide is to reduce the amount entering the atmosphere from the burning of fossil fuels such as coal and oil (Figure 6.4.10). An alternative approach is to use a natural means of removing carbon dioxide from the atmosphere. Increasing the number of photosynthetic organisms in the environment will increase the amount of carbon dioxide being taken from the atmosphere and in some cases store it away for a long time.

About half of a tree's mass is carbon, so large amounts of carbon are stored in forests. The larger the tree, the more carbon is stored in it. For example, a small *Eucalyptus* tree with a trunk circumference of 100 cm stores about 320 kg of carbon. A tree of circumference 300 cm contains about 5540 kg of carbon. To store this much carbon, these trees would have absorbed about 1180 kg and 21 320 kg of carbon dioxide respectively. This is equivalent to the amount of carbon dioxide produced when 500–9035 L of petrol is burned. Just think how much carbon could be stored in some of the giant *Eucalyptus* trees in old-growth forests. Some of them have trunks with circumferences of 40 metres (Figure 6.4.11).

Governments are putting in place schemes in which people can buy carbon credits. In these schemes, people and industries plant trees for the sole purpose of reducing the amount of carbon dioxide in the atmosphere. One carbon credit is the equivalent of reducing the amount of carbon dioxide in the atmosphere by 1 tonne. That is enough carbon dioxide to fill a swimming pool 10 metres wide, 25 metres long and 2 metres deep.

In this way, an industry can balance the carbon dioxide it produces with the carbon it has stored. The effect is that no extra carbon has gone into the atmosphere.

The carbon is then stored in the trees and will remain there as long as the tree lives or as long as the wood in the tree is still intact, as in a building or furniture.

Figure 6.4.11 This *Eucalyptus* (*E. regnans*) is 79 metres tall and stores a large amount of carbon.

6.4 Unit review

Remembering

1 **List** the effects of climate change in the past.

2 **State** the source of evidence used by scientists to suggest that sea levels were higher in the past.

3 **List** the effects of climate change that are predicted to occur in Kakadu National Park.

Understanding

4 **Explain** how animals in natural ecosystems are likely to respond to rising sea levels.

5 **Explain** why it is difficult for animals to move to new areas when climate change makes their present habitat unsuitable.

6 **Describe** what happens to corals when they are bleached.

7 **Explain** why an unusually high rise in sea levels caused by onshore winds could have a negative impact on the Kakadu wetlands.

8 **Explain** the concept of carbon credits and how they could reduce the level of global warming.

Applying

9 Long-spined sea urchins have free-swimming larvae and these are carried south in currents. **Use** this information to suggest possible effects of climate change on the distribution of other organisms such as corals and starfish that also have free-swimming larvae.

Analysing

10 Think about climate change and **compare** the potential effects on it of planting large numbers of trees with the potential effects of destroying forests.

Evaluating

11 a For each case below, **propose** which organism is more likely to survive a change in climate.

b **Justify** your response.

i a plant with seeds that are dispersed by wind
OR
a plant that depends on animals for seed dispersal

ii an animal that produces a large number of offspring each year
OR
an animal that produces one offspring every two or three years

iii plants that have very specific environmental needs
OR
plants that survive in a wide range of habitats

iv plants or animals that live in very cold climates
OR
organisms that live in tropical regions

12 **Propose** possible effects on migratory birds if wetlands such as those in Kakadu National Park were to change significantly or disappear altogether.

13 A symbiotic relationship is one in which both organisms benefit from the relationship. **Deduce** the benefits for the symbiotic relationship between protozoans and corals for the:

a corals

b protozoans.

14 **Propose** what would control how far south the long-spined sea urchin shown in Figure 6.4.7 on page 204 could move and become established in large populations.

15 **Deduce** the effect on other predators of the movement of kookaburras up the slopes of the Australian Alps.

16 The short-term effect of wallabies moving up slopes in response to warmer temperature is increased grazing on the fragile herblands. **Propose** the long-term effects on the area.

Creating

17 **Construct** a consequence wheel for the global implications (potential results) of reduced biodiversity.

Inquiring

1 Identify a plant or animal species from your area that is endangered or vulnerable. Investigate the causes for it being vulnerable and propose the effect on this organism of predicted changes due to climate change.

2 Research the organisms that live on a typical coral reef.

a Use your findings to construct a food web for the reef.

b Describe the impact on the food web from the loss of coral due to bleaching.

3 Research technologies that are aimed at reducing carbon pollution. Carbon capture, sequestration and 'clean coal' are three possible starting points. Present your findings to the class in a poster or audio-visual presentation.

4 Access a map of your local area. The map should cover an area that is about 100 km by 100 km. Research the native animals that live in your local area. Use the map to identify where a colony of a particular animal might live.

a Investigate what could happen to this animal if conditions in its present habitat were no longer suitable.

b Design a scheme to help this animal survive changing conditions.

6.4 Practical activities

1 Where will the sea go?

Purpose

To investigate the effect on Australia of rising sea levels.

Materials

- access to Google Earth on a computer
- map of your state capital (alternatively you could look at your local area or choose an area from the map in Figure 6.4.12)

Figure 6.4.12

Procedure

1. Draw an outline of the map, showing the coastline.
2. List important features of the city such as commercial and administrative areas, centres for transport and shops, education centres and major housing areas.
3. Mark these on your map.
4. Using Google Earth, find the elevation of these features.

Results

Using the elevations, shade the map to show the areas that would be inundated by sea water if there was a 5 metre, 10 metre and 15 metre rise in sea level.

Discussion

1. **Propose** the changes to the function of your city that would be caused by an increase in sea level of:
   a 5 m
   b 10 m
   d 15 m.
2. **Describe** the characteristics of the areas of the city that would be unaffected by the changes in sea level.
3. **Discuss** whether your city would be able to function if there was a rise in sea level.
4. **Propose** some wider effects of the changes to the capital city.
5. **Propose** strategies that would ensure that your state could continue to function.

Chapter review 6

Remembering

1 **Name** two substances that cycle through a natural ecosystem.

2 **State** where ozone is found in the atmosphere.

3 **Name** two major natural cycles that keep matter cycling through the environment.

Understanding

4 **Explain** why there is concern about chemicals that destroy ozone in the atmosphere.

5 **Describe** the most common effect an El Niño event has on Australia.

6 **Explain** how salinity and temperature affect deep ocean currents.

Applying

7 **Identify** two ways in which greenhouse gases can be reduced.

8 A suggested strategy for reducing the impact of carbon emissions is to plant trees. **Demonstrate** why this is a useful strategy.

Analysing

9 A single cow produces over 250 litres of methane every day. The number of cattle in Australia varies with conditions of rain and drought. Using 22 million as the cattle population, **calculate** the amount of methane produced by Australian cattle in:

- **a** 1 day
- **b** 1 year.

10 **Compare** the greenhouse effect and the enhanced greenhouse effect.

11 An Australian scientist was told by a person with no knowledge of climate science that 'Studying ocean currents seems pointless because they could not affect us.' **Analyse** this statement.

Evaluating

12 **Propose** a response to someone who says that humans are totally responsible for the global warming experienced by the world today.

13
- **a** **Analyse** the nitrogen cycle, identifying areas where human activity may have an impact on it.
- **b** **Propose** possible effects these human activities may have.

14 **Use** the information in Figure 6.2.2 on page 184 to **deduce** how the diagram would change as the Earth warms. Take into account changes in the patterns of reflection and absorption of solar radiation.

15 Round-the-world sailors usually follow the route shown in Figure 6.5.1. The loop in the Atlantic Ocean is to make the total distance equal to sailing around the equator, which is obviously impossible because of the land. **Propose** why sailors sail from west to east and not the other way around.

Figure 6.5.1

Creating

16 **Construct** a diagram of the carbon cycle. Label the diagram to show where:

- **a** the carbon moves quickly from one part of the cycle to the next
- **b** carbon moves more slowly
- **c** there are carbon sinks.

17 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

greenhouse effect
enhanced greenhouse effect
global warming
nitrogen cycle
El Niño
La Niña
carbon cycle
climate change
Southern Oscillation
Indian Ocean dipole

6.9

Thinking scientifically

Q1 Table 6.6.1 presents data on changes in water consumption in different sectors of Australian society for the years 1996–97 and 2000–01.

Table 6.6.1 Water consumption by selected industries and sectors, 1996–97 and 2000–01

Sector	Annual water consumption (GL)	
	1996–97	2000–01
Forestry and fishing	19	23
Mining	570	401
Manufacturing	728	866
Electricity and gas supply	1308	1688
Household	1829	2181

Calculate the percentage increases in water consumption and decide which two sectors had the greatest increase in water consumption over this time.

A manufacturing and household
B mining, and electricity and gas supply
C electricity and gas supply, and household
D forestry and fishing, and manufacturing

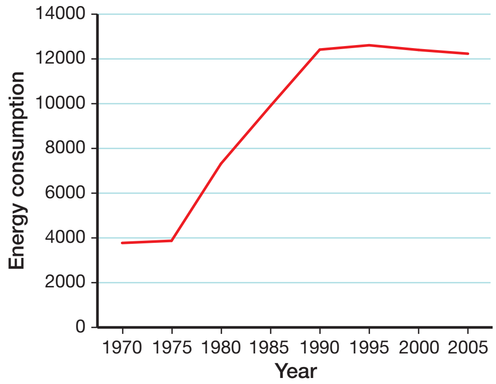
Q2 Table 6.6.2 provides data on energy use per head of population for the United Arab Emirates, one of the major oil-producing nations of the world.

Table 6.6.2

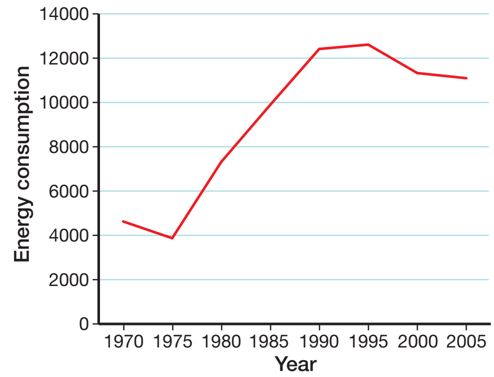
Year	Energy consumption per head of population (kg oil equivalent)
1971	3774
1975	3871
1980	7315
1985	9892
1990	12416
1995	12611
2000	11401
2005	11133

Which graph best represents the data in the table?

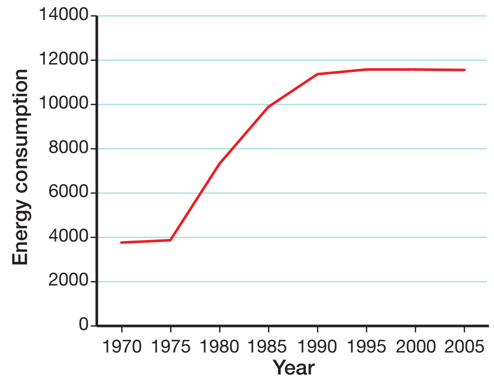
A



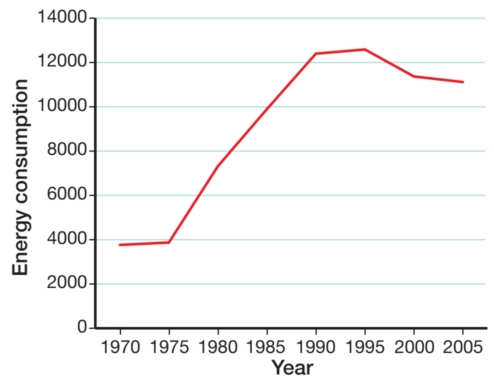
B



C



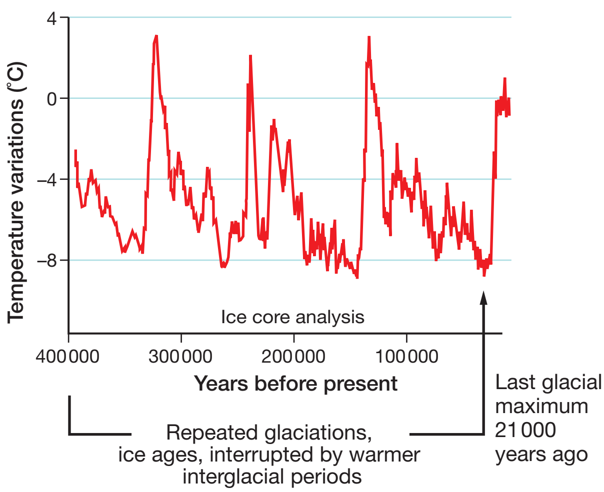
D



Q3 Use the data in Table 6.6.2 to determine the 10-year period that saw the greatest change in energy use.

A 1975–85
B 1980–90
C 1985–95
D 1990–2000

Q4 The graph below shows the variation in average world temperature for the past 400 000 years.



Based on the information in the graph, which of the following is *not* a true statement?

A The Earth is currently in a period of global warming that started about 20 000 years ago.

B There have been four periods of glaciation in the past 400 000 years.

C The current period of global warming has had the greatest increase in temperature of those experienced in the past 400 000 years.

D The longest period of low average temperatures was in the ice age preceding the current period of global warming.

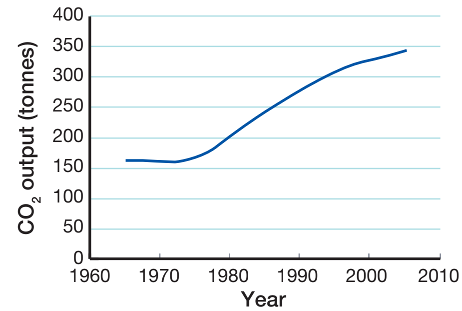
Q5 Table 6.6.3 shows the population and carbon dioxide output per head of population in Australia from 1965 to 2005.

Table 6.6.3

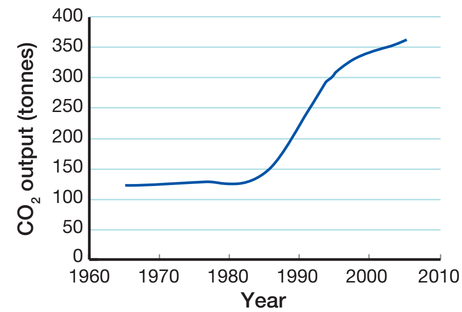
Year	Population (millions)	CO_2 output (metric tonnes per head of population)
1965	11.5	10.6
1975	14	11.9
1985	16	15.2
1995	18	17.1
2005	20	18.1

Which of the following graphs best represents the change in total carbon dioxide output for the nation?

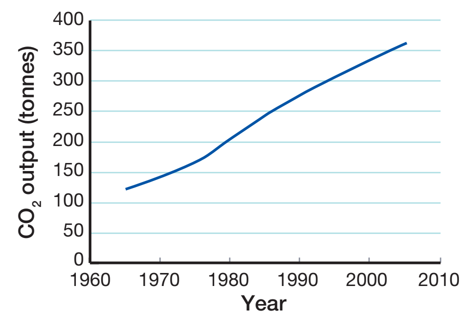
A



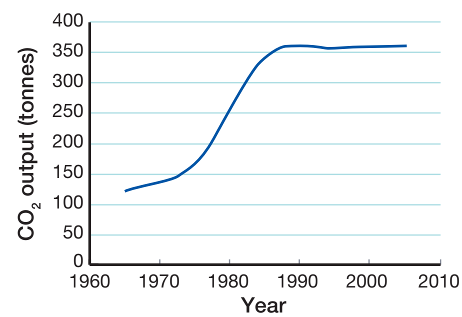
B



C



D



Q6 Use the data in Table 6.6.3 to calculate the decade in which Australians had the largest increase in carbon dioxide output per head of population.

A 1965–75
B 1975–85
C 1985–95
D 1995–2005

Glossary

Unit 6.1

Atmosphere: the layers of gases surrounding the planet

Biosphere: all living things on Earth

Carbon cycle: the process by which carbon is recycled through the soil, water, living things and the atmosphere

Denitrifying bacteria: bacteria that convert nitrates back into gaseous nitrogen (N_2), which is then released back into the atmosphere

Fossil fuels: fuels that contain the carbon of plants and animals that died and were preserved millions of years ago

Fossils: the preserved remains of once-living organisms

Hydrosphere: all the liquid water on the Earth's surface

Leguminous plants

Leguminous plants: plants that can take nitrogen from the air and fix it in their tissues

Lithosphere: the land masses on Earth

Nitrogen cycle: the process by which nitrogen cycles between the living and non-living environments

Nitrogen-fixing bacteria: bacteria that absorb nitrogen from the air and convert it into ammonia and then into nitrates

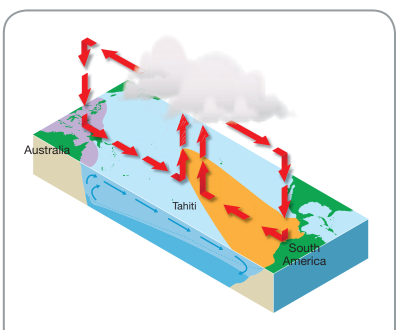
Sustainable ecosystems: ecosystems that are diverse and provide for the needs of the organisms that live there

Unit 6.2

Climate: the long-term averages of weather conditions

Climate change: change to the averages of aspects of climate that persist for decades or longer

El Niño: an extreme of the Southern Oscillation that causes drought in parts of Australia



El Niño

Global conveyor belt: common name for the thermohaline circulation

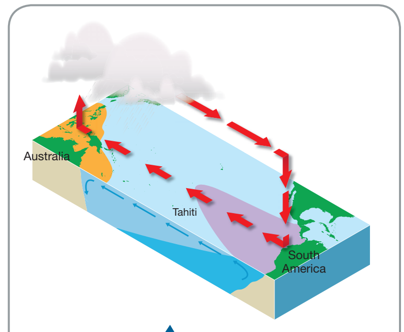
Global warming: a time when the average world temperature is increasing

Greenhouse effect: the warming of Earth caused by greenhouse gases

Greenhouse gases: gases that trap heat close to the Earth's surface

Gyres: the circular patterns shown by the ocean currents in the major ocean basins

Indian Ocean Dipole (IOD): a variable and irregular cycle of warming and cooling of waters in the equatorial area of the Indian Ocean



La Niña

Interglacials: periods between glaciations

La Niña: an extreme of the Southern Oscillation that causes significant rainfall in parts of Australia

Ocean currents: continuous movements of ocean water

Southern Oscillation: a sequence of changes to the atmosphere and ocean circulation across the Pacific Ocean and Indonesian Islands

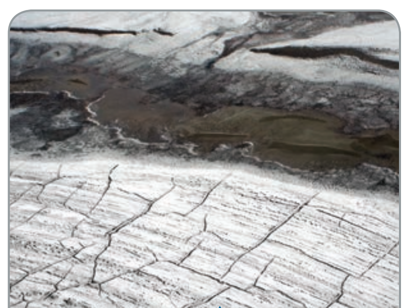
Southern Oscillation Index (SOI): a measure of the Southern Oscillation calculated using the difference in air pressure between Tahiti and Darwin

Thermohaline circulation: scientific term for the *global conveyor belt*, a continuous circulation of water that can be tracked around the whole Earth

Weather: the conditions in the atmosphere

Unit 6.3

Enhanced greenhouse effect: an increase in the natural greenhouse effect caused by human activity



Permafrost

Permafrost: areas on Earth where the temperature in layers of soil or rock beneath the surface never rises above freezing point

Unit 6.4

Biodiversity: the variety of ecosystems in the biosphere, the variety of species within those ecosystems and the genetic variation within those species

SCIENCE TAKES YOU PLACES

Look who is using science

COMPETITION SAILOR

My name is Cam Parsons and I am a competition sailor. I've represented Australia in a Youth World Title in Croatia and competed in a number of national events.

Competition sailors rely heavily on physics concepts. To keep the boat upright, we must counterbalance the force of the wind with our body weight. To turn the boat, we have to change the angle that the blades of the boat cut through the water. We can also turn by changing how the boat is sitting in the water. For example, if we lean the boat over, then it will change direction. Moving our weight back and forth also changes the speed that the boat moves.

I like sailing because I travel to different places. Every time I go out it is different, every time a new experience. I also have many friends within the sailing community from all over Australia and the world.

ASTRONOMER

I am Dr John O'Sullivan. In 2009, I won the Prime Minister's Prize for Science. After I completed a double degree in physics and electrical engineering, I went on to study for a PhD in radio astronomy. This is the field of science that uses radio waves to learn about stars and galaxies.

In the 1980s, while I was working with a team that was searching for exploding black holes, I started working on a technique that allowed complex radio signals to be split up, transmitted and recombined. About 10 years later, we discovered that this same idea could be used to greatly speed up radio signals between computers, mobile phones and other electronic devices.

Today, almost every wireless (WiFi) network system in the world uses the technology that was originally inspired by a search for exploding stars. One estimate has suggested that almost a billion people around the world use our invention every day!

These days I am working on Australia's attempt to build the largest telescope ever constructed—the Square Kilometre Pathfinder Telescope.

CIVIL ENGINEER

My name is Melanie Mindum and I am a civil engineer. A civil engineer puts structures in place that help people move around. We design bridges, plan road and railway links and map drainage systems so that our streets don't flood.

Recently I worked on a project that recommends where power and water services will be positioned in a new housing area. I have also designed railway lines and tram super stops that allow better access for people in wheelchairs, and upgraded railway level crossings to make them more obvious to drivers.

A civil engineer focuses on the needs of today's society, but must also ensure that what is designed now will be sustainable for the future. I enjoy my work because I like dealing with numbers and budgets and thinking logically about how to solve a problem.