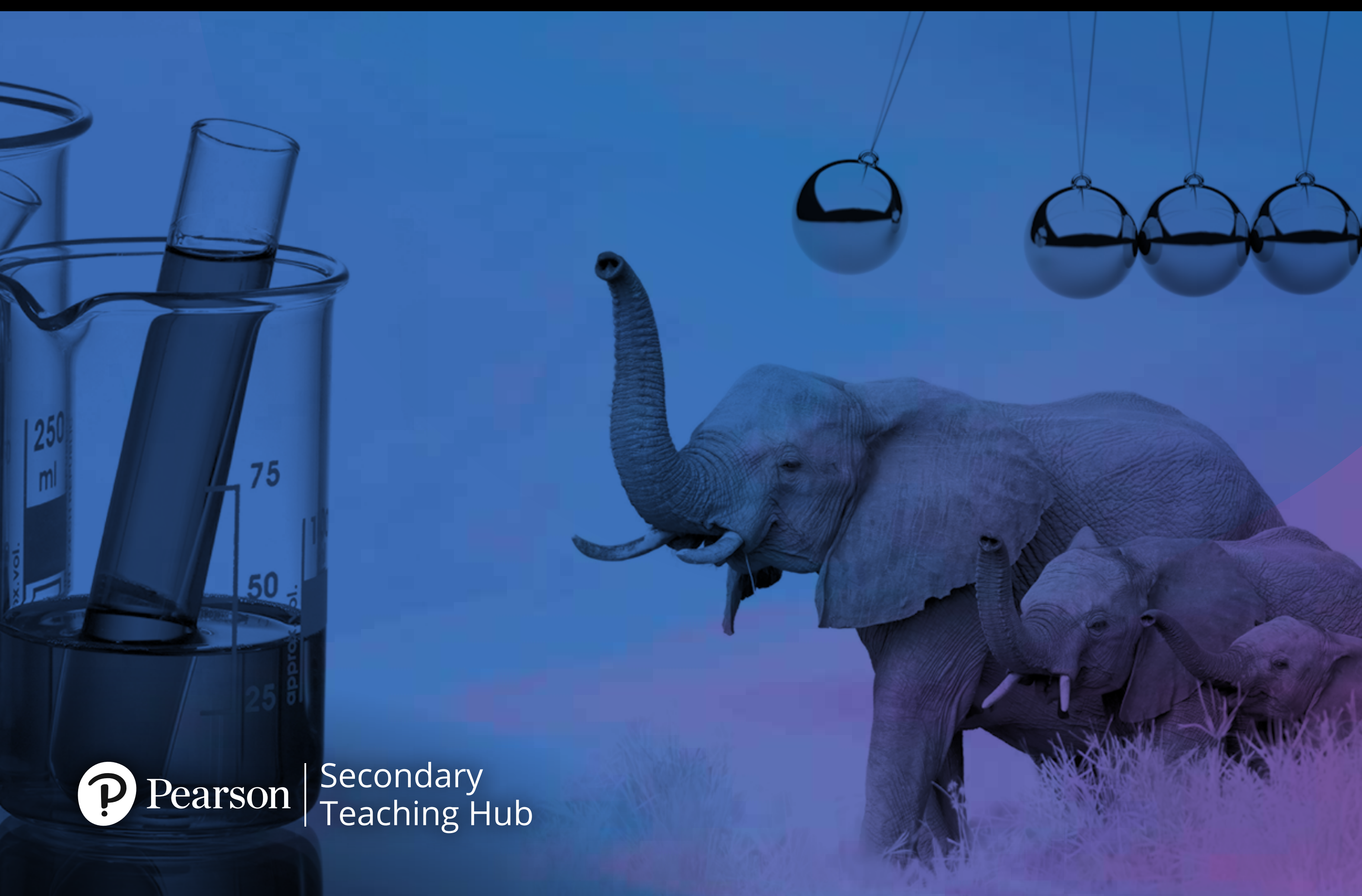
YEAR **10**

Science

STUDENT COMPANION



Pearson | Secondary Teaching Hub

Pearson Secondary Teaching Hub Science 10

Student Companion

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Pearson acknowledges the Traditional Custodians of the lands upon which the many schools throughout Australia are located.

We respect the living cultures of Aboriginal and Torres Strait Islander peoples and their ongoing connection to Country across lands, sky, seas, waterways and communities. We celebrate the richness of Indigenous Knowledge systems, shared with us and with schools Australia-wide.

We pay our respects to Elders, past and present.

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Contents

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Contents

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How to use this Student Companion

The Student Companion is a complementary resource that offers a print medium for corresponding lessons in Pearson Secondary Teaching Hub. It is designed to support teaching and learning by providing learners with a place to create a portfolio of learning to suit their individual needs, whether you are:

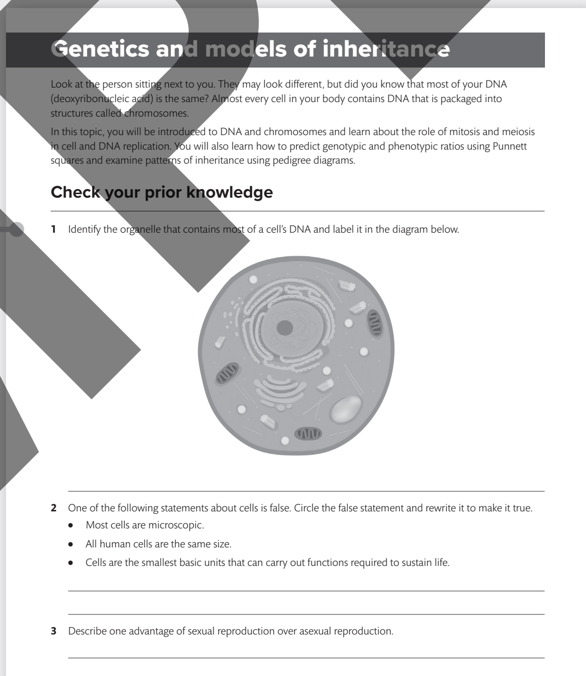
- supporting a blended classroom using the strengths of print and digital
- preparing for exams by creating a study guide or bound reference
- needing a tool to differentiate learning
- looking for meaningful homework tasks.

Learners can develop their portfolio of learning as part of classroom learning or at home as an additional opportunity to engage and re-engage with the knowledge and skills from the lesson.

This could be done as prior learning in a flipped classroom environment or as an additional revision or homework task.

Check your prior knowledge

Each topic begins with 3–5 questions that test learners' knowledge from previous years or topics in the Australian Curriculum. These questions provide insight into learners' prior knowledge before beginning a topic, allowing teachers to adapt their teaching and support as needed.


Genetics and models of inheritance

Look at the person sitting next to you. They may look different, but did you know that most of your DNA (deoxyribonucleic acid) is the same? Almost every cell in your body contains DNA that is packaged into structures called chromosomes.

In this topic, you will be introduced to DNA and chromosomes and learn about the role of mitosis and meiosis in cell and DNA replication. You will also learn how to predict genotypic and phenotypic ratios using Punnett squares and examine patterns of inheritance using pedigree diagrams.

Check your prior knowledge

1 Identify the organelle that contains most of a cell's DNA and label it in the diagram below.

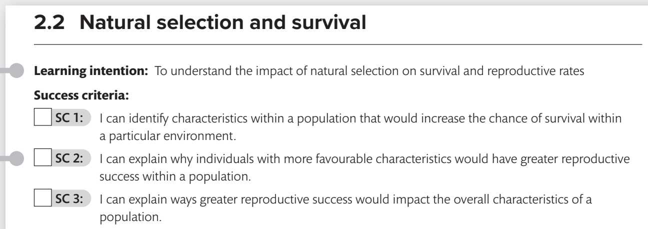
2 One of the following statements about cells is false. Circle the false statement and rewrite it to make it true.
- Most cells are microscopic.
- All human cells are the same size.
- Cells are the smallest basic units that can carry out functions required to sustain life.

3 Describe one advantage of sexual reproduction over asexual reproduction.

Learning intentions and success criteria

Learning intentions are provided for every lesson. The learning intentions are goals or objectives that align to the corresponding digital lesson. They describe what learners should know, understand or be able to do by the end of the lesson.

Success criteria clarify expectations and describe what success looks like. The success criteria are specific, concrete and measurable so learners can actively engage with and reflect on their evidence of learning within each lesson.


2.2 Natural selection and survival

Learning intention: To understand the impact of natural selection on survival and reproductive rates

Success criteria:

☐ SC 1: I can identify characteristics within a population that would increase the chance of survival within a particular environment.

☐ SC 2: I can explain why individuals with more favourable characteristics would have greater reproductive success within a population.

☐ SC 3: I can explain ways greater reproductive success would impact the overall characteristics of a population.

Icons and features

hub

The Teaching Hub icon prompts learners to engage with supporting digital resources to enhance their learning.

SPARKlab

SPARKlab icons direct learners to alternative, online practical investigations.

MATERIALS
- trolley (dynamics cart)
- piece of wood
- G-clamp
- string or fishing line
- electronic balance
- pulley and clamp
- 50 g slotted masses
- calculator
- stopwatch and ruler (to measure acceleration)
- sticky tape (to mark the starting position)
- (Alternatively, use light gates for data-logging, a motion sensor or ticker timer and ticker tape.)

Materials boxes list all the materials needed to complete a practical investigation. Some include a safety icon that highlights any substances or equipment that require care when preparing or using them.

Hint boxes provide hints and tips where relevant in practical investigations and inquiry activities.

HINTS
Use at least one graph or table to support your ideas.

The **safety icon** highlights substances or equipment that may cause harm. Be sure to prepare a risk assessment for these activities and take care when preparing or using these substances and equipment.

KEY TERM
Système international the international system of units used as a global standard for expressing the magnitudes or quantities

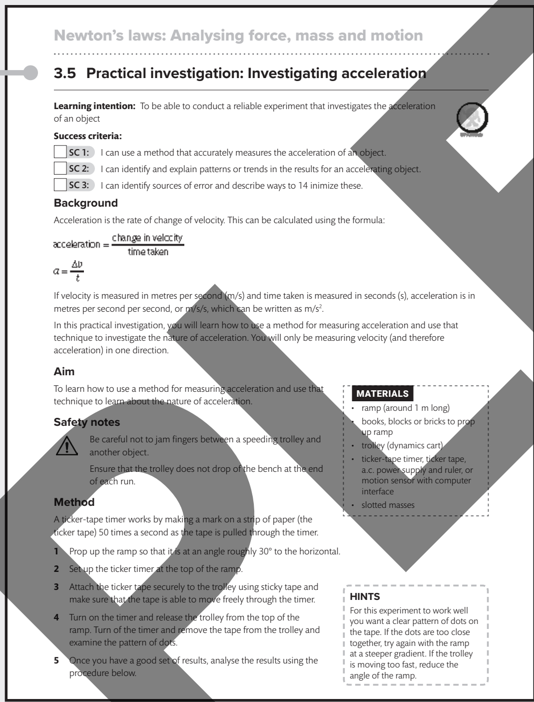
Key term boxes provide learners with definitions for the bolded key terms found throughout the text, supporting the development of their scientific vocabulary and literacy.

Check-in boxes prompt learners to check their risk assessment, method or plan with a teacher before proceeding with the practical investigation or inquiry activity.

☐ Check in with your teacher to discuss your method and risk assessment.

Theory lessons

Theory lessons support the development of science knowledge and understanding by providing content in short, accessible chunks. Questions to check learners' understanding are provided at regular intervals throughout the lesson. Each theory lesson ends with a lesson review that includes 3–6 questions.



Newton's laws: Analysing force, mass and motion

3.5 Practical investigation: Investigating acceleration

Learning intention: To be able to conduct a reliable experiment that investigates the acceleration of an object

Success criteria:

- SC 1: I can use a method that accurately measures the acceleration of an object.
- SC 2: I can identify and explain patterns or trends in the results for an accelerating object.
- SC 3: I can identify sources of error and describe ways to 14 inimize these.

Background

Acceleration is the rate of change of velocity. This can be calculated using the formula:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{\Delta v}{t}$$

If velocity is measured in metres per second (m/s) and time taken is measured in seconds (s), acceleration is in metres per second per second, or m/s/s, which can be written as m/s^2.

In this practical investigation, you will learn how to use a method for measuring acceleration and use that technique to investigate the nature of acceleration. You will only be measuring velocity (and therefore acceleration) in one direction.

Aim

To learn how to use a method for measuring acceleration and use that technique to learn about the nature of acceleration.

MATERIALS

- ramp (around 1 m long)
- books, blocks or bricks to prop up ramp
- trolley (dynamics cart)
- ticker-tape timer, ticker tape, a.c. power supply and ruler, or motion sensor with computer interface
- slotted masses

Safety notes

Be careful not to jam fingers between a speeding trolley and another object.

Ensure that the trolley does not drop of the bench at the end of each run.

Method

A ticker-tape timer works by making a mark on a strip of paper (the ticker tape) 50 times a second as the tape is pulled through the timer.

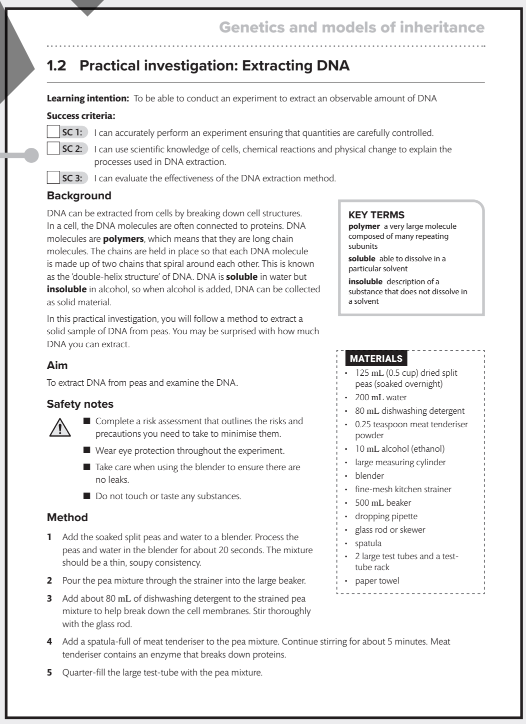
1 Prop up the ramp so that it is at an angle roughly 30° to the horizontal.
2 Set up the ticker timer at the top of the ramp.
3 Attach the ticker tape securely to the trolley using sticky tape and make sure that the tape is able to move freely through the timer.
4 Turn on the timer and release the trolley from the top of the ramp. Turn of the timer and remove the tape from the trolley and examine the pattern of dots.
5 Once you have a good set of results, analyse the results using the procedure below.

HINTS

For this experiment to work well you want a clear pattern of dots on the tape. If the dots are too close together, try again with the ramp at a steeper gradient. If the trolley is moving too fast, reduce the angle of the ramp.

Practical investigations

Practical investigations offer learners the chance to complete practical work related to the topics in their Student Companion. They will have the chance to design and conduct experiments, record results, analyse data, and prepare evidence-based conclusions. Risk assessments will need to be completed for all practical investigations, to ensure learners understand how to conduct investigations safely. SPARKlab icons indicate where an alternative, online practical investigation is available.



Genetics and models of inheritance

1.2 Practical investigation: Extracting DNA

Learning intention: To be able to conduct an experiment to extract an observable amount of DNA

Success criteria:

- SC 1: I can accurately perform an experiment ensuring that quantities are carefully controlled.
- SC 2: I can use scientific knowledge of cells, chemical reactions and physical change to explain the processes used in DNA extraction.
- SC 3: I can evaluate the effectiveness of the DNA extraction method.

Background

DNA can be extracted from cells by breaking down cell structures. In a cell, the DNA molecules are often connected to proteins. DNA molecules are **polymers**, which means that they are long chain molecules. The chains are held in place so that each DNA molecule is made up of two chains that spiral around each other. This is known as the 'double-helix structure' of DNA. DNA is **soluble** in water but **insoluble** in alcohol, so when alcohol is added, DNA can be collected as solid material.

In this practical investigation, you will follow a method to extract a solid sample of DNA from peas. You may be surprised with how much DNA you can extract.

KEY TERMS

polymer a very large molecule composed of many repeating subunits

soluble able to dissolve in a particular solvent

insoluble description of a substance that does not dissolve in a solvent

Aim

To extract DNA from peas and examine the DNA.

MATERIALS

- 125 mL (0.5 cup) dried split peas (soaked overnight)
- 200 mL water
- 80 mL dishwashing detergent
- 0.25 teaspoon meat tenderiser powder
- 10 mL alcohol (ethanol)
- large measuring cylinder
- blender
- fine-mesh kitchen strainer
- 500 mL beaker
- dropping pipette
- glass rod or skewer
- spatula
- 2 large test tubes and a test-tube rack
- paper towel

Safety notes

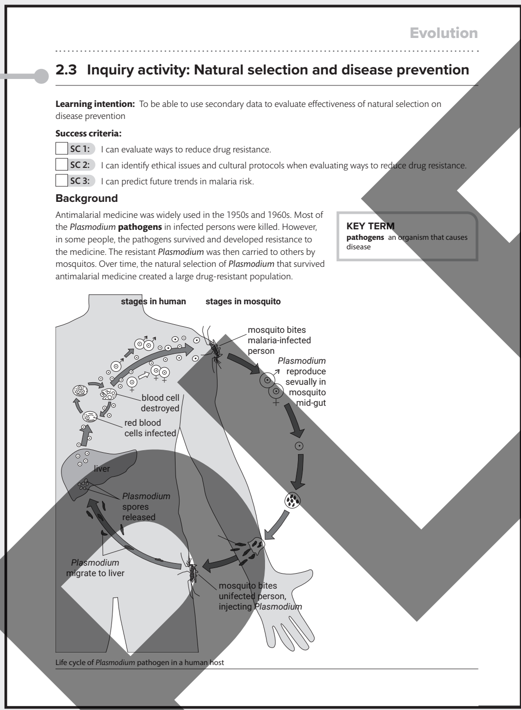
- Complete a risk assessment that outlines the risks and precautions you need to take to minimise them.
- Wear eye protection throughout the experiment.
- Take care when using the blender to ensure there are no leaks.
- Do not touch or taste any substances.

Method

1 Add the soaked split peas and water to a blender. Process the peas and water in the blender for about 20 seconds. The mixture should be a thin, soupy consistency.
2 Pour the pea mixture through the strainer into the large beaker.
3 Add about 80 mL of dishwashing detergent to the strained pea mixture to help break down the cell membranes. Stir thoroughly with the glass rod.
4 Add a spatula-full of meat tenderiser to the pea mixture. Continue stirring for about 5 minutes. Meat tenderiser contains an enzyme that breaks down proteins.
5 Quarter-fill the large test-tube with the pea mixture.

Inquiry activities

Inquiry activities are open-ended investigations that encourage learners to plan and design solutions to problems. Learners are encouraged to improve and evaluate their ideas, designs or investigations. Inquiry activities require learners to use their understanding of scientific concepts and the science inquiry skills that they have developed throughout each topic in the Student Companion.



Evolution

2.3 Inquiry activity: Natural selection and disease prevention

Learning intention: To be able to use secondary data to evaluate effectiveness of natural selection on disease prevention

Success criteria:

- [ ] **SC 1:** I can evaluate ways to reduce drug resistance.
- [ ] **SC 2:** I can identify ethical issues and cultural protocols when evaluating ways to reduce drug resistance.
- [ ] **SC 3:** I can predict future trends in malaria risk.

Background

Antimalarial medicine was widely used in the 1950s and 1960s. Most of the *Plasmodium* **pathogens** in infected persons were killed. However, in some people, the pathogens survived and developed resistance to the medicine. The resistant *Plasmodium* was then carried to others by mosquitos. Over time, the natural selection of *Plasmodium* that survived antimalarial medicine created a large drug-resistant population.

KEY TERM
pathogens an organism that causes disease

Life cycle of *Plasmodium* pathogen in a human host

Worked examples

Worked examples provide learners with a step-by-step solution to a problem. The worked examples in the *Student Companion* correspond to those in the digital lesson and are provided for each skill to:

- scaffold learning
- support skill acquisition
- reduce the cognitive load.

The **worked examples** are an effective tool to demonstrate what success looks like. The ‘try yourself’ format of the worked examples in the Student Companion support the gradual release of responsibility. Learners can view a completed worked example and a video walkthrough of the worked example in the corresponding digital lesson and then apply the scaffolded steps themselves to solve a unique problem.

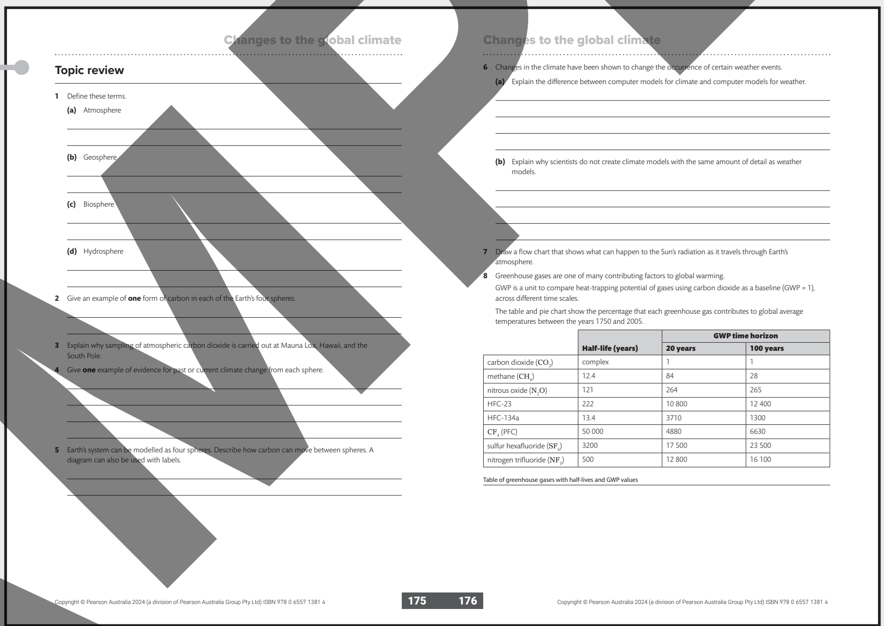
Rate my learning tool

Each lesson in the Student Companion contains a space for students to reflect on their understanding. The simple and intuitive design of the lesson reflection tool allows students to scale their confidence, reflect on their learning and identify areas in which they need support.

RATE MY LEARNING ○ I need some help ○ I am getting there ○ I get it ○ I am confident

Topic review

Each topic finishes with a **topic review** that includes 8–15 questions that address every learning intention in the topic. These questions give learners the opportunity to apply the knowledge and skills they have developed throughout the topic.



Changes to the global climate

Topic review

1 Define these terms.

(a) Atmosphere

(b) Geosphere

(c) Biosphere

(d) Hydrosphere

2 Give an example of **one** form of carbon in each of the Earth's four spheres.

3 Explain why sampling of atmospheric carbon dioxide is carried out at Mauna Loa, Hawaii, and the South Pole.

4 Give **one** example of evidence for past or current climate change from each sphere.

5 Earth's system can be modelled as four spheres. Describe how carbon can move between spheres. A diagram can also be used with labels.

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Changes to the global climate

6 Changes in the climate have been shown to change the occurrence of certain weather events.

(a) Explain the difference between computer models for climate and computer models for weather.

(b) Explain why scientists do not create climate models with the same amount of detail as weather models.

7 Draw a flow chart that shows what can happen to the Sun's radiation as it travels through Earth's atmosphere.

8 Greenhouse gases are one of many contributing factors to global warming.

GWP is a unit to compare heat-trapping potential of gases using carbon dioxide as a baseline (GWP = 1), across different time scales.

The table and pie chart show the percentage that each greenhouse gas contributes to global average temperatures between the years 1750 and 2005.

	Half-life (years)	GWP time horizon	
		20 years	100 years
carbon dioxide (CO_2)	complex	1	1
methane (CH_4)	12.4	84	28
nitrous oxide (N_2O)	121	264	265
HFC-23	222	10 800	12 400
HFC-134a	13.4	3710	1300
CF_4 (PFC)	50 000	4880	6630
sulfur hexafluoride (SF_6)	3200	17 500	23 500
nitrogen trifluoride (NF_3)	500	12 800	16 100

Table of greenhouse gases with half-lives and GWP values

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Changes to the global climate

On 24 December 1968, astronaut William Anders took a photograph known as *Earthrise*. It was the first photo ever taken from space, showing Earth as a miniscule part of a gigantic universe. Anders stated, "People realised that we lived on this fragile planet and that we needed to take care of it."

In this topic you will learn about the connections between Earth's spheres, its climate and its weather, including the influences on this dynamic system and various attempts to understand it through modelling.

Check your prior knowledge

1 Draw a diagram that shows how the greenhouse effect works.

2 Explain why photosynthesis in plants is an important reaction for humans.

3 Fossil fuels have been used to create power. Where do these types of fuels come from?

RATE MY LEARNING | I need some help | I am getting there | I get it | I am confident

6.1 Earth's spheres

Learning intention: To understand the components of Earth's four spheres and how natural interactions among the spheres can occur

Success criteria:

- ☐ **SC 1:** I can describe the components of the biosphere, atmosphere, geosphere and hydrosphere.
- ☐ **SC 2:** I can outline how energy is involved in cycling matter (including carbon, nitrogen and water) through and across the spheres.

Describing the components of the Earth's spheres

Atmosphere
• The gases that surround us are approximately 78% nitrogen, 21% oxygen, 0.9% argon, and trace gases, including carbon dioxide, neon, nitrous oxide and methane • Extends upwards for approximately 500–1000 km, although it does not have a definite boundary and is divided into different levels. • Retains some of the Sun's energy, which keeps Earth warm enough for life to exist. • Without it, Earth would average around 33°C cooler, which would be too cold for life to survive.
Hydrosphere
• All of Earth's water, whether it is solid, liquid or gas. • Includes rivers and oceans, water vapour that makes up clouds, and sea ice and ice caps. • Interacts with the three other spheres as water is used by plants and animals in the biosphere, seeps through rock in the geosphere, and moves through the atmosphere as water vapour.
Biosphere
• All living things on Earth, from tiny single-celled organisms to giant trees and mammals. • It is made up of Earth's various ecosystems. • Interacts with the other spheres as plants use carbon dioxide from the atmosphere and water from the hydrosphere in photosynthesis, and animals and plants use oxygen from the atmosphere and water from the hydrosphere for respiration, and minerals from the geosphere.
Geosphere
• Describes Earth's crust and the cool part of the mantle immediately below, all the rocks and minerals, and the inorganic (non-living) parts of soil.

1 Describe the main features of each of Earth's spheres.

(a) Atmosphere

____

____

(b) Biosphere

____

____

(c) Hydrosphere

(d) Geosphere

Energy's involvement in cycling matter through and across the spheres

Energy is needed for matter to cycle through Earth's spheres. This energy comes directly or indirectly from the Sun.

The water cycle
• Energy from the Sun is essential for the water cycle. • It causes water to evaporate from oceans and lakes, plants and animals. • This water vapour rises into the atmosphere, condenses into clouds, and moves through the atmosphere via convection. • Water falls back to land as precipitation (rain, snow and hail). • Energy from the Sun causes snow and ice to melt. • Liquid water soaks into the ground to be taken up by plant roots, runs off land into streams, rivers and then into the ocean, where the cycle starts again.
The carbon cycle
• Carbon is essential for all living things and is found in all four spheres. • It does not move through the carbon cycle at a uniform rate. • Some parts of the cycle, such as photosynthesis (of plants) and respiration (of animals), use energy from the Sun and move carbon through the spheres quickly. • Others, such as the formation of fossil fuels and limestone rocks, lock away carbon for millions of years. Extracting and burning fossil fuels alters this by releasing stored carbon into the atmosphere quickly.
The nitrogen cycle
• Nitrogen is also essential for living things. • The air is 78% nitrogen, but most organisms cannot use it directly from the air. Instead, it must be made into a form that they can use as part of the nitrogen cycle. • Nitrogen is continually cycled through the atmosphere, hydrosphere, geosphere and biosphere. • Nitrogen-fixing bacteria and some plants' roots convert nitrogen from the air into a form that plants can absorb. The plants use energy from the Sun for photosynthesis as part of this process.

2 Nitrogen is essential to living things because it forms the basis of proteins. Plants and animals do not absorb nitrogen directly from the air. Describe how nitrogen gets into living things from the air.

Give an example of how energy from the Sun is needed in this process.

Lesson review

1 Describe how energy from the Sun is involved in:

(a) the water cycle

(b) the carbon cycle.

2 In the Northern Hemisphere winter, plant growth slows, and many trees lose their leaves. There is not an equivalent increase in growth in the Southern Hemisphere. Use your knowledge of the carbon cycle to predict how you would expect the carbon dioxide concentration in the atmosphere to change in the Northern Hemisphere winter. Explain your answer.

3 Give an example of something very small and something very large from the hydrosphere, geosphere and biosphere.

RATE MY LEARNING | I need some help | I am getting there | I get it | I am confident

6.2 Greenhouse gases

Learning intention: To understand how greenhouse gas molecules can absorb infrared radiation (IR) photons

Success criteria:

- [ ] **SC 1:** I can compare the nature of visible and ultraviolet (UV) radiation from the Sun to infrared radiation (IR) from the surface of Earth in terms of the energy of photons.
- [ ] **SC 2:** I can describe how greenhouse gases absorb infrared radiation (IR) photons.
- [ ] **SC 3:** I can compare the effect of a range of greenhouse gases on the warming of the atmosphere in relation to the enhanced greenhouse effect.

Comparing visible and ultraviolet (UV) radiation from the Sun to infrared radiation (IR) from the surface of Earth through photon energy

Electromagnetic radiation

Light is also known as electromagnetic radiation. This includes visible light, UV (which plants use in photosynthesis) and IR (which we feel as warmth). Together, these are part of the electromagnetic spectrum.

Electromagnetic radiation can be described by the energy or wavelength of its **photons**. The energy of photons is inversely proportional to wavelength: the greater the energy, the shorter the wavelength. UV-light photons have high energies and short wavelengths. Radio-wave photons have low energies and long wavelengths.

KEY TERM
photon a particle without mass that carries a specific amount of energy representing a minute quantity of light or other electromagnetic radiation

The energy from the Sun

The Sun's radiation that reaches Earth is mainly visible light, with some IR and UV. The most energetic UV is blocked by the ozone layer in the upper atmosphere.

Some of the Sun's radiation is absorbed or reflected by the atmosphere and clouds and does not reach Earth. Of the radiation that reaches Earth, most is absorbed, but a small amount is reflected.

Shiny white ice or white clouds reflect much of the radiation that hits them (for example, ice reflects 84% of light). Dark surfaces such as bare earth, dark buildings or deep ocean absorb more radiation.

Energy absorbed by Earth

The Sun's energy absorbed by Earth is later re-emitted as lower-energy (longer-wavelength) IR radiation.

Some of this IR radiation is transmitted back into space, and some is absorbed by greenhouse gases and clouds in the atmosphere. Due to the principle of energy conservation, Earth must emit the same amount of energy it absorbs. However, Earth does this at longer wavelengths (lower energies) over an extended period.

1 Describe what happens to the radiation from the Sun as it reaches Earth's atmosphere.

How the structure of greenhouse gas molecules allows them to absorb IR photons

Most of the gases in Earth's atmosphere are transparent to visible and UV light from the Sun, which means those gases allow the Sun's light to pass through to reach Earth. Gas molecules only absorb photons of light with specific wavelengths or energies due to the nature of the chemical bonds that hold the molecules together. Other wavelengths pass through unaffected.

KEY TERM
greenhouse gases gases that trap heat close to the Earth's surface

The **greenhouse gases** methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) absorb light in the IR range. Water vapour absorbs IR as well as other wavelengths.

When the Sun's energy is absorbed and re-emitted as IR radiation by Earth, small amounts of greenhouse gases in the atmosphere absorb and re-emit some of it. This retains a significant amount of the IR energy emitted by Earth, resulting in Earth being about 30°C warmer than it would be without greenhouse gases.

2 Give **three** examples of a greenhouse gas, and explain how they lead to Earth retaining energy from the Sun.

Comparing the effect of greenhouse gases

Different greenhouse gases retain different amounts of infrared energy and remain in the atmosphere for different lengths of time. To compare them, we can use the following measures.

KEY TERMS
radiative forcing the extra radiation retained by Earth because of a greenhouse gas
global warming potential a measure of energy retained by Earth because of a greenhouse gas; includes the radiative forcing and lifetime of the gas. Measured in carbon dioxide equivalent

Radiative forcing describes the extra energy retained by Earth because of a greenhouse gas. This depends on how much greenhouse gas there is and the effect it has.

Global warming potential (GWP) describes how much extra infrared radiation that gas would retain (its radiative forcing) and how long the gas stays in the atmosphere.

The GWP is given as a carbon dioxide equivalent, which is the amount of warming that 1 tonne of the gas would create relative to the amount of warming from 1 tonne of carbon dioxide over a period (for example, 100 years).

The table below shows the concentrations of the main greenhouse gases, their GWP over 100 years and their average lifetime in the atmosphere.

Greenhouse gas	Source	Atmospheric concentration	GWP100 (carbon dioxide equivalent over 100 years)	Average lifetime in atmosphere
carbon dioxide (CO_2)	burning fossil fuels	414.4 ppm	1	long (thousands of years)
methane (CH_4)	livestock, fossil fuel production, landfill, deforestation, some farming	1890 ppb	28	short (approx. 12 years)
nitrous oxide (N_2O)	agriculture (from fertilisers)	334 ppb	265	long (121 years)

The amount of carbon dioxide, methane and nitrous oxide in the atmosphere has increased sharply since pre-industrial times. The CO_2 equivalent for all greenhouse gases was 516 ppm in 2021, almost double the pre-industrial level of 278 ppm.

3 When scientists compare the effects of different greenhouse gases, they need to consider variables such as its concentration, the amount of energy it retains and how long it stays in the atmosphere. Describe how they do this.

Lesson review

1 Describe the differences between the radiation Earth receives from the Sun and the radiation Earth re-emits in terms of its energy and wavelength.

2 Greenhouse gases include carbon dioxide, methane, nitrous oxide, and synthetic greenhouse gases used in industry such as chlorofluorocarbons (CFCs).

Write these greenhouse gases in order of their:

(a) warming potential over 100 years (from least to greatest)

(b) atmospheric concentration (from lowest to highest).

3 Other greenhouse gases have a much higher global warming potential than carbon dioxide. Why does carbon dioxide have such a big impact on the enhanced greenhouse effect?

RATE MY LEARNING — I need some help | I am getting there | I get it | I am confident

6.3 Earth's climate and global temperatures

Learning intention: To understand how climate is affected by energy flow within and between Earth's spheres

Success criteria:

- [ ] **SC 1:** I can describe the Earth's climate as a system of interactions between the atmosphere, geosphere and hydrosphere and how deep ocean currents regulate climate.
- [ ] **SC 2:** I can describe climatic events, including El Niño and La Niña.
- [ ] **SC 3:** I can describe, using evidence, how the enhanced greenhouse effect is affecting Earth's climate processes.

Earth's climate

Earth's climate is formed by the interaction between the hydrosphere, atmosphere and geosphere, as thermal energy is moved around Earth via radiation, convection and conduction.

Energy flow in the hydrosphere

Water has a high **specific heat capacity**, in which it can store large amounts of thermal energy. Ocean currents move this thermal energy over long distances by **convection**. This movement of thermal energy affects the climates around the world.

KEY TERMS

convection the transfer of heat through movement in a liquid or gas

specific heat capacity the amount of energy required to raise a specific amount of a substance by a specific temperature. Normally one kilogram of the substance by one degree Celsius

Ocean currents occur because of:

- differences in water temperature and salinity (salt concentration)
- wind
- the rotation of Earth
- the gravitational pull of the Sun and moon.

One well-known part of the global conveyor belt is the Gulf Stream. This carries warm water up the east coast of the Americas towards Europe. Without it, Western Europe would be much cooler.

Energy flow in the atmosphere

Energy is transferred around Earth's atmosphere via convection. This happens much more quickly than in the hydrosphere.

- Different parts of Earth absorb different amounts of energy from the Sun – the equator receives more energy from the Sun than the poles, and dark land absorbs more energy than snow and ice.
- As air is heated, becomes less dense and rises, being replaced by cooler, more dense air. This creates convection currents.

1 State the name of the circulation of water around Earth's oceans. Give an example of how the thermal energy it carries affects the climate of a region of Earth.

Understanding climatic events, including El Niño and La Niña

Earth experiences climate cycles from year to year because of natural changes in the way thermal energy circulates around the atmosphere and oceans. Two major cycles that affect Australia's climate are the El Niño Southern Oscillation and the Indian Ocean Dipole.

El Niño Southern Oscillation

The El Niño Southern Oscillation (ENSO) is a sequence of changes to the way thermal energy circulates across the Pacific Ocean in the ocean and atmosphere. It describes the cycle between El Niño and La Niña climate conditions, which affect the weather around the world, especially in Australia and South America. An El Niño typically happens every three to eight years, although sometimes El Niño or La Niña can happen for two or more years in a row and can vary in strength.

Cycle	Formation	Typical effects
El Niño	• trade winds that usually blow from east to west across the Pacific Ocean weaken or even reverse • sea surface temperatures in the central and eastern Pacific Ocean are higher than average • the sea heats the air above it and changes the circulation of air in the atmosphere	• Eastern Australia: hotter, drier weather and often droughts • South America: warmer and wetter
La Niña	• trade winds at the equator strengthen • this pushes warm surface water to the western Pacific Ocean and north of Australia • cool water pools in the eastern Pacific	• Most of Australia: wetter weather, floods and cooler weather are more likely • Northern Australia: increased probability of cyclones • South America: drier weather

2 Name the **two** major cycles that affect Australia's climate and give the names for the two states each of these cycle through.

Understanding how the enhanced greenhouse effect is affecting Earth's climate systems

The extra thermal energy retained by Earth because of the **enhanced greenhouse effect** moves through the hydrosphere, atmosphere and geosphere and affects the Earth's climate.

KEY TERM
enhanced greenhouse effect xxxxxxxxxxxxxx

Energy stored in the oceans

It is thought that over 90% of the extra thermal energy Earth has retained because of the enhanced greenhouse effect caused by human activity is stored in the oceans. Even if atmospheric warming stops, the heat stored in the oceans is likely to be released for some time.

This stored heat could change ocean currents and the cycles that regulate our climates. For example, warmer oceans are melting ice at the poles and stopping the usual formation of sea ice in winter.

3 Since the Industrial Revolution, Earth has stored significantly more thermal energy because of the enhanced greenhouse effect. Where is this energy mostly stored?

Lesson review

1 Explain the difference between deep ocean currents and surface ocean currents. In your answer, refer to how they form and their direction.

2 Explain the difference between the El Niño Southern Oscillation and the Indian Ocean Dipole. Refer to where they occur and their impact on Australia.

3 Earth has retained thermal energy because of the enhanced greenhouse effect. Where is this energy mostly stored? Explain whether this is a good thing or not, giving an example of an effect this could have.

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6.4 Climate and weather

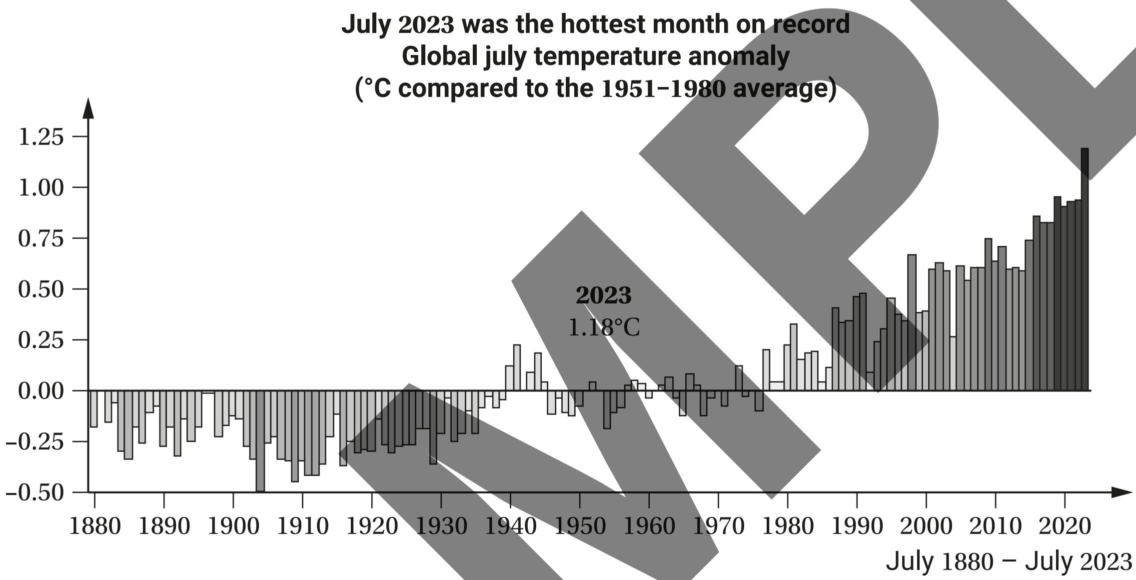
Learning intention: To understand how climate change and the enhanced greenhouse effect can lead to specific weather events

Success criteria:

- [ ] **SC 1:** I can describe how complex climate and weather systems are modelled.
- [ ] **SC 2:** I can analyse evidence that suggests cause-and-effect relationships between weather events and climate change.
- [ ] **SC 3:** I can describe specific weather events related to climate change.

Rising global temperatures

July 2023 was hotter than any previous July, with an average global temperature of 16.95°C. The NASA graph below shows how the July 2023 temperature differed from the July average (1951–80).



Graph showing the difference in temperature between July 2023 and the 1951–80 average

Climate change can lead to **extreme weather events** such as intense heat or rainfall becoming more frequent and more severe. Scientists can link weather events to climate change using models that are complex but based on simple scientific principles.

> **KEY TERMS**
> **climate change** long-term changes in climate including temperature change and weather patterns
> **extreme weather event** a weather event that is rare for that place and time of year

Understanding how complex climate and weather systems are modelled

To understand and predict the effects of climate change, scientists must analyse past weather data and the corresponding climate conditions to identify trends or patterns.

Scientific models

To test and compare models, scientists run simulations using a standardised set of data and make their results available for analysis and evaluation. They also run simulations modelling historical climate events to check the model's accuracy.

To increase the reliability of results, several simulations can be run using the same model or different models to make sure there is good agreement between results.

Climate versus weather models

The models used for climate and weather are similar but look at different scales of time and/or level of spatial **resolution**, as shown in the table.

KEY TERM
resolution the smallest change in a quantity being measured that is able to be detected by a measuring device or process

Climate models	Weather models
• consider averages over the long term and over large areas • generally, have low resolution • consider processes that act over long timescales and distances such as the ocean conveyor belt • can consider processes that act over shorter timescales and distances such as turbulence in the atmosphere • include natural factors such as volcanic eruptions and variations in the energy emitted by the Sun	• look at the short term and over more-detailed areas • generally, have high resolution • require detailed information about the current state of the atmosphere • deal with **chaotic systems** (in other words, very complicated behaviour of the atmosphere and oceans that is difficult to predict due a lack of repeating patterns) • are accurate only over the short term because a small change in initial conditions can lead to large errors in forecasts over a week or more.

hub **SkillBuilder:** Mathematical models

1 Explain the difference between climate modelling and weather modelling.

Understanding evidence that suggests cause-and-effect relationships between weather events and climate change

After an extreme event, people often ask 'Did climate change cause this?'. Although it is a reasonable question to ask, it is a difficult one to test scientifically. Better questions are: 'Did climate change make this event more likely to happen?' or 'Did climate change make this event more severe?'

These inquiry questions can be refined to make them more specific and, therefore, more testable. For example, 'By how much has the probability of having three days of temperatures above 40°C increased?'

Attribution science uses data about past weather events and climate modelling to determine whether human-caused climate change could have affected an extreme weather event. To do this, the models assess the likelihood of the event by comparing two climate simulations: one that factors in the effects of human-caused climate change, and one that assumes there has been no change in the climate due to human influence.

2 Using modelling, scientists can predict the types of weather events we are likely to see. Explain how modelling is used to show that particular types of weather events are more likely to happen.

How specific weather events relate to climate change

Scientists have observed and can forecast the following weather events linked to climate change.

Heatwaves
• climate change has already increased the frequency, intensity, and length of heatwaves – short periods of unusually hot weather – and models predict this will continue
Cold weather
• number and severity of cold weather events are decreasing – for example, the Australian Alps have less snow cover and fewer snow days
Fire weather
• fire season is longer across large parts of Australia, which gives less time to safely reduce fuel loads with burn offs
Flooding and storms
• the atmosphere can hold around 7% more moisture per degree of warming • this leads to heavier bursts of rain, which increases the risk of flooding • floods occurred in New South Wales and Queensland in 2022 when extreme rainfall fell onto land that was already saturated from consecutive La Niña events
Drought
• Southeast Australia has had a 10% decrease in April–October rain since the 1990s • Southwest Australia has had a 9% decrease in April–October rain since 1970
Cyclones and hurricanes
• the number of tropical cyclones around Australia has decreased over the past 40 years • however, some models forecast a greater proportion of high-intensity hurricanes and cyclones from warmer sea-surface temperatures and higher sea levels

3 The following data from a 2023 Intergovernmental Panel on Climate Change (IPCC) report shows the effect of different amounts of warming on hot-weather events in Southern Africa.

Amount of warming above pre-industrial average	1.5°C	2°C	3°C
Increase in the number of heatwaves each year	2–4 times	4–8 times	8–12 times
Increase in the number of days each year with a maximum temperature above 35°C	45–58	52–68	66–87

Draw a graph or chart to show:

(a) the increase in the number of heatwaves

(b) the increase in the number of days with a maximum temperature over 35°C.

Lesson review

1 Explain why it is important to run climate simulations multiple times and to analyse results from different climate models when making predictions about climate change trends.

2 Climate change modelling predicts that Australia will experience fewer cyclones, however, there are some models that predict a greater number of high-intensity cyclones. Suggest a reason for the variation in predictions between different models.

3 When designing a climate change model, suggest which of the following three factors; accuracy, precision, or rapidity, is the most important factor to ensure a model is useful. Justify your answer.

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6.5 Evidence for a changing climate

Learning intention: To understand what evidence can be used to show how the Earth's climate has changed throughout history

Success criteria:

- [ ] **SC 1:** I can describe how the atmosphere and geosphere can provide evidence of climate change, including changes in atmospheric temperatures and evidence of past ice ages.
- [ ] **SC 2:** I can explain how the hydrosphere can provide evidence of climate change, including changes in ocean temperatures, polar ice coverage and sea levels.

How the atmosphere and geosphere provide evidence of climate change

Collecting evidence of climate change

Standardised records of weather conditions have only been accurately recorded for approximately the last 130 years. **Paleoclimate** research looks for data before 1880 from sources such as ice cores, corals, rock formations, tree rings and ocean sediments.

KEY TERM
paleoclimate the study of past climates using various sources of evidence to understand how Earth's climate has changed over long periods of time

Evidence in the geosphere

The geosphere contains evidence for historical changes to the Earth's climate, as shown in this table.

rocks and carbon dating	rocks can show evidence of past ice or glaciers, which can then be dated using carbon dating
borehole sampling	surface temperatures affect rocks' thermal properties during their formation
ice core sampling	ice cores from glaciers or polar areas can inform about past greenhouse gases and sea levels
pollen content	pollen grains preserved in fossils can give information about the climate in a location at that time
fossils in sedimentary rocks	show where sea levels were in the past
ocean sediments	give information about currents, sea levels, temperatures and ice ages
dendrochronology (analysis of tree rings)	can calculate the growing seasons and rates of growth; this gives information about rain and temperature over the life of the tree

Evidence in the atmosphere

Evidence about past changes in climate can be compared to present measurements taken in the atmosphere. Paleoclimatologists can use this to infer past temperature variations and extrapolate long-term climate trends over geological time scales.

- Temperature can be measured using thermometers and remote sensing satellites.
- Observing convection currents, radiation transfer and wind currents tracks heat movement.
- Air pollutants, such as ozone and volatile organic compounds, and greenhouse gases are monitored and assessed for their ability to trap heat in the atmosphere.

1 List evidence palaeoclimatologists use to help determine past climate trends.

How the hydrosphere provides evidence of climate change

Changes in the water cycle, including drought and changing amounts of rainfall, snow, and ice, can give indications of long-term trends in climate. A variety of measurements of the hydrosphere contribute to our understanding of the changing climate.

Temperature
• Earth's climate is affected by the heat stored in the oceans • information about ocean temperature, salinity and depth helps scientists monitor changes in temperature and circulation patterns, which directly influence climate dynamics
Sea level changes
• data from sediment cores, coastal dunes and ancient shorelines can give information about past sea levels • satellite data can be used to measure changes in sea levels and the volume of water in our oceans, lakes and rivers
Polar ice and ice-core data
• researchers drill ice cores up to 2 km deep inside polar ice sheets in Greenland and Antarctica • pollen and other particles and atmospheric gases trapped inside for hundreds of thousands of years give information about the climate at the time • satellites can measure the thickness of polar sea ice and snow cover
Streamflow
• changes in river and stream shape and size, sediment composition, and aquatic organisms can reflect changes in rainfall, temperature, melting ice or drought • scientists can use this to reconstruct past climate conditions and understand how they have changed over geological timescales

2 Explain, with examples, how satellites have improved our ability to collect information about the hydrosphere.

Lesson review

1 Describe what kind of climate data was available before standardised sampling began. Explain why it was not reliable for predicting global climate trends.

2 Describe how the age of samples taken from ice cores can be interpreted.

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6.6 Managing and reversing the impact of climate change

Learning intention: To understand ways to limit changes to Earth's climate and reduce impacts of climate change

Success criteria:

- [ ] **SC 1:** I can identify strategies, including traditional fire-management regimes, that humans use to reduce greenhouse gas emissions.
- [ ] **SC 2:** I can use evidence to explain how new technology can be used to reduce greenhouse gas emissions.
- [ ] **SC 3:** I can compare the effectiveness of reducing greenhouse gas emissions to carbon sequestration.

Human strategies for reducing greenhouse gas emissions

Strategies to reduce greenhouse gas emissions or remove carbon from the atmosphere include the following.

Traditional fire management

Traditional fire management practices aim to prevent hotter and uncontrolled fires that emit more greenhouse gases including carbon dioxide, nitrous oxide and methane than cooler, controlled burns. Controlled burns are also more selective about what burns, often sparing plants that are tolerant of cooler temperatures. Currently, Indigenous-led fire management projects cover 22 million hectares of land and reduce emissions by one million tonnes each year.

Generating energy without emissions

Renewable energy sources include solar energy, **geothermal energy**, wind turbines, ocean wave and tidal energy, organic waste and **biomass** energy and **hydropower**. These sources do not burn fossil fuels or release greenhouse gases as they generate electricity. This is part of a process referred to as **decarbonising**. It is important to consider the overall climate impact, including the materials needed and the cost. Some renewable energy sources far outweigh others in terms of cost and environmental benefits.

Nuclear energy also does not directly create greenhouse gases but the extent of its use around the world varies considerably due to factors like economics, risk and radioactive waste management. While Australia has never had a nuclear power plant, we are the third largest producer of radioactive uranium, which is used in nuclear power generation overseas.

KEY TERMS

geothermal energy the heat energy that comes from within the Earth

biomass all plant and animal matter found on Earth

hydropower the process of using water falling from a height to turn turbines and generate electricity

decarbonising ssssss

Increasing carbon sinks

Natural **carbon sinks** absorb carbon dioxide from the atmosphere in plants, soil and the oceans, in a process called **carbon sequestration**.

Natural carbon sinks include plants that absorb CO_2 through photosynthesis and store carbon. These include forests and rainforests, seagrass meadows in oceans, marine algae, alpine grasslands and tropical savannas. Carbon can be stored in the soil long-term where organic matter accumulates, such as in wetlands and permafrost (frozen soils) in Arctic and subarctic regions.

Many of these carbon sinks have been lost through human activities since industrialisation began. Reversing these losses, by replanting trees and other plants, planting cover crops, and conserving forests and marine parks, is important to mitigate the impacts of climate change.

KEY TERMS

carbon sink a substance or system that that absorbs more carbon from the atmosphere than it releases

carbon sequestration the process used to capture and store carbon, normally in the form of carbon dioxide, from the atmosphere

Reducing emissions

Emission reduction methods include using materials such as bioplastics that aren't made directly from fossil fuels, sourcing energy from renewable sources and recycling material such as plastics. Opportunities also exist to develop alternative products for materials like concrete, which releases greenhouse gases as it hardens. Renewable energy can replace fossil fuels for transport and more efficient transport options can be used. For example, overland transport generally uses less fuel than cargo ships.

Improving energy efficiency – for example, by adding insulation – reduces energy use for heating.

Reduce waste

Waste in landfill releases greenhouse gases, with almost half of the emissions being methane, a potent greenhouse gas. Reducing consumption, reusing, repurposing, and recycling can prevent waste going to landfill.

Changes to transport

Burning fossil fuels for transport makes up 14% of global greenhouse gas emissions. Alternatives such as public transport, carpooling, bike riding and walking all reduce emissions. Electric vehicles (EVs) are becoming more common, although it is important to source power for these from renewable sources to maximise emission reductions.

1 State **three** examples of natural carbon sequestration.

Using evidence to explain how new technology can be used to reduce greenhouse gas emissions

In the last decades we have seen incredible technological advances including technologies aimed at producing energy without creating greenhouse emissions. These developments use data to improve planning and can be used to reduce emissions stop greenhouse gases being emitted into the atmosphere, remove greenhouse gases from the atmosphere, or a combination of these.

Artificial Intelligence (AI)

Artificial Intelligence can be used to reduce greenhouse gas emissions by improving modelling for freight movement, energy use, building efficiency, water use and materials research.

> **KEY TERM**
> **artificial Intelligence** computer systems that are able to perform tasks such as reasoning, learning and acting in a way normally requiring human intelligence

Direct air capture (DAC)

DAC removes greenhouse gases using giant filters, which capture carbon and inject it deep underground. However, DAC is very expensive, because of the energy needed to run the system, and is only just becoming commercially available.

Carbon capture and storage (CCS)

CCS captures CO_2 at the site of production, such as a gas liquification plant or coal-fired power station, and then pumps it deep underground. Because CCS must be at the site of the plant or power station, there is a risk that the stored CO_2 could leak from its underground reservoir if the geology of the site is not right. Currently, CCS is extremely expensive.

Cloud seeding

Cloud seeding increases water supply in a specific area by changing where rain falls. It works by spraying small particles onto clouds to speed up the processes that cause precipitation. Its effectiveness or impact on the environment is still being researched.

It is important to note that cloud seeding is an attempt to manage the *symptoms* of accelerated climate change. It is not addressing the cause – the rapid increase in greenhouse gases.

2 Explain the differences and similarities between DAC and CCS systems.

The effectiveness of reducing greenhouse gas emissions and carbon sequestration

The Intergovernmental Panel on Climate Change (IPCC) sixth assessment report states that we would need to reach net zero emissions by 2050 to keep warming below 1.5°C. To do this, both carbon sequestration and emission reduction are needed. At least 6 billion tonnes of CO_2 would need to be removed per year by 2050 and about 14 billion tonnes per year by 2100 to give a 50% chance of limiting global warming to below 1.5°C. To do this, we need to do a combination of:

- increasing carbon sequestration—current rates would need to at least triple by 2050 and increase by 7 times by 2100 to meet these targets (however, there is also a limit to how much carbon can be sequestered, meaning it cannot be used as the only solution to reduce greenhouse gases in the atmosphere; protecting or restoring natural carbon sinks such as coastal wetlands, many of which were destroyed as land reclamation projects in the past)
- increasing the capacity of artificial methods such as DAC and CCS
- reducing greenhouse gas emissions.

3 Carbon capture storage (CSS) only accounts for 0.12% of the world's carbon sequestration. Describe at least **two** reasons why it is not more widely used.

Lesson review

1 How can adopting a reuse and recycle mindset help reduce household greenhouse gases?

2 What does decarbonising the electricity supply mean?

3 Name the **two** main methods of carbon sequestration.

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6.7 Inquiry activity: Modelling climate changes

Learning intention: To be able to use models and simulations to make predictions about future changes in Earth's climate

Success criteria

- [ ] **SC 1:** I can describe how scientists construct climate models.
- [ ] **SC 2:** I can use simulations to explore and predict patterns of climate changes.
- [ ] **SC 3:** I can use climate models to predict future effects on the Earth's temperature.

Background

Modern climate models use scenarios called Representative Concentration Pathways (RCPs). These are sets of standardised data about factors such as future emissions, changes to land and vegetation, economic growth and energy use that are used to forecast future warming to our climate.

The Paris Agreement goal, using RCP 2.6, was for CO_2 emissions to have started declining by 2020 and get to zero by 2100 for the temperature rise to be limited to 2°C.

In this inquiry activity, you will learn how models are used and will explore a simulation to find patterns and make predictions about Earth's future climate.

Aim

To explore three scenarios using a simplified climate model, found on the Center for Science Education website.

- **Scenario 1**: What happens if we reduce our emissions from the current 10.6 gigatonnes of carbon per year (GtC/yr) to under 9 GtC/yr?
- **Scenario 2**: What happens if our emissions rise above 10.6 GtC/yr before dropping after 2050?
- **Scenario 3**: What is required to meet an RCP 2.6 and stay there after 2100?

Plan

Carry out the modelling using the three scenarios listed and note your findings. Continue in your notebook if necessary.

hub **SkillBuilder:** Analysing a line graph
hub **SkillBuilder:** Determining the gradient
hub **Worked example:** Determining the gradient

Design

Design a set of tables to collate data from your simulations. Consider what data is important to capture and analyse when using a climate model.

hub **SkillBuilder:** Designing a results table

HINTS

Recording data for each year can help you see trends.

Do you need data on just the temperature? Can you use CO_2 measurements?

Explore the temperature and CO_2 gradients and what climate trends are likely to continue after 2100.

Conduct

1. Run the model for the three scenarios using the methods you planned.
2. Record your data in your tables.
3. For each scenario, analyse your results and consider if your results give enough information to respond to each scenario. If you cannot answer 'yes' for a scenario, review your method for changes needed, and repeat the simulation.

   Scenario 1: What happens if we reduce our emissions to under 9GtC/yr?

   Scenario 2: What happens if our emissions rise above 10.6 GtC/yr before dropping down after the year 2050?

   Scenario 3: What is required to meet an RCP 2.6 and to stay there after 2100?

Improve

Review how you conducted the investigation. Write a short statement about how you could improve your investigation. Use the following prompts to assist you.

- Did you follow your process exactly or did you need to make changes as you were working?
- What can you do to improve your method now that you have completed the modelling?
- Could you have made any changes or improvements to the table you created?
- Are you able to answer each of the scenario questions?

Evaluate

1. Assess what you have learnt from this investigation by working through the following tasks.
2. Give your assessment of the Earth's future and climate by combining the data you have gained from each of the modelled scenarios. For each of the scenarios, what do you predict will happen to the Earth's temperature after 2100?

3 Evaluate how reliable your predictions are and list their limitations.

hub **Worked example:** Evaluating reliability

HINTS

Create a prediction of the best- and worst-case scenarios from the results of your investigation.
Remember to use data from your tables and graphs to support your statements.
Use the gradient of the temperature line to help predict future temperature trends on Earth.
Compare your model with Earth system models (ESMs) used by climate scientists.

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Topic review

1 Define these terms.

(a) Atmosphere

(b) Geosphere

(c) Biosphere

(d) Hydrosphere

2 Give an example of **one** form of carbon in each of the Earth's four spheres.

3 Explain why sampling of atmospheric carbon dioxide is carried out at Mauna Loa, Hawaii, and the South Pole.

4 Give **one** example of evidence for past or current climate change from each sphere.

5 Earth's system can be modelled as four spheres. Describe how carbon can move between spheres. A diagram can also be used with labels.

6 Changes in the climate have been shown to change the occurrence of certain weather events.

(a) Explain the difference between computer models for climate and computer models for weather.

(b) Explain why scientists do not create climate models with the same amount of detail as weather models.

7 Draw a flow chart that shows what can happen to the Sun's radiation as it travels through Earth's atmosphere.

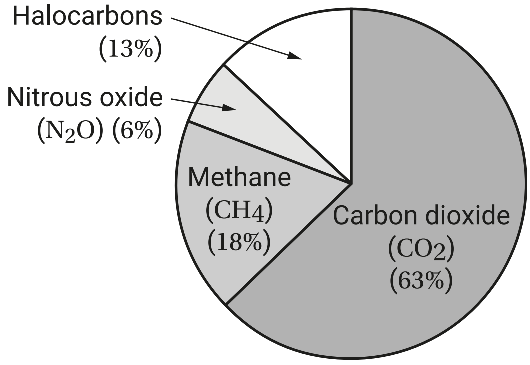
8 Greenhouse gases are one of many contributing factors to global warming.

GWP is a unit to compare heat-trapping potential of gases using carbon dioxide as a baseline (GWP = 1), across different time scales.

The table and pie chart show the percentage that each greenhouse gas contributes to global average temperatures between the years 1750 and 2005.

		GWP time horizon	
	Half-life (years)	**20 years**	**100 years**
carbon dioxide (CO_2)	complex	1	1
methane (CH_4)	12.4	84	28
nitrous oxide (N_2O)	121	264	265
HFC-23	222	10 800	12 400
HFC-134a	13.4	3710	1300
CF_4 (PFC)	50 000	4880	6630
sulfur hexafluoride (SF_6)	3200	17 500	23 500
nitrogen trifluoride (NF_3)	500	12 800	16 100

Table of greenhouse gases with half-lives and GWP values



Contributions of greenhouse gases to the increase in atmospheric temperatures. The above figures are based on the best estimates from 1750 to 2005. (Source: IPCC Fourth Assessment Report)

Using this information, make an argument for which greenhouse gas emissions you would choose to reduce if you could pick only one. Justify your answer. What strategies would you adopt to help this?

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