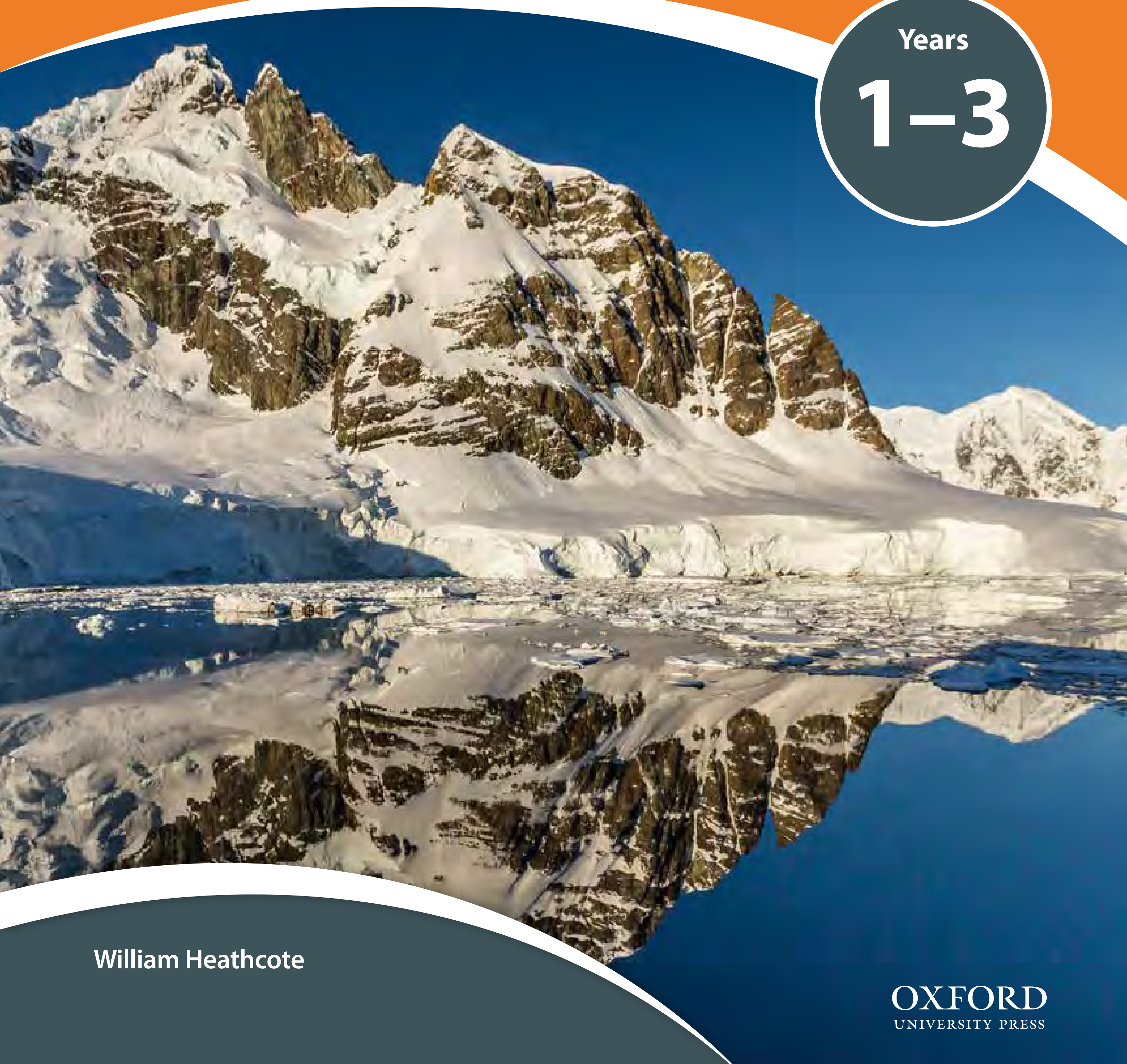
MYP Physical and Earth Sciences

A concept-based approach

Years 1–3



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Introduction

The MYP Physical and Earth Sciences course, like all MYP Sciences, is inquiry based. To promote conceptual understanding, the MYP uses key concepts and related concepts. Key concepts represent big ideas that are relevant across disciplines. The key concepts used in MYP Sciences are change, relationships and systems. Related concepts are more specific to each subject and help to promote more detailed exploration. Each chapter is focused on a topic area in Physical and Earth Sciences, one key concept and two of the 12 related concepts.

The 12 chapters in this book do not form a fixed linear sequence. They form a 3×4 matrix, organized by key concept:

Change	Systems	Relationships
Motion	Balanced forces	Unbalanced forces
Potential energy, kinetic energy and gravity	Heat and light	Waves and sound
Chemical reactions	Atoms, elements and compounds	Properties of matter
The Earth	The atmosphere	The universe

There are many different ways of navigating through this matrix. The ideal route will depend on students' ages and any additional requirements from the local science curriculum.

The objectives of MYP Science are categorized into four criteria, which contain descriptions of specific targets that are accomplished as a result of studying MYP Science:

A. Knowing and understanding

B. Inquiring and designing

C. Processing and evaluating

D. Reflecting on the impacts of science

Within each chapter, we have included activities designed to promote achievement of these objectives, such as experiments and data-based questions. We have also included activities designed to promote development of approaches to learning skills. The summative assessment found at the end of each chapter is framed by a statement of inquiry relating the concepts addressed to one of the six global contexts and features both multiple-choice questions and questions that require longer answers.

Overall, this book is meant to guide a student's exploration of Physical and Earth Sciences and aid development of specific skills that are essential for academic success and getting the most out of this educational experience.

How to use this book

To help you get the most out of your book, here is an overview of its features.

Concepts, global context and statement of inquiry

The key and related concepts, the global context and the statement of inquiry used in each chapter are clearly listed on the introduction page.

Activities

A range of activities that encourage you to think further about the topics you studied, research these topics and build connections between physical and earth sciences and other disciplines.

ABC

Vocabulary features are designed to introduce and familiarize you with the key terms you will need to know when studying the physical and earth sciences.

Experiments

Practical activities that help you develop skills for assessment criteria B & C.

Data-based questions

These questions allow you to test your factual understanding of physical and earth sciences, as well as study and analyse data. Data-based questions help you prepare for assessment criteria A, B & C.

ATL Skills

These approaches to learning sections introduce new skills or give you the opportunity to reflect on skills you might already have. They are mapped to the MYP skills clusters and are aimed at supporting you become an independent learner.

Summative assessment

There is a summative assessment at the end of each chapter; this covers all four MYP assessment criteria.

Mapping grid

This table shows you which key concept, related concepts, global context and statement of inquiry guide the learning in each chapter.

Chapter	Key concept	Related concepts	Global context	Statement of inquiry	ATL skills
1 Motion	Change	Movement Patterns	Orientation in space and time	Knowing our position in space and time helps us to understand our place in the world.	**Communication skills**: Using mathematical notation **Research skills:** Understanding intellectual property
2 Balanced forces	Systems	Interaction Function	Identities and relationships	The interaction of forces can create a balanced system.	**Communication skills**: Communicating numerical quantities
3 Unbalanced forces	Relationships	Energy Consequences	Scientific and technical innovation	The relationship between unbalanced forces and energy has enabled huge improvements in technology.	**Transfer skills**: Isaac Newton
4 Potential energy, kinetic energy and gravity	Change	Form Energy	Orientation in space and time	Changes in energy drive the basic processes of nature.	**Critical thinking skills**: Observing carefully in order to recognize problems
5 Waves and sound	Relationships	Models Interaction	Personal and cultural expression	The waves that we see and hear help to form our relationship with the outside world.	**Communication skills**: Understanding human perception
6 Heat and light	Systems	Environment Development	Globalization and sustainability	Our environment is governed by the behaviour of heat and light.	**Self-management skills:** Emotional management

Chapter	Key concept	Related concepts	Global context	Statement of inquiry	ATL skills
7 Atoms, elements and compounds	Systems	Patterns Models	Identities and relationships	The complex chemicals that enable life to exist are formed from only a few different types of atom.	**Communication skills**: Organizing and depicting information logically
8 Properties of matter	Relationships	Form Transformation	Globalization and sustainability	New materials with differing properties have helped to create today's global society and may hold the answers to some of the problems of the future.	**Communication skills**: Technology and collaboration
9 Chemical reactions	Change	Function Evidence	Fairness and development	As people have used chemical reactions, their society has changed and developed.	**Communication skills**: Choosing a line of best fit
10 The Earth	Change	Transformation Development	Fairness and development	The Earth has been transformed by slow processes that still continue today.	**Creativity and innovation skills**: Earthquakes in cities
11 The atmosphere	Systems	Consequences Environment	Globalization and sustainability	The atmosphere around us creates the conditions necessary for life.	**Communication skills**: International cooperation
12 The universe	Relationships	Evidence Movement	Orientation in time and space	The study of our solar system and the wider universe can lead to a better understanding of our own planet.	**Communication skills**: Making contact

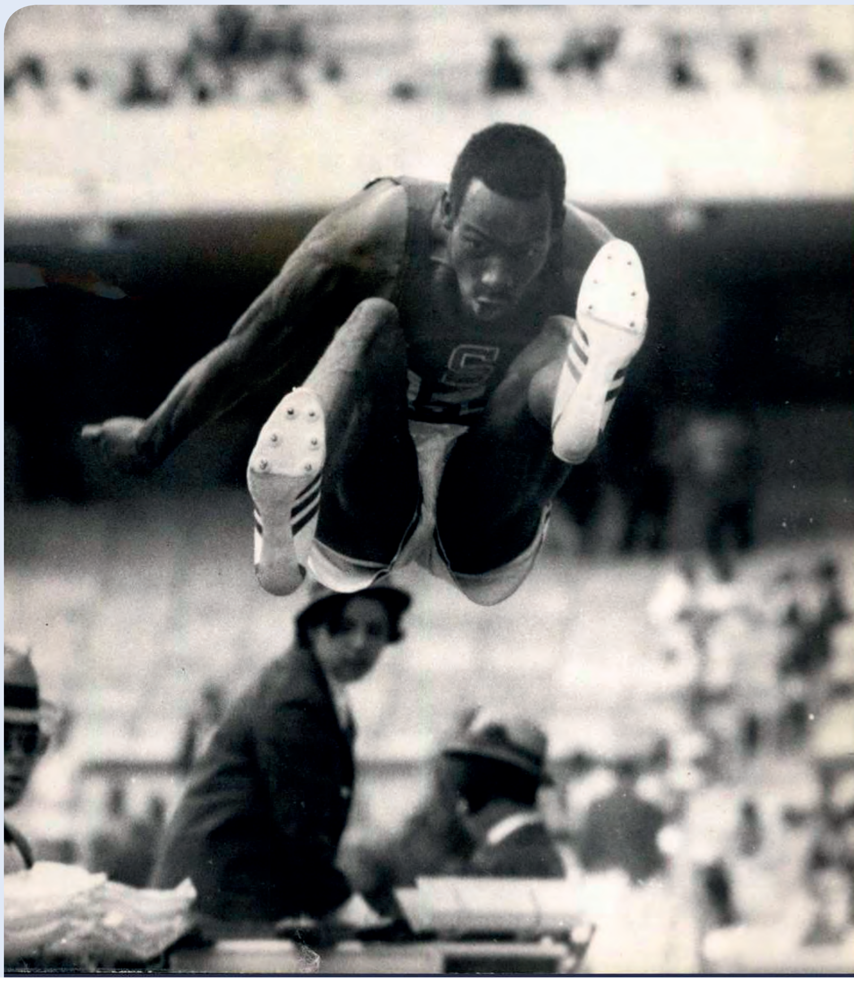
11 The atmosphere

Key concept: Systems

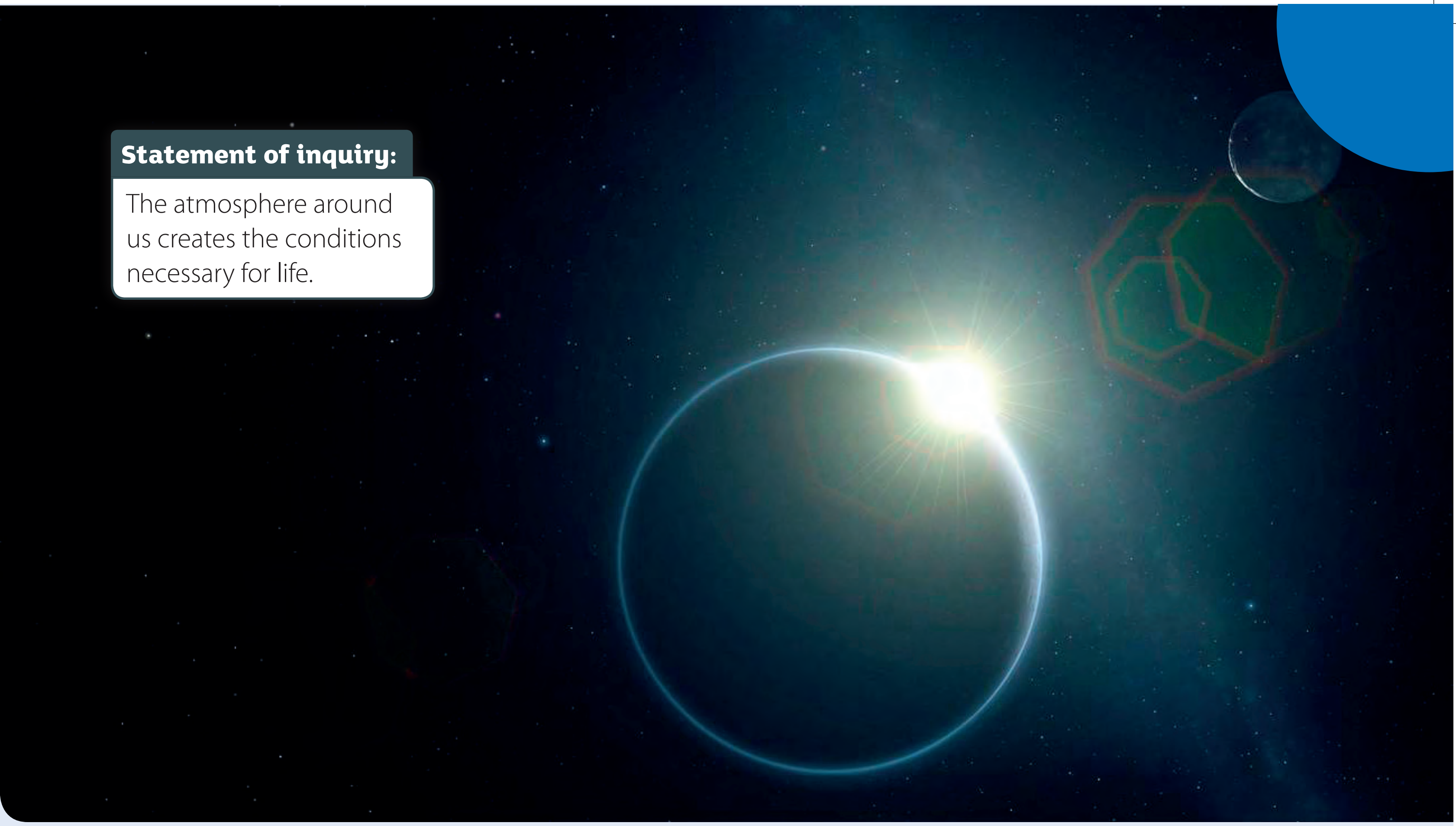
Related concepts: Consequences, Environment

Global context: Globalization and sustainability

Water vapor in the atmosphere forms clouds and eventually falls as rain. Rain is important for life. It brings water to the land, dissolves soluble gases from the atmosphere and washes out dust. Which other processes make life possible?



The 1968 Olympic Games were held in Mexico City, which is at an altitude of 2,200 m. The lower atmospheric pressure helped athletes to produce fast times in speed events. The world records for the men's and women's 100 m and 200 m were broken, and it was the first time that the 100 m was run in under 10 s, and the 200 m in under 20 s. Another world record was set in the men's long jump when Bob Beamon jumped 55 cm further than anyone had before, with a jump of 8.9 m. This world record stood for 23 years and is still the second furthest jump of all time. How else can the environment affect our performance?



▲ The Earth isn't the only object in the solar system to have an atmosphere. There are many planets, dwarf planets and moons that have an atmosphere. In 2015, the *New Horizons* probe passed Pluto and observed its atmosphere. The atmospheric pressure at the surface of Pluto is about 100,000 times less than on Earth and therefore the atmosphere is much thinner. However, it still creates a greenhouse effect and may even have clouds. Why do you think that scientists are interested in atmospheres on planets other than the Earth?

◀ Humans pollute the atmosphere with emissions from vehicles and factories. This can become a serious problem in large cities. What are the impacts of this pollution?

Key concept: Systems

Related concepts: Consequences, Environment

Global context: Globalization and sustainability

Introduction

The Earth's atmosphere is vital for supporting life. It contains the air that we breathe, it is responsible for the weather that brings water onto the land and it protects us from some of the Sun's more harmful radiation. Without the atmosphere, there would be no possibility of life on the Earth. In this chapter, we will investigate what the atmosphere is and what it does. We will look at some of the systems such as the water cycle and weather systems that occur in the atmosphere. For this reason, the key concept of the chapter is systems. One of the related concepts is environments because of the way in which weather and the atmosphere affect the local environment.

Human activity is changing the nature of the atmosphere and the consequences of this are still yet to be fully understood. As we release quantities of greenhouse gases into the atmosphere, we add to the greenhouse effect and alter some of the balanced environmental systems. The second related concept of the chapter is consequences and the global context is globalization and sustainability.

▲ The Earth's atmosphere has been different in the past. It is thought that between 350 and 300 million years ago, in the Carboniferous period, the amount of oxygen in the atmosphere was significantly higher than it is today. This enabled the insects that inhabited the Earth at the time to evolve into large creatures. The fossil in this picture is from a millipede, *Arthropleura*, and only contains part of its leg. The fossil itself is about 7 cm in size; it is thought that these millipedes could be 50 cm wide and over 2 m long

▶ As the Sun's light passes through the atmosphere, the rays of light are scattered by dust in the air and the air molecules themselves. Blue light is scattered more, and this scattered blue light will therefore arrive at all angles and the sky appears to be blue. When the Sun is low in the sky, at sunset for instance, the light passes through more of the atmosphere. The blue light is scattered away, leaving more red light

What is our atmosphere made of?

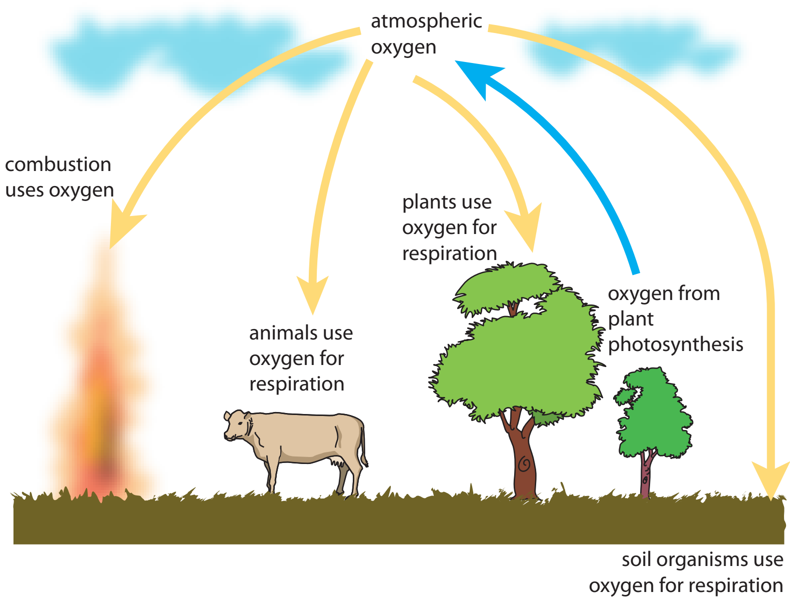
The atmosphere is mainly formed of nitrogen gas (N_2) which accounts for 78% of the atmosphere. The next most common constituent is oxygen gas (O_2) which accounts for 21%. Together, these two gases account for 99% of the atmosphere. After these, the next most common constituents are water vapor, argon and carbon dioxide.

The nitrogen in the air does not react easily. However, nitrogen compounds form important nutrients for plant growth and are important for animals to make proteins. Some plants such as peas and beans, as well as some bacteria, can convert nitrogen from the air into soluble nitrogen compounds. Lightning can also convert nitrogen into chemical compounds that can be used by plants and animals. Chemical compounds are discussed in Chapter 7, Atoms, elements and compounds.

The oxygen in the air is essential for the process of respiration. This process allows animals to breathe and they use the oxygen in chemical reactions that release energy. As they do so, they convert oxygen into carbon dioxide. The process of respiration occurs in all organisms.

The oxygen is replaced as plants use the Sun's energy to convert carbon dioxide back to oxygen. This process is called photosynthesis.

▼ This diagram shows the oxygen cycle. All organisms require oxygen for the process of respiration. Combustion also requires oxygen. The oxygen in the atmosphere is replaced by the process of photosynthesis in plants



ABC

Altitude is the height above the surface of the Earth.

The **troposphere** is the lowest layer of Earth's atmosphere.

The **stratosphere** is the second layer of the atmosphere above the Earth's surface. It contains the ozone layer.

The **ozone layer** is a region of ozone gas in the stratosphere. It absorbs harmful UV radiation from the Sun.

Constructing pie charts

When a set of data gives the components that make up a whole, it is often useful to present the data as a pie chart. Use the table below to construct a pie chart which shows the constituents of the atmosphere. To do this you will need to calculate the angle which each slice of the chart should occupy.

Constituent	Proportion of the atmosphere (%)	Angle represented on the pie chart (°)
nitrogen	78	281
oxygen	21	
other	1	

How does the atmosphere change with height?

If you were to travel upwards, the atmosphere would change. The air pressure, density and temperature all change with increasing **altitude**.

The atmosphere is not uniform; instead, it is divided into layers. The lowest layer is the **troposphere**, which spans from the ground up to about 12 km in height. The troposphere is the densest layer of the atmosphere and most of the mass of the atmosphere is in this layer. The clouds are within the troposphere and most planes will also fly in this layer of the atmosphere. Even the top of Mount Everest is still within the troposphere.

As you move upwards through the troposphere, the temperature and pressure decrease. At the top of the troposphere, temperatures are about –80°C, and the pressure is a tenth of what it was at sea level.

▼ The atmosphere at the top of Mount Kilimanjaro (in the background of this picture) is much thinner and colder than at the base of the mountain. The air pressure at the top is about half that at sea level, which makes climbing Mount Kilimanjaro difficult

Above the troposphere is a layer called the **stratosphere**. The stratosphere extends from the top of the troposphere to about 50 km above the Earth. In the stratosphere, a type of oxygen gas called ozone (O_3) is found. Ozone absorbs harmful ultraviolet rays from the Sun. This layer of ozone, referred to as the **ozone layer**, helps to shield the surface of the Earth from these ultraviolet rays.

The atmospheric pressure in the stratosphere is 10 to 1,000 times lower than at sea level.

Temperatures in the stratosphere actually increase with height because of the ultraviolet light that is absorbed.

Beyond the stratosphere is the **mesosphere**, which reaches up to 90 km above the surface of the Earth. The mesosphere has a low pressure (1,000th to 100,000th of sea level air pressure) and the temperatures decrease from around –15 °C to about –150 °C.

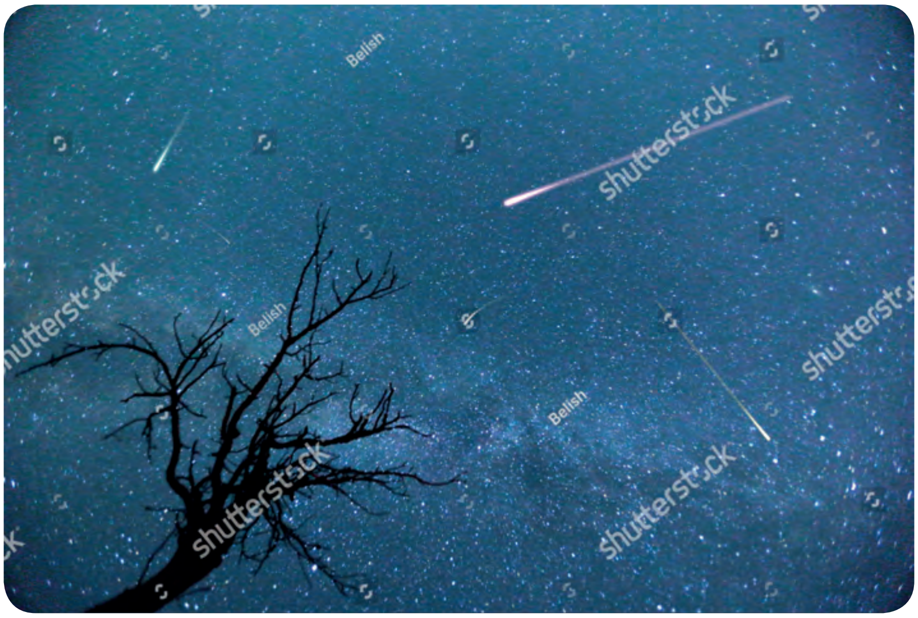
The mesosphere is the layer of the atmosphere that is responsible for shooting stars. Shooting stars, or **meteors**, occur when a small rock, a small asteroid or a fragment of a comet falls into the Earth's atmosphere from space. As they fall, they get heated by air resistance. A small rock will get so hot that it completely burns up in the mesosphere. Sometimes, if the rock is large enough, fragments will reach the ground. This is a **meteorite**.

ABC

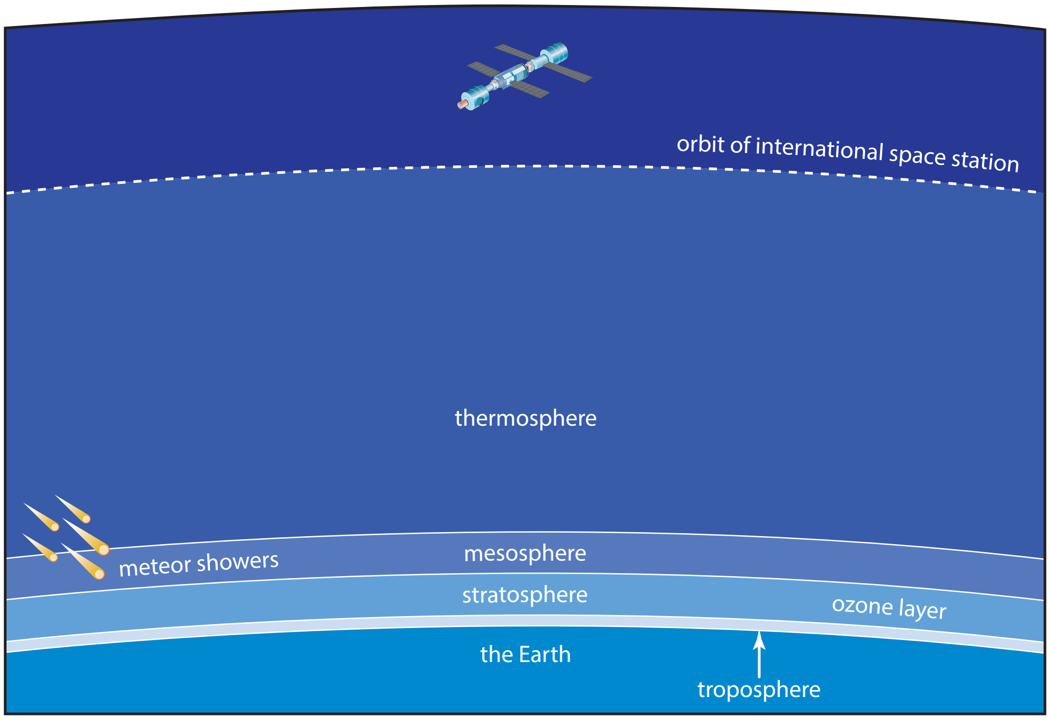
The **mesosphere** is the layer of the atmosphere between 50 and 90 km above the surface of the Earth.

A **meteor** is a small fragment of rock that falls into the Earth's atmosphere and burns up in the atmosphere.

A **meteorite** is a rock from space which enters the Earth's atmosphere and falls to the ground. (Technically, it is not called a meteorite until it has been found.)



Meteor showers are caused by rocks from space burning up in the mesosphere



This diagram shows the layers of the Earth's atmosphere. The diagram is to scale and shows the Earth's curvature. The troposphere, which contains the entire breathable atmosphere, is a tiny layer when compared to the size of the Earth

ABC The **thermosphere** is the outer layer of the Earth's atmosphere, between 90 and 600 km above the Earth. The thermosphere is considered to be the start of space.

Above the mesosphere is the **thermosphere**, which extends to about 600 km above the surface of the Earth. At this height, the atmospheric pressure is so low that satellites can orbit at this altitude without experiencing significant air resistance. The International Space Station (ISS) orbits in the thermosphere and the air resistance from the thermosphere only causes it to lose about 60 m of altitude every day. The ISS, and other satellites that orbit in the thermosphere, need a periodic rocket thrust to keep them in orbit.

▶ The International Space Station (ISS) orbits at a height of about 400 km. Although this is inside a layer of the Earth's atmosphere called the thermosphere, the density of the air is so low (approximately 2 million million times lower than at sea level) that the space station and other satellites can orbit freely

Aurora occur in the thermosphere. Charged particles from the Sun are guided by the Earth's magnetic field towards the poles. Near the North and South Poles, the charged particles enter the thermosphere and release their energy, creating spectacular glowing displays such as the northern lights, or aurora borealis.

▶ Aurora are caused by charged particles from the Sun hitting the thermosphere and losing energy

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1. When a small rock enters the atmosphere, it burns up in the mesosphere as a meteor. Describe the energy change that occurs as the rock burns up.
2. Outer space is defined for legal purposes as starting at 100 km. In which part of the atmosphere is this?
3. Planes on long journeys sometimes fly at the base of the stratosphere. They do not fly higher than this because they remove ozone from the stratosphere. Give one advantage and one disadvantage of flying at a high altitude.

How does our atmosphere enable life?

The atmosphere is essential for providing an environment in which life can exist. One of the ways it does this is by enabling liquid water to exist.

If you were to climb a mountain, the atmospheric pressure would decrease. As it did so, you would find that the boiling point of water also decreased. At an altitude of 1,000 m, the decreased pressure would mean that water would boil at about 96°C rather than 100°C. At the top of Mt Everest, the lower pressure would make water boil at 72°C. At an altitude of 18 to 19 km, the boiling point of water gets lower than body temperature. This is called the Armstrong limit: to survive at this altitude and low pressure requires a pressurized space suit. If you kept going upwards, the pressure would drop so low that the boiling point of water would become equal to the melting point. As a result, ice would sublimate directly to water vapor and liquid water could not exist. (See Chapter 8, Properties of matter for more on sublimation and other changes of state)

Scientists think that liquid water is essential for life. Many chemicals can be dissolved in water, and this allows them to flow easily around an organism. Mammals have a blood supply that uses liquids to transport nutrients and oxygen, and plants have xylem and phloem, which achieve the same result. The xylem moves water and minerals from the soil that are absorbed by the roots up the stem and to the leaves of the plant. The phloem moves the chemicals which the plants create in their leaves around the plant. These substances are an energy store, similar to food, for the plant and might be used for the plant to grow, or might be stored.

The liquid involved in life does not necessarily have to be water—it is possible that life could form on other planets using a different liquid substance. However, water is a compound consisting of hydrogen and oxygen atoms. These are common elements and therefore water is often thought to be the most likely liquid to support life. Since liquids require an atmospheric pressure to exist, it is thought that life would evolve on planets that have an atmosphere.

We have also seen that the stratosphere contains the ozone layer, which shields the Earth from harmful UV rays. Without this ozone layer, the high energy UV rays would disrupt the chemistry that enables life. Life could exist underground or underwater, but most of the life on Earth would not be possible without the ozone layer.

What is the greenhouse effect?

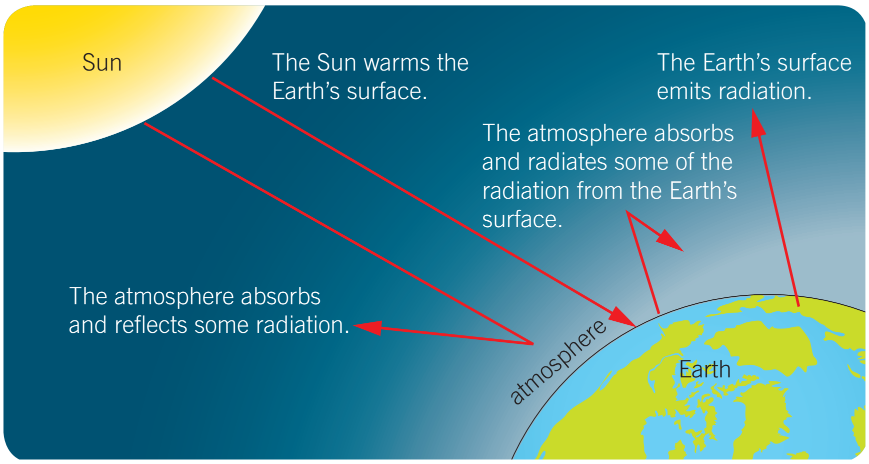
The greenhouse effect occurs in the atmosphere. This is another way that the atmosphere creates the conditions on the Earth's surface that enable life to flourish.

The Sun's heat and light warm the surface of the Earth. Because the Earth's surface is warm, it too radiates heat energy in the form of infrared waves. However, because the Earth is much cooler than the Sun, the wavelength of these waves is longer.

The atmosphere contains water vapor and carbon dioxide, which absorb the longer wavelength infrared waves. The absorbed radiation heats up the atmosphere and this warm air radiates heat energy back to the Earth's surface. As a result, the atmosphere acts like a layer of insulation, keeping the Earth's surface warm. This is called the greenhouse effect.

Without the greenhouse effect, the surface of the Earth would be frozen. Instead, the average surface temperature of the Earth is about 15°C.

▼ The Earth's atmosphere lets most of the Sun's heat and light through to the surface. However, the Earth is cooler and radiates energy at longer wavelengths. The atmosphere absorbs much of this radiation and some of this is re-radiated back to Earth. This effect, called the greenhouse effect, keeps the surface of the Earth warmer than it would be if there was no atmosphere



▶ Water vapor contributes strongly to the greenhouse effect, even more so than carbon dioxide. On Venus, the high temperatures caused water to evaporate, resulting in more water vapor. This contributed to the greenhouse effect and made the temperatures even hotter. In turn, the hotter temperature caused more water to evaporate, leading to a runaway greenhouse effect. As a result, the atmosphere of Venus is very thick, with surface pressures that are about 90 times greater than the Earth, and temperatures that average about 460°C

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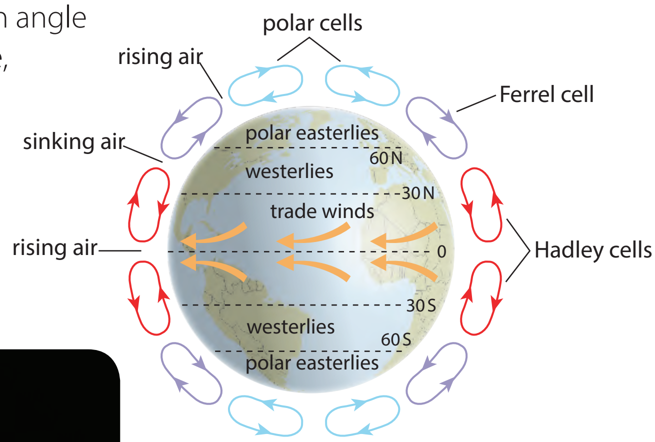
How does our atmosphere move?

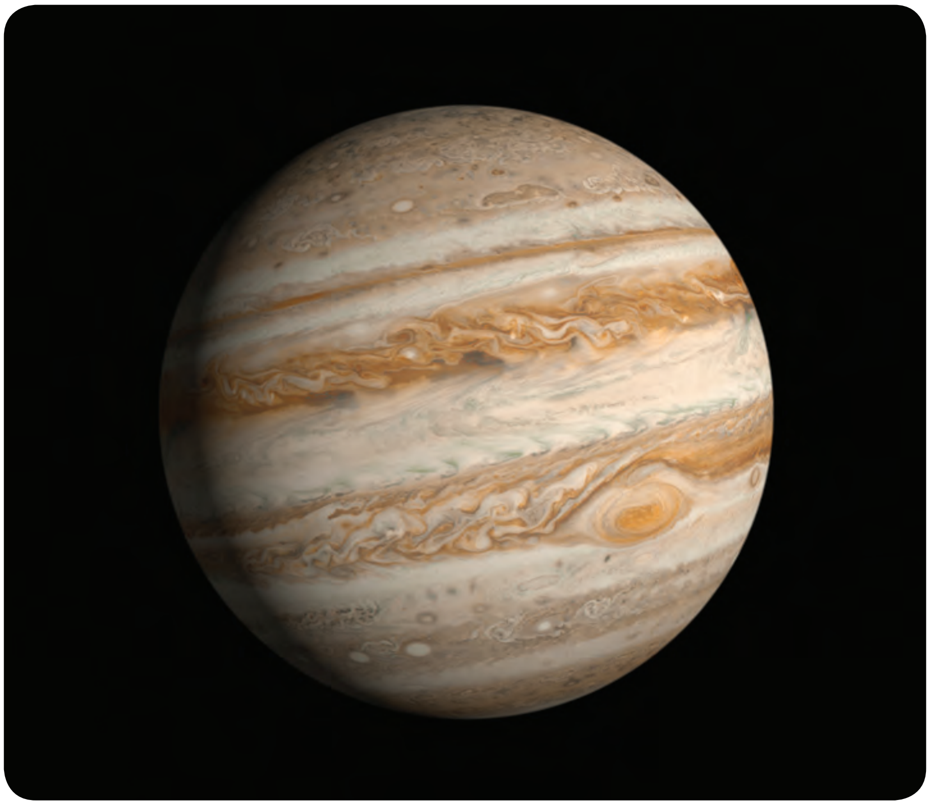
When the Sun's rays hit the Earth and heat the land, the air above is also heated. This hot air expands and rises. As this air moves upwards, air is drawn in from the side. This effect drives the Earth's winds. The land nearer the equator is hotter because the Sun's rays are more directly overhead and therefore the air gets hotter more near to the equator. At the poles, however, the Sun's rays hit the Earth at an angle and therefore the land (and the air above it) is cooler. Therefore, the air around the equator is heated and rises, while the air above the poles cools and sinks.

The Earth's rotation breaks this air circulation into atmospheric cells, which provide regular wind patterns around the globe. Other planets also have these patterns—the banded pattern of Jupiter is caused by a similar effect.

ABC An **atmospheric cell** is a region of air circulation where the hot air rises and the cooler air sinks.



▲ The pattern of rising and sinking air in the atmosphere is driven by energy from the Sun. The Earth's rotation causes these air currents to be broken into cells called Hadley, Ferrel and polar cells. This gives rise to global air circulation and the wind



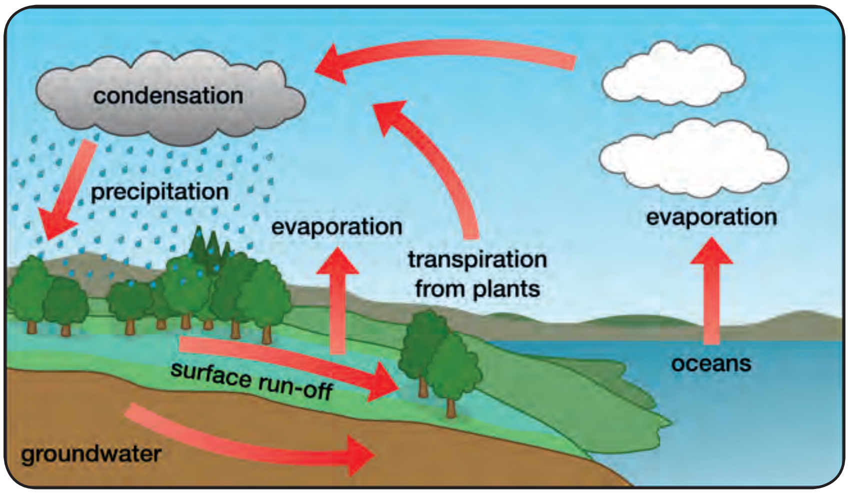
▲ The bands on Jupiter are caused by the same effect that causes wind circulation on Earth. Because Jupiter is larger than the Earth and rotates faster, the currents are broken into more cells than in the Earth's atmosphere

What is weather?

Although the Earth has some regular wind patterns on a large scale, the wind direction is less reliable on a smaller scale. As the wind moves air around, it creates different weather patterns. Sometimes the wind blows from a cooler part of the globe and brings cold weather, while wind from a different direction can bring warmer weather.

ABC **Transpiration** is the process where water is lost through evaporation from the leaves.

An important consideration in weather is the amount of water vapor in the air. When the Sun's rays hit the ocean, they can cause water to evaporate from the surface. Water is also released through **transpiration** from plants. Higher in the atmosphere, where the temperature is colder, the water vapor can condense and form clouds. Eventually, when there is enough water in a cloud, it will fall as rain or snow.



▲ The hydrological cycle, or water cycle, is responsible for providing fresh water to the land

The wind can move clouds over land and therefore much of this rain and snow will fall on land. Some of this water will soak into the ground and be used by plants. Some of the water will run off the surface of the land and form streams and rivers that will eventually return the water to the oceans. These processes are called the water cycle, or hydrological cycle.

Why is the water cycle important?

Without the water cycle, the land would not have water, and life could only exist in the ocean or near the shore. Instead, rain enables plants to grow on land and provide food for animals. Rain is also important as it provides fresh water that does not have salt dissolved in it, unlike seawater. This means that rainwater can be used as drinking water for animals and humans.

Rain is responsible for washing sediment down rivers. In this process, the rivers wash away at their banks in a process called erosion. The action of rivers over thousands of years shapes the land and causes the formation of valleys. The material that is washed from rivers will eventually be deposited at the mouth of the river. As more material

Experiment

Investigating evaporation

In this experiment, you will investigate how surface area affects the rate of evaporation. You need a test tube, boiling tube, a small beaker and a larger beaker.

Method

- Using a measuring cylinder, put 10 cm^3 of water in each of the beakers and the test tube and boiling tube.
- Place the test tube, boiling tube and beakers together and leave for 24 hours.
- Use the measuring cylinder to measure the amount of water that is left in each container and record your results.

Questions

1. In which container did the water have the smallest surface area? In which container did it have the largest area?
2. Plot a suitable graph of your data.
3. Why was it important to put the same volume in each container?
4. Why was it important to put the containers near each other when they were left for 24 hours?

◀ The water cycle causes rain to fall on the land. Some of this water flows off the land in streams and rivers back to the sea

▼ The water cycle deposits water on the land. As it flows back towards the sea in the form of rivers or glaciers, it carves valleys into the landscape

is deposited, the sediment can be compressed to form sedimentary rocks. Sedimentary rocks are discussed further in Chapter 10, The Earth.

Rainwater can also weather rocks directly. As rain falls through the atmosphere, gases such as carbon dioxide dissolve in it. This causes the rainwater to be mildly acidic. Rocks such as limestone or chalk are made from calcium carbonate. This reacts with the acidic rain to form calcium hydrogen carbonate. Calcium hydrogen carbonate is a soluble salt that dissolves in the water and is washed away. This process not only causes the weathering of the rocks but also leaves the calcium salts dissolved in the water.

Tap water that contains a lot of dissolved calcium salts is called hard water. If the water does not have many calcium compounds dissolved in it, then it is soft water. If water that contains calcium hydrogen carbonate is heated and evaporates, calcium carbonate is left behind. This causes limescale, which can block pipes and leave deposits on surfaces where water is able to evaporate.

▼ These limestone rocks are weathered by acidic rain

▼ These stalagmites and stalactites in Mae Usu Cave, Thailand, are caused by acidic rain dissolving some of the rock above. As the water drips into the cave, it evaporates and deposits the compounds that are dissolved in it

1. When hard water evaporates, it can deposit calcium carbonate as limescale. Household cleaners that remove limescale often contain acids.

   a) Why do these cleaning products use acids rather than alkalis?

   b) What hazards are associated with using these cleaning products?

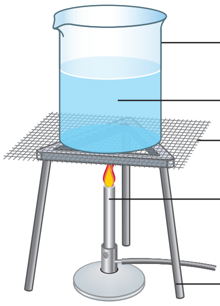
Experiment

Finding the quantity of solutes in water

For this experiment you will need two different samples of water. One could be the water from the tap, the other might be bottled water, rainwater or water collected from a stream.

Method

- Measure the mass of a 250 mL beaker.
- Measure 100 mL of one of your water samples and pour this into the beaker.
- Gently heat the beaker. If using a Bunsen burner, use a medium heat with the beaker placed on a gauze.
- Stop heating the beaker when most of the water has evaporated.
- Leave the beaker to cool and allow the remainder of the water to evaporate.
- Measure the mass of the beaker once all the water has evaporated.
- Repeat the experiment for your other sample of water.



Questions

1. How much extra mass was recorded for each sample?
2. Which sample of water contains the most solutes?

What is climate?

The weather can change every day. There are also seasonal weather patterns that cause the weather to be warmer in summer and cooler in winter. This means that the weather can be different at different times and in different places.

The climate is a measure of the average weather. While different countries will have differing climates, this climate does not change regularly. The climate in a particular location might be affected by altitude, and whether it is close to the equator or closer to the poles. Being near the sea can create milder winter and summer temperatures, while being further inland can give more variation in seasonal temperatures. Other features, such as being near to hills, can change the amount of rainfall.

Features that affect rainfall

The table below shows the average rainfall in mm for some US states. The data is derived from data published by the National Oceanic and Atmospheric Administration, which covers the years 1981 to 2010. The average elevation (height of the land above sea level) of the monitoring stations is also given and if the state borders the ocean, then it is marked as coastal.

State	Elevation (m)	Rainfall (mm)	Coastal	State	Elevation (m)	Rainfall (mm)	Coastal
Alabama	134	1413	Y	Montana	1101	384	
Arkansas	166	1304		New Hampshire	250	1180	Y
California	497	612	Y	New Jersey	62	1207	Y
Delaware	24	1166	Y	North Carolina	284	1263	Y
Florida	16	1386	Y	North Dakota	553	465	
Idaho	1230	442		Oregon	562	934	Y
Illinois	190	1017		Pennsylvania	308	1107	
Kansas	503	799		South Dakota	662	543	
Kentucky	226	1224		Tennessee	262	1360	
Maryland	144	1114	Y	Vermont	292	1136	
Massachusetts	125	1241	Y	Virginia	287	1119	Y
Mississippi	88	1469	Y	Wisconsin	300	845	
Missouri	255	1107		Wyoming	1684	336	

1. Find the average rainfall for the coastal states.
2. Find the average rainfall for the states which do not have a coastline.
3. Do your answers suggest that being nearer the sea affects the amount of rainfall?
4. Plot a graph of rainfall on the y-axis vs elevation on the x-axis.
5. How does elevation affect rainfall?

How is the climate changing?

The global climate has always been changing slowly. In the past, the average temperature has gone through periods of warmth, as well as ice ages. These changes happen over thousands of years.

Occasionally major events can temporarily affect the Earth's climate. Huge meteorite impacts or large volcanic eruptions can increase the amount of dust at high levels of the atmosphere. These can block some of the sunlight reaching the Earth and cause a shorter period of cooler temperatures.

More recently, studies have shown that human activity is altering the contents of the atmosphere. We are releasing increased amounts of gases such as carbon dioxide, which contribute to the greenhouse effect. As a result, the Earth's climate is getting warmer.

ATL **Communication skills**

International cooperation

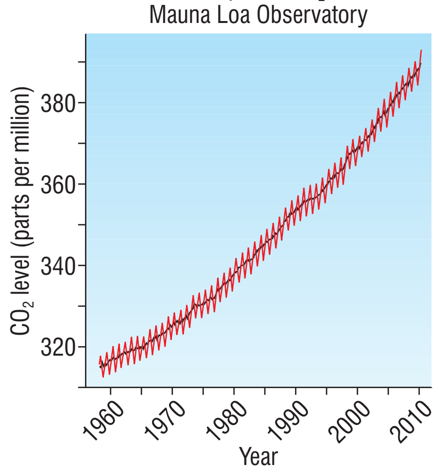
Human activity is releasing greenhouse gases into the atmosphere which contribute to global warming. All countries must collaborate to reduce the amount of these gases released into the atmosphere and slow the rate of global warming.

The Paris Agreement, which was finalized in 2015, is an agreement that countries can sign up to. The goal of the agreement is to stop the average global temperature from rising by more than 2°C. Countries that sign up must plan to reduce their contribution to global warming and report their progress. By February 2019, 195 countries and member states had signed the agreement.

Measuring carbon dioxide in the atmosphere

Scientists have measured the amount of carbon dioxide in the air for many years. The Mauna Loa Observatory is located in Hawaii at the top of a tall volcano. Scientists use this location to measure the amount of carbon dioxide in the air as its high altitude means that it is above local human sources of carbon dioxide.

The measurements of atmospheric carbon dioxide are shown in the graph below. The amount of carbon dioxide varies within each year. The units of the amount of carbon dioxide are parts per million. One part per million means 1 cm^3 of carbon dioxide in one million cm^3 of air (one million cm^3 is one m^3). Hence, 320 parts per million indicates 320 cm^3 per cubic meter of air, which is a concentration of 0.032%.



1. Use the graph to estimate the amount of carbon dioxide in the atmosphere in the following years:
   a) 1970
   b) 2000

2. Using your answers to question 1, estimate how much the amount of carbon dioxide increases each year.

3. The monitoring station is located on a volcano, which can emit carbon dioxide. Why is it important to take account of the carbon dioxide emitted by the volcano when measuring atmospheric carbon dioxide?

What are the problems of climate change?

Scientists are keen to predict what might happen if the average temperatures on Earth rise. There are large amounts of ice in Greenland and Antarctica that could melt if temperatures rise too much. The resulting water would flow off the land and into the oceans, causing the sea levels to rise. Sea levels are currently rising by about 3 mm per year, but this might increase such that sea levels rise by 2 m or more over 100 years. The increase in sea levels will depend on how much global temperatures rise.

If sea levels rise too much, then people living near the coast will be affected. Many cities are located near to the sea. Rising sea levels will require people living in these cities to relocate, and significant flood defenses may need to be built.

1. If sea levels continue to rise at 3 mm per year, how much would the levels rise over 100 years?

2. If sea levels rise by 2 m in 100 years, how many millimeters would sea levels rise on average per year?

A changing climate will result in many regions of the Earth becoming hotter. Some areas, particularly those inland, will become drier and have more extreme seasonal temperature changes. As a result, these areas would be hotter in summer but cooler in winter. Coastal areas might experience warmer temperatures but with increased rainfall and milder winters.

As a changing climate affects weather patterns, land that was once used for farming might no longer be suitable for this purpose. Farmers will have to adapt by growing different crops in different parts of the world.

◀ If the sea level rises too much, coastal cities such as New York will have a problem

Summative assessment

Statement of inquiry:

The atmosphere around us creates the conditions necessary for life.

This assessment is based on the movement of the atmosphere and how wind can be used to generate power.

Properties of the atmosphere

1. The wind stores energy in which form?

A. Gravitational potential

B. Heat

C. Kinetic

D. Sound

2. What is the original source of this energy?

A. Heat energy from inside the Earth

B. The orbit of the Earth around the Sun

C. The Sun

D. The Moon

3. What is the most common element in the wind?

A. Argon

B. Nitrogen

C. Oxygen

D. Water

4. Winds in the stratosphere can have a higher speed than those nearer the surface of the Earth. Which of the following reasons explains why the energy carried by these winds is lower?

A. The winds are at a higher height.

B. The wind is at a higher temperature.

C. The wind is at a lower temperature.

D. The air has a lower density.

5. Most weather occurs in the troposphere. Which change in the atmosphere occurs as you go to a higher altitude in the troposphere?

A. The density increases

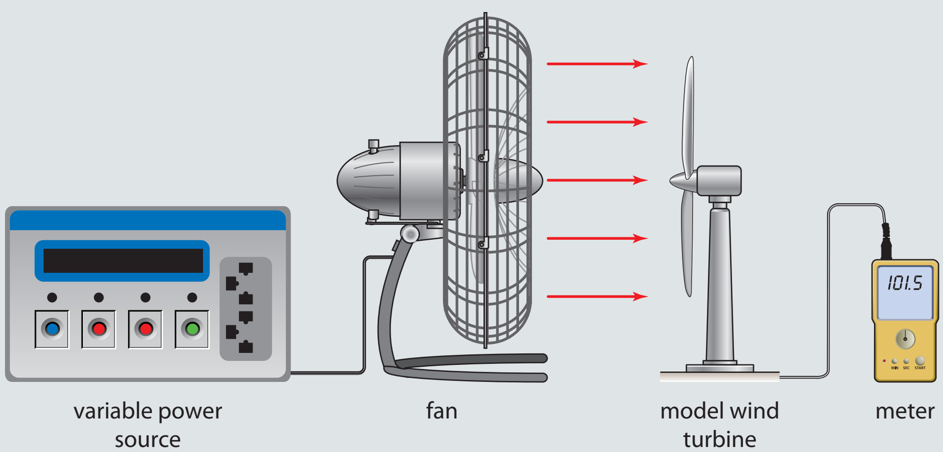
B. The temperature increases

C. The amount of nitrogen increases

D. The pressure decreases

Investigating a model wind turbine

An engineer is investigating how the power output of a wind turbine depends on the wind speed. She decides to make a model of a wind turbine for this investigation. She uses a fan to generate a flow of air which hits the blades of a model wind turbine. The fan has a variable power supply so that the speed of the air can be changed. The model wind turbine turns a small electric generator and the output power from the generator is recorded. A schematic diagram of the apparatus is shown below.



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6. Describe the advantages and disadvantages of using a model wind turbine rather than using an industrial wind turbine for this investigation. [4]
7. The engineer has a device called an anemometer, which measures the air speed generated by the fan. Describe a method that the engineer could follow in order to measure how the power output of the fan changes with the speed of the air. [4]
8. As part of further investigations, the engineer wants to investigate other factors which affect the power output of a wind turbine. Suggest a different factor that might affect the power output. [2]

Factors affecting the output of wind turbines

The table right shows the radius of the arms of different makes of wind turbines and the power output of the turbines.

Radius of wind turbine arms (m)	Power output (MW)
70	1.5
80	1.8
90	3.0
120	4.1
190	11.0

9. Plot a graph of the data in the table. [4]
10. Add a line of best fit to your graph. [1]
11. The wind turbine with a radius of 190 m is yet to become commercially available. The largest available wind turbines have a radius of about 150 m. Use your graph to estimate the power output of this type of turbine. [2]
12. The data in the table suggest that larger turbines generate more power. Describe the disadvantages of building large wind turbines. [3]

Wind turbines

13. Wind turbines are an important source of renewable energy.
    a) Explain what is meant by renewable energy. [2]
    b) Describe the problems associated with non-renewable sources of energy. [3]
    c) Describe the disadvantages of the use of wind turbines to solve the problems of non-renewable energy. [2]
    d) Describe the energy transfers which occur when a wind turbine is used to supply power. [3]

Wind turbines are an important source of renewable energy