SCIENCE
for a Successful Scotland

An introductory science learning resource

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for a Successful Scotland

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What is Science for a Successful Scotland?

Science for a Successful Scotland is a learning and teaching resource for tutors to use with learners. It has been funded by Glasgow Clyde Education Foundation.

It can be used to introduce science topics in an interesting, engaging and inspiring way, and can be used to deliver learning in community settings as well as in colleges and schools.

It can be used with young learners and with adults, including parents of children who are making learning and career choices.

It exists as a hard copy 'book' and as an online e-learning resource.

It contains learning and teaching materials such as information, activities (including experiments), investigations and case studies.

Why have we produced it?

We want to encourage people back into learning

In 2012, WEA Scotland and Heather Reid launched the *Counting on a Greener Scotland* resource (known informally as "COGS"), which was funded by Education Scotland. COGS provides tutor activities to promote numeracy learning in the contexts of weather, climate change and energy. The resource has had a positive impact on communities across Scotland, by developing existing learners' skills, knowledge and interest in numeracy and science, and by engaging new learners.

We wanted to build on the success of the award-winning COGS and the associated course, which was credit-rated at level 4 of the Scottish Credit and Qualifications Framework (SCQF)[1]. We have now created a broader resource, looking at different aspects of science and linking science to further learning options and career opportunities.

There is a gap in SCQF level 4 learning provision where learners can gain an introduction to science topics, and we wanted to fill that gap for those learners who want to come back to learning and possibly progress into further, and eventually higher, education.

We want to promote STEM

STEM stands for Science, Technology, Engineering and Maths. These areas are heavily intertwined in the real world, and we know that we need more people to have STEM skills in order to help sustain and grow our economy.

In Scotland, improving STEM education is a key priority for Curriculum for Excellence. Anecdotal evidence, however, has suggested to us that many adults (including parents and carers of school-age children) are unaware of what STEM stands for, and why it is so important.

[1] www.scqf.org.uk

The Scottish Government has published a STEM education and training strategy[2] and we hope that this resource will contribute to that strategy, leading to increased awareness of STEM and many of the exciting (and vital) employment possibilities in this area. We have included case studies in the resource to stimulate ideas about STEM learning and STEM careers.

The resource also supports Glasgow Clyde College's STEM Manifesto[3], whose pledges include:

- Ensuring that STEM is given prominence and status in the college and the community it serves
- Committing to building a strong STEM capability for the region
- Committing to supporting and delivering STEM progression for students from schools in the region and into further and higher education or work or training, and
- Ensuring that we raise the level of STEM literacy, numeracy and employability skills in our students.

We want to raise awareness of Scotland's 'growth sectors'

The Scottish Government's Economic Strategy[4] identifies Scotland as having a "distinct comparative advantage" in six sectors:

- Energy (including renewables)
- Sustainable Tourism
- Life Sciences
- Creative Industries (including digital)
- Food and Drink (including agriculture and fisheries)
- Financial and Business Services

We have structured the resource around the first five of these sectors.

Who is it for?

We have designed the resource for use with learners who are likely to face barriers to learning, for example people who:

- did not have a good experience of school or other learning
- lack confidence in their ability to learn, or to learn in a group
- need extra support to learn, for example if they have difficulty with reading, writing or numbers
- want to take their 'first steps' back into learning
- are interested in science but would like to take an informal introductory course in the first instance
- are thinking of going to college and want to try an introductory course to find out what subjects they might be interested in.

In particular we have designed the course for use with parents who want to:

- help their children with their own learning in the sciences
- help their children to make choices about future careers, which might be in the sciences.

[2] http://www.gov.scot/Publications/2017/10/1386/downloads
[3] http://www.glasgowclyde.ac.uk/__data/assets/pdf_file/0009/50697/STEM-Manifesto.pdf
[4] http://www.gov.scot/Topics/Economy/EconomicStrategy

How is it structured?

The resource contains five units. Each unit focuses on a key area of the sciences.

The units are:

1. Energy

2. Tourism and Environmental Science

3. Life Sciences

4. Science and the Creative Industries

5. Science of Food and Drink

Each unit contains:

- learning content about the science topic
- activities, experiments and/or a local investigation.

There is a further section featuring four career case studies where people talk about how science helps them in their jobs.

How you can use it

You can use it flexibly

We want tutors to use the resource with their learners in the way that suits them best. We have written it in such a way that it can be used flexibly, dipped in and out of, or adapted and added-to as need be.

The e-learning version will really help enable tutors and learners with access to the internet to make the most of the resource.

Some tutors might want to start with the science topic, others by exploring careers. Some will start with activities and experiments, as a way of assessing learners' existing knowledge and skills, before 'back-filling' any learning that is necessary.

Learners can even use the e-learning resource on their own, asking a tutor or a friend to help them where necessary.

We haven't designed the resource to be comprehensive – we want you to think of it as a springboard to further learning and exploration of important and exciting subjects.

You can map it to learning outcomes

We have mapped each unit to Experiences and Outcomes from Curriculum for Excellence and to SQA's Core Skills units. The mapping information appears in the section: **Useful Information and Acknowledgements**.

Taster Activities

These taster activities aim to develop learners' confidence in thinking about and discussing science topics in relation to everyday life.

Activity 1: What is science?

This is a discussion activity which asks learners to define some key terms.

Did you enjoy learning science at school?

Do you have positive or negative memories of it?

How would you describe what science is?

Can you say what the following scientific subjects might involve?

Biology

Chemistry

Physics

?

At the end of this introduction we've put in some definitions.

Take a look at these definitions.

What do you think of them?

Activity 2: Science diary

This activity encourages learners to make connections between science and everyday life. It can be done as an individual activity or in a group discussion.

How do we use science in an average day?

Write down everyday activities that take place in the morning, the afternoon and in the evening. Try to say how this activity uses chemistry, physics and/or biology). We've given you some examples.

There are more suggestions at the back of this section.

Morning:	• Getting washed/showered (chemistry in the soap and shampoo, physics to heat the water)
Afternoon:	• Gardening (biology in the plant growth, chemistry in fertiliser)
Evening:	• Reading by lamplight (physics in the light bulb)

Activity 3: A day without science

Can you imagine a day without science?

With a friend or in a small group, try to think of an activity that does not involve the use of science. Make your suggestion and ask your friend/other group members to prove you wrong.

? Do you think there is any activity at all that does not involve the use of science?

Possible answers:

Taster activity 1: What is science?

A definition of "science" from the UK Science Council:

> "Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence."

http://sciencecouncil.org

Definitions of "physics", "biology" and "chemistry" from the BBC:

> "Physics is the study of energy, forces, mechanics, waves, and the structure of atoms and the physical universe."

> "Biology is the study of living organisms and their structure, life-cycles, adaptations and environment."

> "Chemistry is the study of the composition, behaviour and properties of matter, and of the elements of the Earth and its atmosphere."

www.bbc.co.uk/education/subjects/zrkw2hv

Taster activity 2: Science diary

More suggestions:

Morning:

- Boiling an egg (chemistry in the egg as it cooks, physics in the heat from the hob)
- Eating breakfast (chemistry and biology as the body digests the egg and turns the food into energy)
- Getting to work/college (physics in travelling in a car or bus)

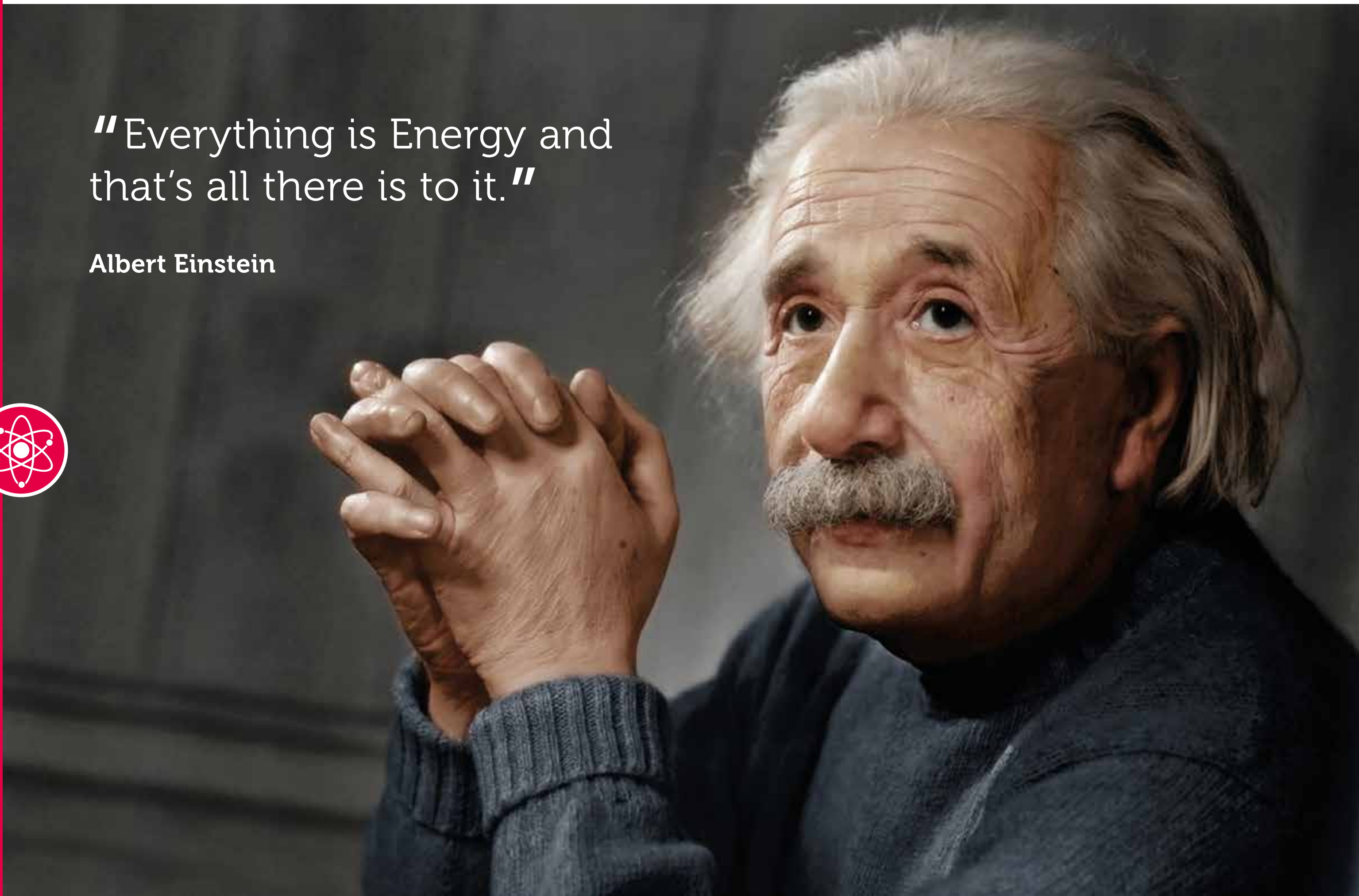
Afternoon:

- Walking home from work or college (biology in using muscles and burning energy)
- Studying online (physics in the electricity to power the computer and transfer information through cables/satellite)

Evening:

- Cooking dinner (physics in heating the food, chemistry in combining ingredients and in cooking them, chemistry and biology in digesting the food)
- Watching TV (physics in the electricity powering the TV and in light and sound in the programme)
- Taking medicine (chemistry in the development of the medicine, biology in the interaction between the body and the medicine)

Energy



"Everything is Energy and that's all there is to it."

Albert Einstein

Scientists define energy as the ability to do work. Everything that happens in our world, from growing plants, to driving a car, playing sport or switching on the lights, needs energy.

Over time, we have gradually harnessed more and more energy from the Earth's natural resources to improve our quality of life. This has two consequences: Firstly, the burning of fossil fuels has produced carbon dioxide emissions which most scientists believe are causing our planet to warm dramatically. Secondly, an increasing global population continues to place a growing demand on energy supplies and processes.

The potential for an 'Energy Crisis', where our energy demands overtake supply, is a real concern. We will need new ideas and solutions in order to meet our 21st Century energy needs.

Developing an understanding about different energy types, energy transfer and how energy is used in the modern world, will help learners to:

- make informed decisions about local and global issues
- appreciate the importance of the concept of energy to all areas of science
- recognise the value of a strong engineering sector within Scotland

Learn about:

Energy Types p10

The Law of Conservation of Energy p12

Energy and Biology p15

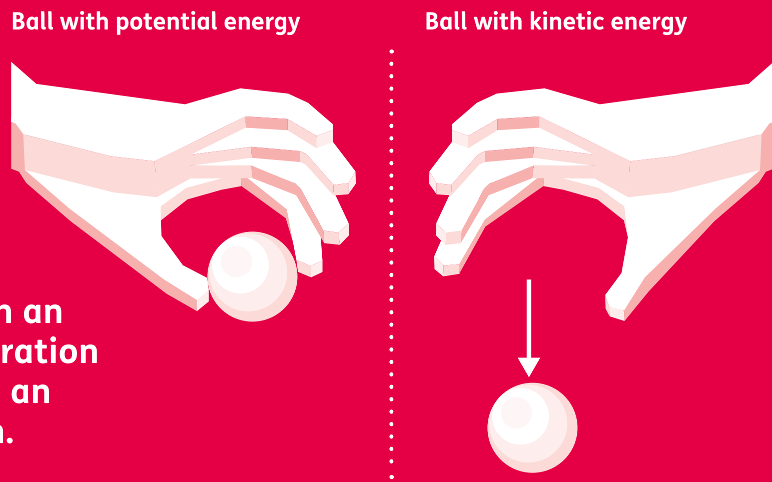
Energy and Chemistry p20

Energy and Physics p24

Energy Types

There are many different types of energy in the world around us and they are normally divided into two categories – Potential or Kinetic.

Potential Energy is the energy stored in an object due to its position or its configuration and Kinetic Energy is the energy which an object possesses because of its motion.



Potential Energy

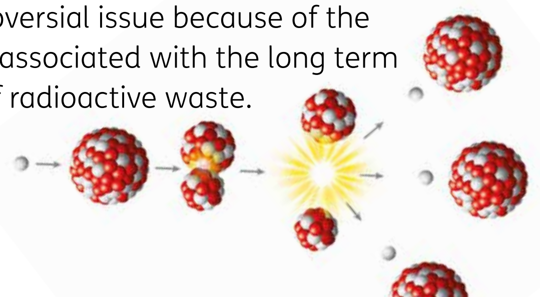
Potential Energy is the term we use when energy is stored and waiting to be used. **Gravitational Potential Energy, Elastic Potential Energy, Chemical Energy** and **Nuclear Energy** are all examples of Potential (stored) Energy.

Gravitational Potential Energy is the energy stored in an object as the result of its vertical position or height. The energy is stored because of the gravitational attraction of the Earth for the object and is proportional to the objects mass and height about the ground. A rock sitting at the top of a hill is an example of an object which contains Gravitational Potential Energy. Hydroelectric schemes store Gravitational Potential Energy in the water in high up reservoirs.

Elastic Potential Energy is the energy stored in elastic materials as the result of their ability to be stretched or compressed. Elastic Potential Energy can be stored in rubber bands, trampolines, springs, catapults, an arrow drawn into a bow, etc. The amount of Elastic Potential Energy stored in the elastic material is related to the amount of stretch applied – the more stretch, the more stored energy.

Chemical Energy is the energy stored in the bonds of atoms and molecules. This type of energy is released in a chemical reaction, often producing heat as a by-product. Batteries, food, petrol, candles and coal are all examples of stored Chemical Energy.

Nuclear Energy is the energy stored in the nucleus (core) of an atom. This energy can be released when the nucleus is split apart. Nuclear power stations spilt the nuclei of uranium atoms in a process called nuclear fission. In contrast to fossil fuel power stations, the nuclear process does not produce greenhouse gases or contribute to climate change. However, nuclear power is a controversial issue because of the problems associated with the long term storage of radioactive waste.



Kinetic Energy

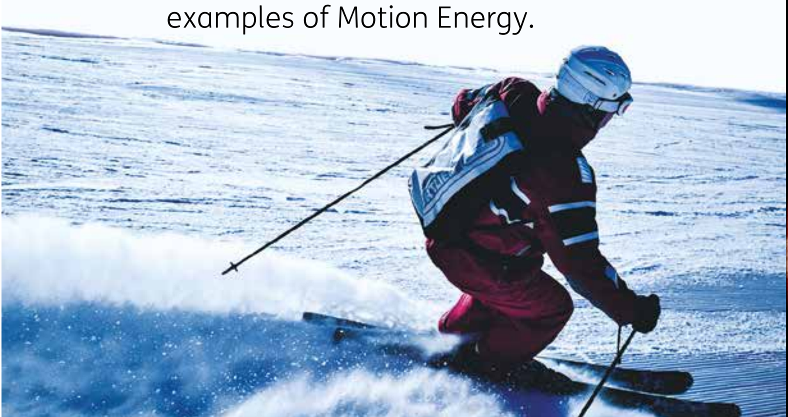
When energy is being used to do something, we call it Kinetic Energy. Kinetic comes from the Greek word kineticos meaning 'of motion' and the term 'Kinetic Energy' was first used by the University of Glasgow scientist Lord Kelvin. The kinetic energy of an object is related to its mass and how fast it is moving. **Light, Heat, Electricity, Motion** and **Sound** are all examples of Kinetic Energy.

Light Energy is a type of energy that can travel through space. The energy travels in the form of waves. These waves are a vibrating pattern of electricity and magnetism that we call electromagnetic energy. This includes visible light that we can see and also ultraviolet, infrared, microwaves, radio waves, X-rays and gamma rays.

Heat Energy is one of the most familiar types of energy in the world and we make use of it every day. Heat is a measure of the internal energy of an object. All objects are made up of particles and these particles can move or vibrate. The amount of movement or vibration depends on temperature. The more Heat Energy in a substance, then the faster the particles move and vibrate.

Electrical Energy is the energy produced by the movement of electrons. Electrons are particles with a negative charge. When electrons move through a wire they produce electricity. The British scientist Michael Faraday was the first person to show that electricity could be produced by continually rotating a copper coil within a magnetic field. Modern day power stations are based on this principle and Electrical Energy has transformed how we live in the world today.

Motion Energy is the movement of objects from one place to another. This type of energy is also often simply referred to as 'Kinetic Energy'. Moving vehicles, the wind, a downhill skier, a spinning top and a flowing river are all examples of Motion Energy.



Sound is a type of energy associated with vibrations. When a force causes an object or substance to vibrate it produces sound waves. These waves can only travel through a solid, liquid or gas. They cannot travel through empty space. We can detect sound waves in our ear where the vibrations are transferred to signals that our brain interprets as sound.

The Law of Conservation of Energy

The Law of Conservation of Energy is one of the most important laws of physics and states that:

> 'in a closed system, energy can never be created or destroyed, but can only be transferred from one type of energy to another.'

The law was first proposed by the German scientist Julius von Mayer in 1841. It was then confirmed through experiments by the British physicist James Prescott Joule in 1843. Joule's work on energy was recognized when the international scientific unit of energy (the joule) was named after him.

We can see the Law of Conservation of Energy in action in the world around us every day. When we eat food the human body transfers the chemical energy in the food into motion energy to enable us to lead our lives. A guitar transfers motion energy into sound and a television transfers electrical energy into light and sound.

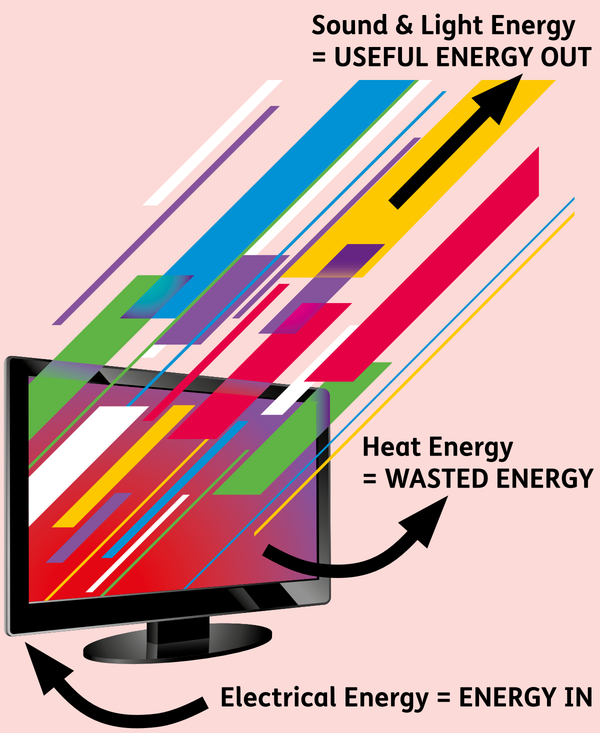
Most energy transfers result in more than one output energy. For example, a motor converts electrical energy (input) into motion energy along with some heat and sound energy (outputs). The heat and sound are regarded as 'wasted energies' and motors are normally designed to limit the amount of heat and sound and maximise the amount of motion. Most electrical appliances like televisions, radios and mobile phones try to limit the amount of heat energy produced in order to make the appliance more 'efficient'.

The efficiency of a device can be calculated using the equation

$$\textbf{Efficiency (\%)} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} \times 100$$

Energy and energy transfers are important concepts in all areas of science. Biology, Chemistry and Physics all rely on an understanding of the role energy plays on our planet and within the universe.

Energy Transfer



$$\text{Efficiency (\%)} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} \times 100$$

Energy Transfers in Everyday Life

Activity

Below are pictures of devices that can transfer energy from one type to another. Some may transfer energy into more than one type.

1. Write the energy transfers beneath each picture.

a. 

____

____

b. 

____

____

c. 

____

____

d. 

____

____

e. 

____

____

f. 

____

____

2. In your own words give a short definition for the following energy types:

Heat Energy

____

Light Energy

____

Electrical Energy

____

Sound Energy

____

Motion Energy

____

Chemical Energy

____

Gravitational Potential Energy

____

Nuclear Energy

____

Elastic Potential Energy

____

Energy Efficiency Calculations

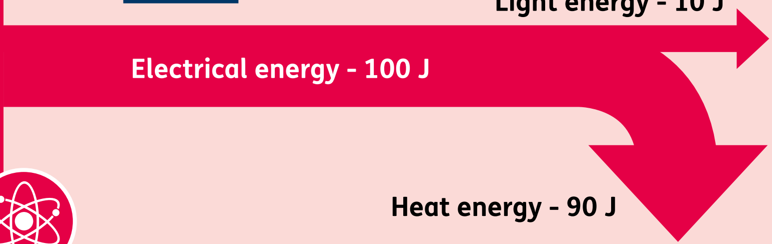
Activity

Most energy transfers result in more than one output energy.

For example, a light bulb converts electrical energy (input) into light and heat energies (outputs). The heat is regarded as a 'wasted energy' output and is transferred into the surroundings where it spreads out making it difficult to do anything useful with it.

Traditional electric light bulbs work by 'glowing' when electricity passes through a thin metal filament. This is actually a very 'inefficient' process because most of the electrical energy is transferred to heat energy instead of light energy as shown in Figure 1. We call this diagram a 'Sankey Diagram'

Figure 1



The percentage efficiency of the device can be calculated using the equation

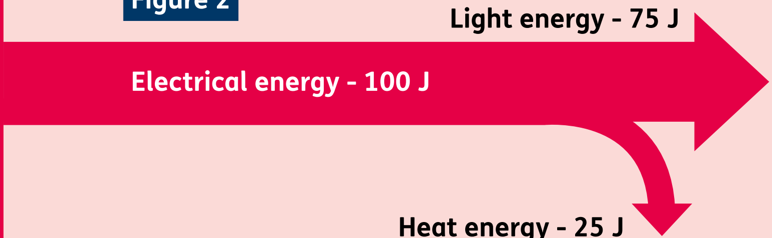
$$\text{Efficiency (\%)} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} \times 100$$

So for the filament light bulb the efficiency would be

$(10 \div 100) \times 100 = 10\%$

Modern energy-saving bulbs work in a different way and transfer more electrical energy into light energy, making them more efficient. This can be seen in the Sankey diagram in Figure 2.

Figure 2



The equation to calculate the efficiency of the energy saving light bulb would be

$(75 \div 100) \times 100 = 75\%$

$$\textbf{Efficiency (\%)} = \frac{\text{Useful Energy Out}}{\text{Total Energy In}} \times 100$$

Use the efficiency equation to calculate the efficiency of the following devices:

1. A kettle has an energy input of 400J. 350J are transferred to heat energy and 50J are transferred to sound energy.

Efficiency = ______________________

____

2. A lawnmower has an energy input of 500J. 300J are transferred to kinetic energy, 150J are transferred to sound energy and 50J are transferred to heat energy.

Efficiency = ______________________

____

3. A wind turbine has an input energy of 10,000J. 8000J are transferred into electrical energy and 2000J are transferred into heat energy.

Efficiency = ______________________

____

4. A set of speakers have an input energy of 300J. 200J are transferred into sound energy and 50J are transferred into heat energy.

Efficiency = ______________________

____

Energy and Biology

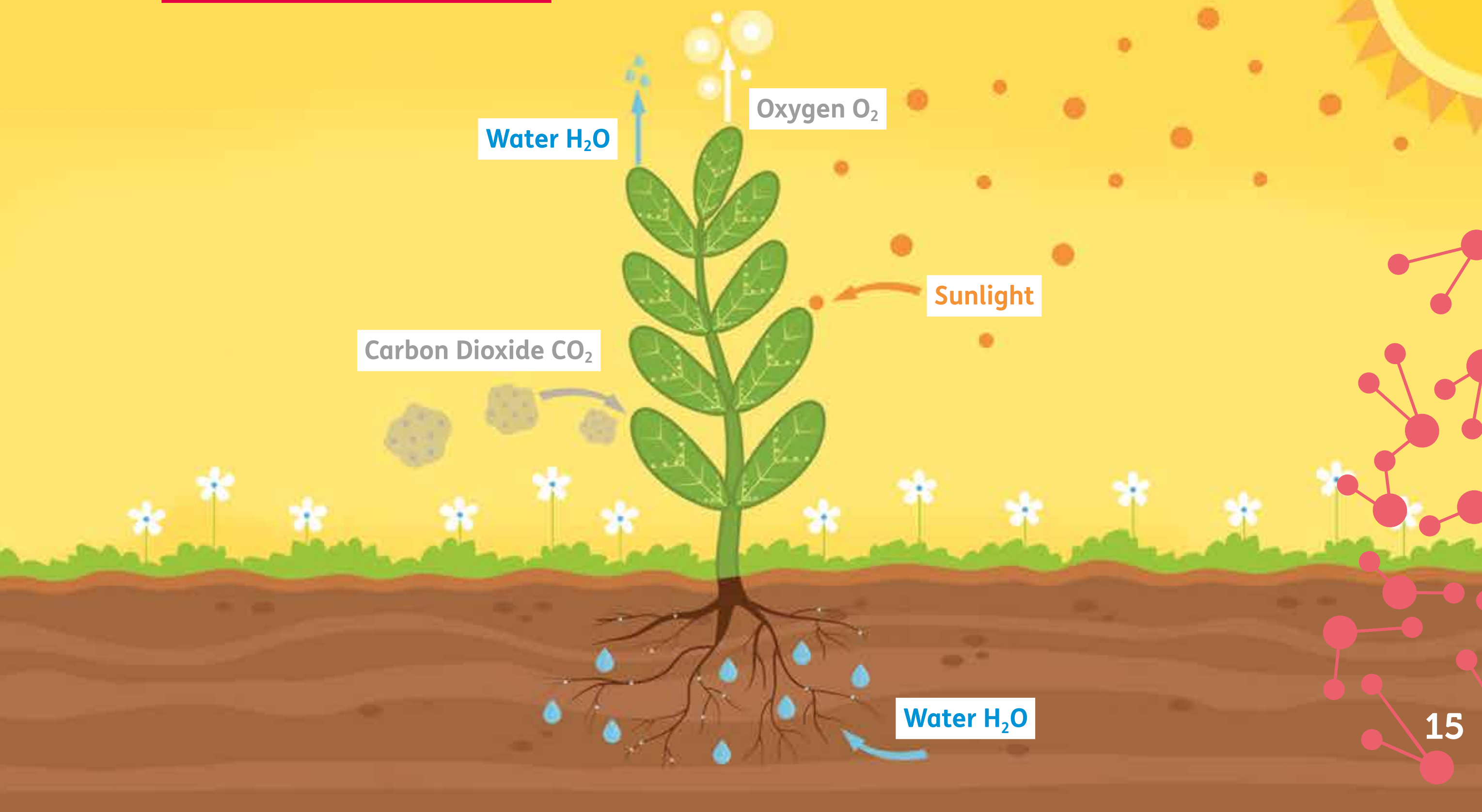
Biology is the science of life and living organisms. Energy is a key concept within the study of biology because all living things use different types of energy to power the biological processes that allow them to grow and survive.

The biological energy journey begins with plants making their own food by a process called photosynthesis. 'Photo' means 'light' and 'synthesis' means 'putting together'. Plants absorb light energy from the Sun using chlorophyll in their leaves. They also absorb the gas carbon dioxide from the air and water from the soil. Light, carbon dioxide and water are the essential building blocks for photosynthesis. The light energy enables plants to split water molecules into hydrogen and oxygen. The oxygen is then released from the leaves into our atmosphere while the plant puts the hydrogen and carbon dioxide together to make a food called glucose.

Carbon Dioxide + Water —(**Sunlight**)→ **Glucose + Oxygen**

This food provides chemical energy for the plant to grow and carry out its normal living processes such as producing flowers or seeds. Energy is released from the glucose through a chemical reaction called respiration. This process uses oxygen and gives off carbon dioxide. Fortunately, plants use up more carbon dioxide in photosynthesis than they produce during respiration, and produce more oxygen in photosynthesis than they use up while respiring. This means plants play an essential role in maintaining the oxygen/carbon dioxide balance within our atmosphere. Removing plants and trees on a large scale can upset this balance. That leads to increasing amounts of carbon dioxide in the atmosphere. Carbon dioxide is a greenhouse gas which can trap heat energy within our atmosphere and lead to global warming.

Photosynthesis



Planning a seed growing investigation – Tutor Notes

Activity

Plants make their own food by a process called **photosynthesis**. Plants absorb light energy from the Sun using chlorophyll in their leaves. They also absorb carbon dioxide from the air, and water from the soil. The light energy allows chemical reactions to take place that produce a food called glucose.

Seeds have a limited amount of 'stored food' within them and rely upon water, the correct temperature and a good location (soil) to allow them to use their stored food to grow large enough for their own leaves to then begin making food through photosynthesis.

A seed growing investigation allows learners to explore the essential building blocks of photosynthesis through experiment.

Before learners carry out the investigation they should discuss some key ideas as listed below.

Questions
What do seeds and plants need to grow? e.g. water, light, heat, food.

Measurements
What do you want to measure/observe? e.g. height of plants.

Variables
What will you change and what you will keep the same? e.g. light/no light.

Discuss fair testing i.e to ensure that your experiment is fair, you should **change only one variable at a time while keeping all other conditions the same**.

Predictions
Using answers from the questions and discussions above, predict what you think might happen in the different scenarios.

Conclusions
Were predictions correct? What were best/worst growing conditions?

Equipment needed
Recycled yogurt pots, fast growing seeds (e.g. cress) water, soil, lids labels, data observation sheet (to be used to collect observations over a period of time).

Preparation
Prepare one yogurt pot with all the variables present this will be the control. Now prepare all the other yoghurt pots with only one variable missing.

Label pots clearly and try to keep the variables the same (e.g. Adding the same amount of water to each pot). Observe daily over a period of time noting changes on the data chart. Use this information to form conclusions and decide on the best growing conditions.

Data observation sheet (template)

Investigating the best way to grow cress

Start date:____________

Variables – make sure they are same (eg. same heat/same amount of water)	**Control** – Water, soil, light, heat		**Water, soil, light** – no heat		**Water, soil, heat** – no light		**Water, heat, light** – no soil		**Heat, light, soil** – no water	
Observations Write down any changes										
Day 1										
Day 2										
Day3										
Day 4										
Day 5										

?

What variables gave poor cress growth?

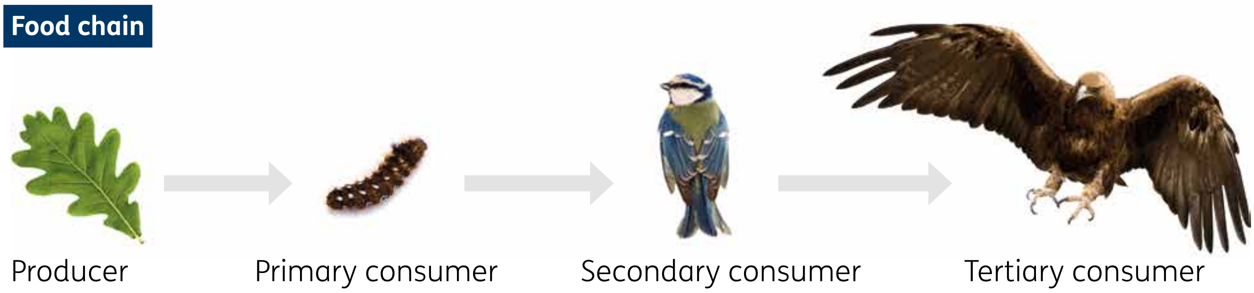
What variables gave good cress growth?

Use your knowledge of photosynthesis to write a summary of your investigation/ conclusions. Discuss the role fertiliser could play.

Plants also need small amounts of minerals, such as magnesium and potassium, to help them grow and support the photosynthesis process. They usually get these minerals from the soil, but fertilisers can also be used to supply plants with essential nutrients. When farmers harvest their crops they often remove minerals from the soil and need to use natural fertilisers like manure, or artificial chemical fertilisers to put back the soil nutrients before growing further crops.

Animals, including humans, cannot make food by photosynthesis. However, by eating plants they can get the energy they need. When plant eating animals are eaten by other animals, some of the energy is ‘passed on’. This flow of energy is called a food chain.

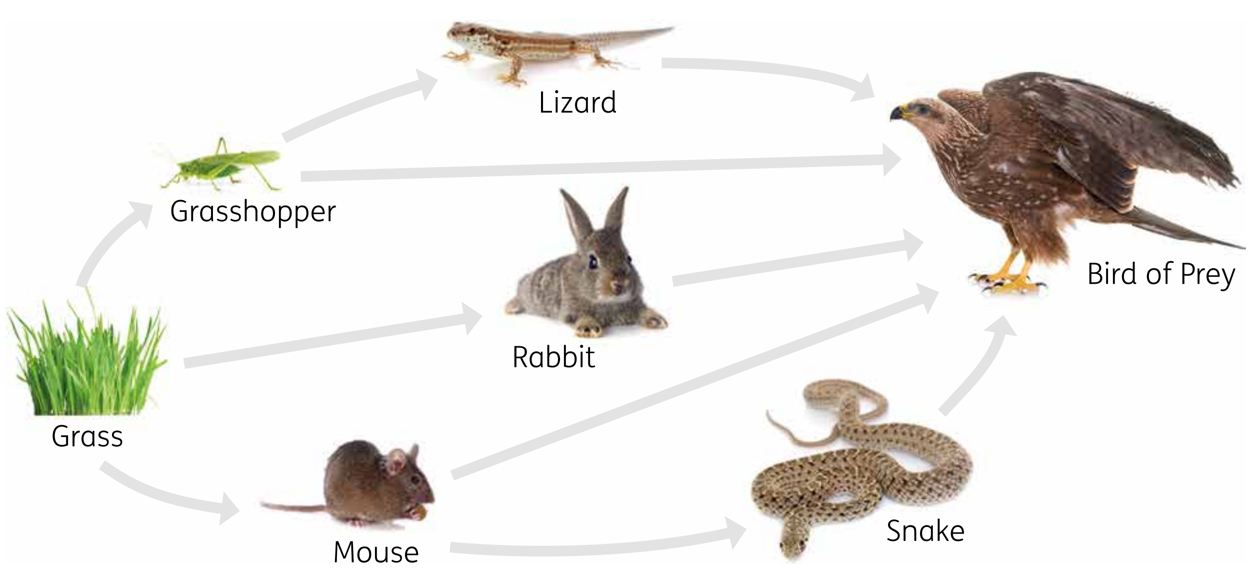
Food chain



The producer is a green plant which makes its own food by photosynthesis. A primary consumer eats the producer (green plant). The primary consumer can then be eaten by a range of secondary consumers and so on. A consumer that only eats plants is called a herbivore. A consumer that only eats other animals is called a carnivore. If an animal eats both plants and animals, it’s called an omnivore.

Food chains often become inter-connected because animals within a specific habitat can have a range of food choices. This can produce a food web where there is interdependence within the habitant. This means that living things depend on each other for survival and if the population of one particular plant or animal increases or decreases it can affect the populations of other organisms within the food web. Light energy from the Sun is the starting point for photosynthesis and this simple biological process sustains life by providing a flow of energy that extends through all living things on our planet.

Food web in a grassland ecosystem with five possible food chains



Food Chains and Food Webs

Activity

Animals, including humans, cannot make food by photosynthesis. However, by eating plants they can get the energy they need. When plant eating animals are eaten by other animals, some of the energy is 'passed on'. This flow of energy is called a food chain.

A producer is a green plant which makes its own food by photosynthesis.

A primary consumer eats the producer (green plant).

The primary consumer can then be eaten by a range of secondary consumers and so on.

1. **Create 2 simple food chains from the following list of producers, primary and secondary consumers.**

   Wildflowers   Hawk   Snake   Mouse   Rabbit   Grass

Food chains often become inter-connected because animals within a specific habitat can have a range of food choices. This can produce a food web where there is interdependence within the habitant.

2. **Choose one of the following habitats.**

   Marine   Rainforest   Arctic   African   Grasslands

Research the plant and animal life within your chosen habitat and construct a sample food web to demonstrate the interdependence within the habitat. Identify at least 2 examples of the producers, primary and secondary consumers.

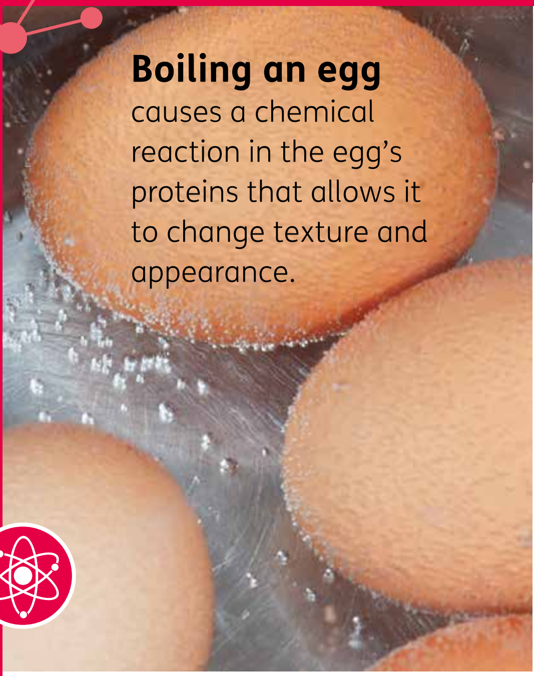
Discuss what could happen if disease or pollution were to affect one of the key producers within your habitat. How would this affect the populations of the other species?

3. **Research the advantages and disadvantages of pesticide use. Apply your knowledge of food webs to discuss the possible impacts on local habitats.**

Energy and Chemistry

Chemistry is the science that deals with the properties and composition of substances and the changes they undergo. When one substance is changed to form a different substance, a 'chemical reaction' has taken place and this usually involves an energy transfer.

Chemical reactions are happening all around us.

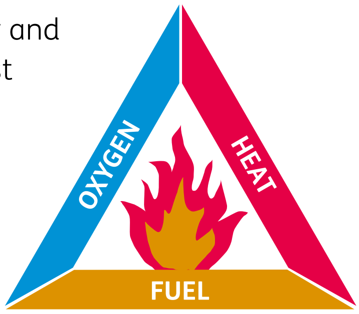


Boiling an egg causes a chemical reaction in the egg's proteins that allows it to change texture and appearance.

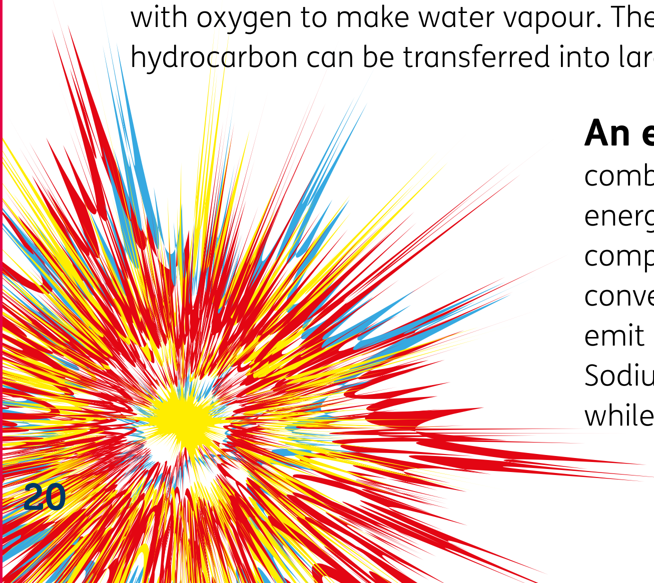
A chemical reaction is used in batteries to produce the electrons that are needed to supply electrical energy.

Rust is the result of a chemical reaction between iron and oxygen and water.

Many chemical reactions transfer chemical energy into heat energy and are called exothermic reactions. Combustion, or burning, is the most common example of an exothermic reaction.



Coal, oil and gas are fuels with stored chemical energy and are normally used for combustion. Heat energy from these fuels allows us to use our cars and heat our homes. They contain hydrocarbons which are compounds of hydrogen and carbon. When the fuel burns, the hydrocarbons react with oxygen. The carbon combines with oxygen to make carbon dioxide and the hydrogen combines with oxygen to make water vapour. The chemical energy stored within the bonds of the hydrocarbon can be transferred into large amounts of heat energy during this reaction.



An exploding firework is an example of a combustion reaction that generates heat, light and sound energy. The firework is filled with a mixture of metal compounds that burn with the oxygen in the air and convert into other chemicals. Different metal compounds emit different colours of light energy when they burn. Sodium compounds give yellow, copper produces blue while calcium or strontium make red.

Chemical reactions also happen all the time in the kitchen.

When we make a cake, heat energy causes a chemical reaction that allows baking powder to break down and produce carbon dioxide that helps the cake to rise.

A toaster provides heat energy which turns bread brown by breaking down sugars in the bread to form carbon. Bananas eventually turn brown in your fruit bowl because of a reaction between chemicals in the banana and oxygen producing a brown colour in the skin.

Scientists have also developed a variety of ways to control the speed of chemical reactions. For example,

- A banana will turn brown more slowly if it is placed in a fridge and its temperature is lowered.
- Food will last longer if it contains preservatives that stop chemical reactions with oxygen.
- Special paints have been created that will slow down the rusting process.

It is also important to control the speed of chemical reactions in medicines. Often the medicine is coated in a plastic which reacts slowly in the body, helping the medicine to be used over a longer period of time.

The speed of chemical reactions can also be increased by the addition of a substance called a catalyst.

Catalytic convertors are used in cars to reduce the amount of pollution emitted into the air. They use a transition metal like platinum to speed up the change of harmful gases from a car exhaust into less harmful ones.

Our bodies also contain thousands of enzymes which act as catalysts during the millions of chemical reactions which take place every day. Without enzymes most of these reactions, like digestion, would not take place quickly enough to sustain life. Everything in the world is made of chemicals and many of the changes that we see every day occur because of chemical reactions. These reactions involve energy transfers that are essential for life to survive on our planet.

Kitchen Chemistry: a toasty experiment!

Activity

A toaster provides heat energy which 'toasts' or turns bread brown by a series of chemical reactions. The heat energy causes the break down of sugars in bread to form carbon.

? Imagine you've slept in, but you really need some breakfast before you leave the house. Which bread will toast fastest, white or brown?

You will need:

- Slice of white bread
- Slice of brown bread
- Toaster
- Something to spread on your toast – try butter, jam or honey

Method:

1. Put the slice of white bread in one side of the toaster and the slice of brown bread in the other side of the toaster.
2. Every 15 seconds, check the bread. Which one visibly appears to 'harden' and 'change colour' faster?

What's happening?

Brown bread normally toasts faster than white bread.
There are three reasons for this:

1. Brown bread can absorb more heat than white bread. This increased heat produces the required chemical reactions to toast the bread more quickly.
2. Brown bread contains less water than white bread. Water needs a lot of energy to heat up, so white bread takes longer to toast.
3. Brown bread can contain slightly more sugar than white bread. This allows more of the required chemical reactions to take place in brown bread and a faster toasting time.

Did you find that brown bread toasts more quickly?

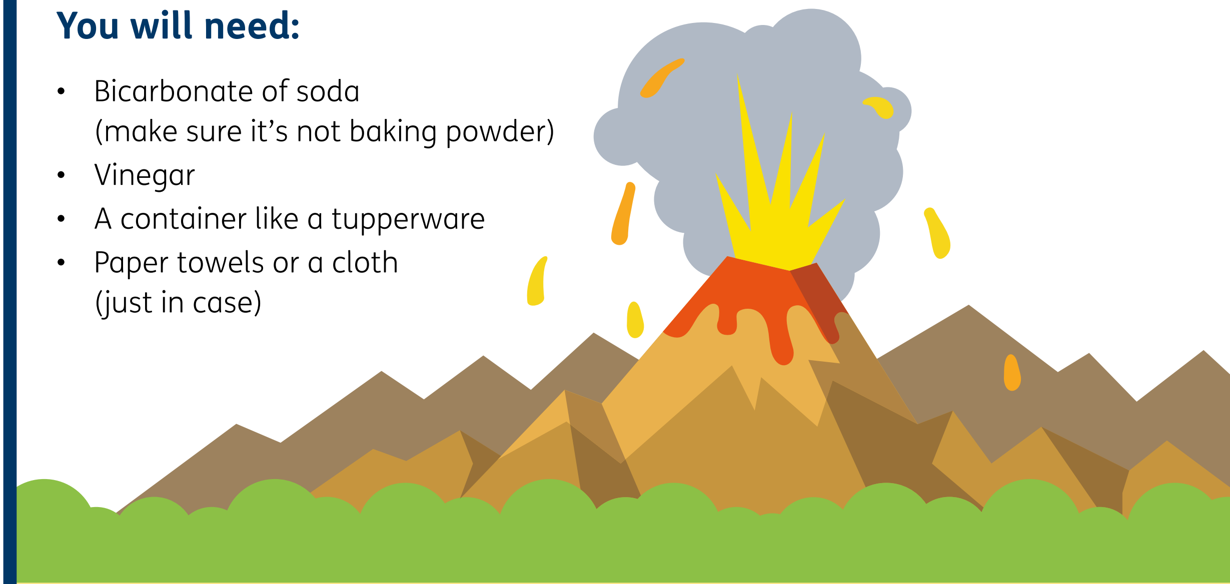
If you found that white bread toasted more quickly, it could be that your toaster is toasting the bread unevenly.

Bicarbonate of Soda Volcano: a chemical reaction experiment

Activity

You will need:

- Bicarbonate of soda (make sure it's not baking powder)
- Vinegar
- A container like a tupperware
- Paper towels or a cloth (just in case)



Method:

1. Place some of the bicarbonate of soda into your container.
2. Pour in some of the vinegar.
3. Watch as the reaction takes place!

What's happening?

The bicarbonate of soda (sodium bicarbonate) and the vinegar (acetic acid) produce a chemical reaction. This reaction forms carbonic acid which is very unstable and instantly breaks apart into water and carbon dioxide, which creates all the fizzing as it escapes the solution.

Extension Activities

1. Try replacing the vinegar with other household acids like tomato ketchup, lemon or apple juice.
2. Does the chemical reaction still take place? Describe the rate and size of the reaction.
3. Bicarbonate of soda is often used to produce chemical reactions during baking. Write a short description about the role bicarbonate of soda can play in a cake.

Energy and Physics

Physics is the study of all physical objects and how they move and behave, especially when they interact with forces and energy. The science is based on experiments, measurements and mathematical analysis with the aim of finding laws to describe how the universe works.

In physics, energy is defined as the capacity of a system to do work and is measured in joules.

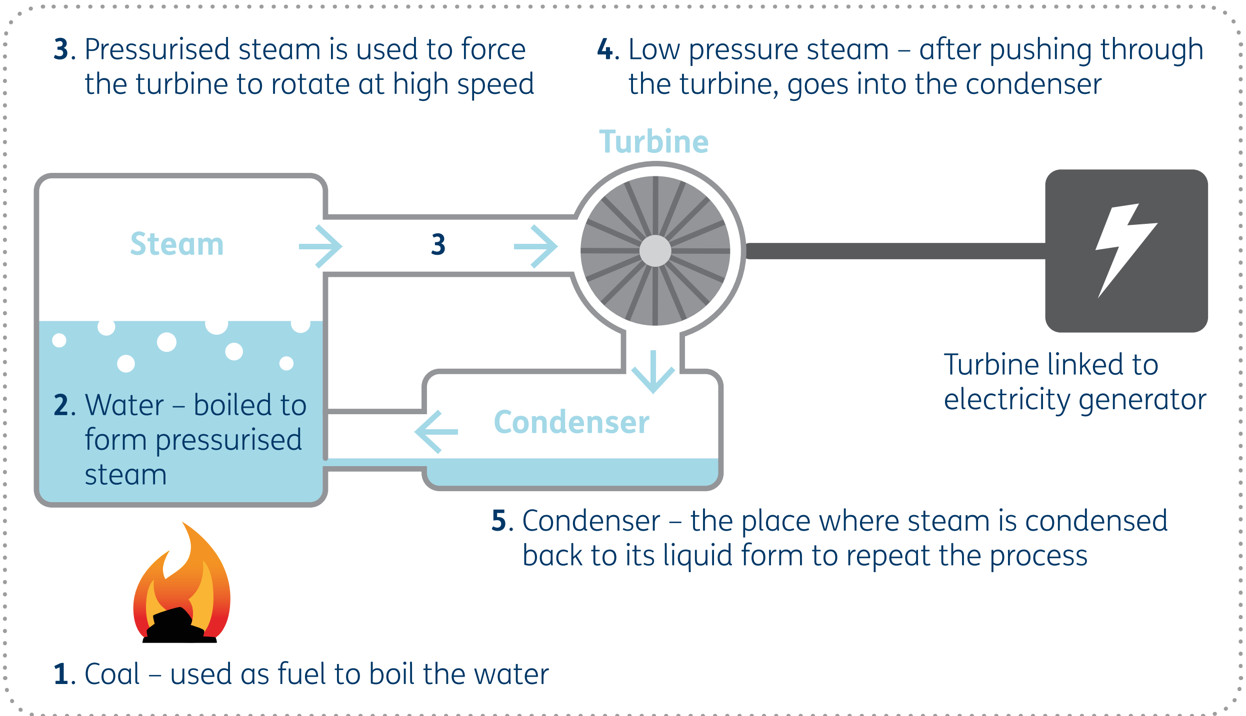
One of the most important fields of physics is the study of electrical energy. This form of energy is possibly the most versatile and easy to control. It has transformed the way we lead our lives with an array of electrical appliances now taken for granted in the 21st Century.

One early electrical energy pioneer was Benjamin Franklin, who carried out experiments to show that lightning was a form of electricity. Another was Michael Faraday, who invented the electrical generator. Faraday showed how electricity can be produced by continually rotating a copper coil within a magnetic field.

By the early 20th Century power stations were using this scientific principle to generate electrical energy by burning fossil fuels.

A coal fired power station burns coal to transfer chemical energy into heat energy. This is used to boil water. The water then evaporates to produce steam. The steam is pressurised and used to force a turbine to rotate at high speed. The turbine is connected to a generator which transfers the motion energy into electrical energy by continually rotating a copper coil within a magnetic field.

Once electricity has been generated, it is then transmitted and distributed to consumers.



Electric Power is measured in watts and is a measure of how much electrical energy is being used each second.

To find out how much energy an electric appliance uses, we multiply the power it uses per second (usually labelled on the appliance) by the total number of seconds it is used for. The result is measured in units of Power x Time, and instead of using Joules, is often converted into a standard unit called the kilowatt hour (kWh) where 1 kilowatt is 1000 watts.

Electrical Energy = Power x Time

If an electric toaster is rated at 1000 watts (1 kilowatt) and used for a whole hour, it uses 1 kilowatt hour of energy. The same amount of energy is required to run a 2000 watt heater for 0.5 hours or a 100-watt light for 10 hours.

Calculating the running costs of electrical appliances

Activity

The amount of Electrical Energy used by an appliance each second is a measure of its Electrical Power and is measured in watts.

To find out how much energy an electrical appliance uses, we multiply the power it uses per second (usually labelled on the appliance) by the total number of seconds it is used for.

We can then calculate how much it costs to run the electrical appliances in our homes.

To re-cap: **Electrical Energy =** Power x Time

Instead of using Joules, our electricity bills use a different unit for Energy called the 'kilowatt hour' (kWh) where 1 kilowatt is 1000 watts. The bill will tell you how much you pay per kilowatt hour and how many kilowatt hours of energy you have used.

For example:

If an electric toaster is rated at 1000 watts (1 kilowatt) and used for a whole hour, it uses 1 kilowatt hour of energy.

If the cost of 1 kilowatt hour is 10 pence, and the toaster is used for 8 hours a year, it will cost **8 x 10 pence = 80 pence per year to run**.

Continued on page 26 →

Calculating the running costs of electrical appliances - *continued*

Activity

If a 2000 watt (2 kilowatt) heater is used for 2 hours per day it will use 2 x 2 = 4 kilowatt hours of energy per day. If the cost of 1 kilowatt hour is only 8 pence it will cost **4 x 8 pence = 32 pence per day to run**.

If a 100-watt (0.1kilowatt) light bulb is used for 30 hours per week. It will use 0.1 x 30 = 3 kilowatt hours per week. If the cost of 1 kilowatt hour is 9 pence it will cost **3 x 9 = 27 pence per week to run**.

Now calculate how much the following electrical appliances cost to run each day.

Appliance	Power (kW)	Time used (hours)	Energy (kWh)	Cost per kWh (pence)	Cost of Energy used (pence)
Light Bulb	0.1	5		10	
4 Slice Toaster	1.3	0.1		10	
Kettle	3.0	0.5		10	
Hairdryer	2.0	0.2		10	
Microwave	0.8	0.3		10	
Tumble Dryer	4.5	1		10	

Now make your own table with electrical appliances from your home.

Find out how much your electricity supplier charges for 1 kilowatt hour (you can find this on your electricity bill). Think carefully about the amount of time you use each electrical appliance per day and then work out how much it costs per week to run all the appliances in your home.

In Scotland most of our electrical energy has been generated by either fossil fuels or nuclear power stations for the past 50 years. However, the burning of fossil fuels has left us with carbon dioxide emissions which most scientists believe is causing our planet to warm in an unsustainable way. Therefore, Scotland is increasingly turning to renewable energy from natural resources which won't run out or harm the planet.

Nuclear Energy Discussion

Activity

Should Scotland Use Nuclear Energy?

Research the advantages and disadvantages of nuclear energy use in Scotland. Write down 3 reasons that reflect the arguments for and against nuclear energy.

?

Are you for or against?

Be prepared to discuss your own views.

NO	YES
List 3 arguments for why Scotland **should not use** nuclear energy	List 3 arguments for why Scotland **should use** nuclear energy
1.	1.
2.	2.
3.	3.

Scotland's wet and windy climate means we are ideally placed to harness wind, wave, hydro and tidal power to meet our electrical energy needs.

Wind

Wind turbines can be located on land or off-shore. The wind is a type of motion energy and can be used to turn the blades of the turbine which then turns a shaft which is connected to an electricity generator. Turbines need strong and reliable winds and have to be situated carefully. Whitelee Windfarm near Eaglesham is the largest wind farm in Europe. It has 140 wind turbines which generate enough energy to power 180,000 homes.

Tidal

Turbines can also be used underwater and the tide provides the motion energy required to turn the blades of the turbine which then can be used to drive a generator. The European Marine Energy Centre in Orkney aims to harness the significant tidal potential of the Pentland Firth.

Wave

Waves are very powerful but it is difficult to harness this energy in order to generate electricity. Various devices are being developed and tested in Scotland. The world's first commercial wave power generator, the Limpet, is based on the coast of Islay and uses waves to move air through turbines which can then produce electricity via a generator.

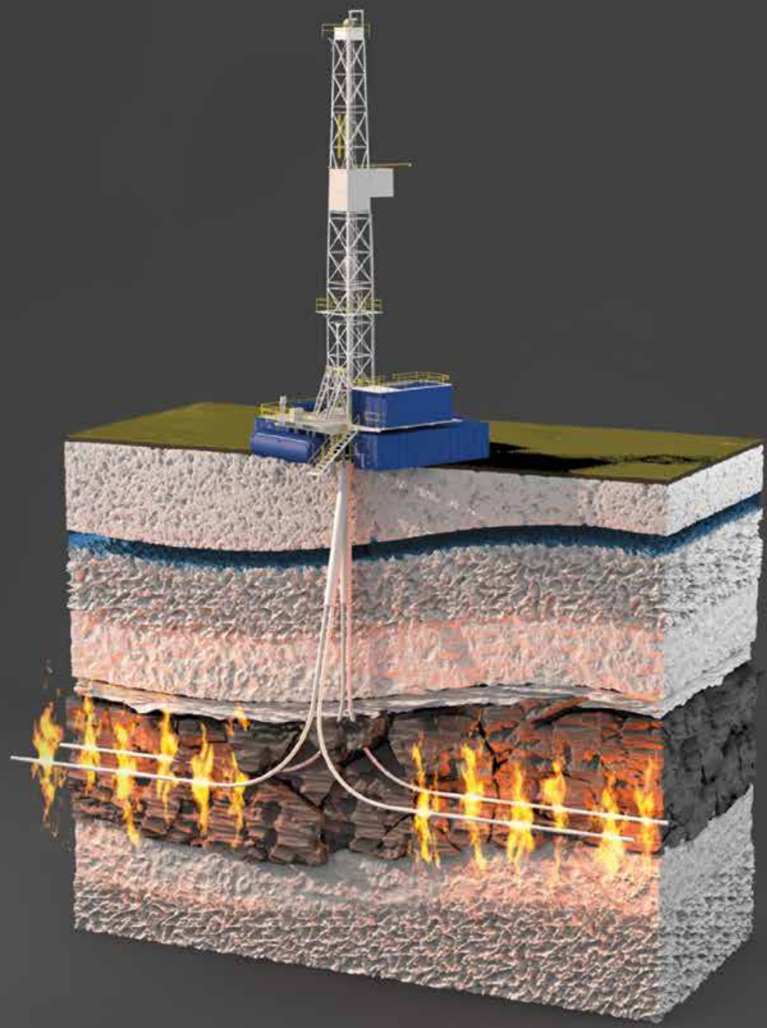
Hydro

Hydro power is well established in Scotland. The wet Scottish weather can provide a useful supply of water which is collected and stores gravitational potential energy high above the power station in a loch, reservoir or river. When required, this water is allowed to fall and provides the motion energy needed to turn turbines in order to generate electricity. Hydro schemes can be expensive and difficult to build, but once established, the energy is virtually free and produces no waste or pollution.

Other types of renewable energy that can be used to generate electricity include:

- Solar which uses heat or light energy from the Sun
- Biomass which transfers chemical energy found in plant or animal waste
- Geothermal that uses heat energy found within the earth

Another, much debated energy source is shale gas which can be obtained by a process called 'fracking'. This process involves drilling down into the earth to allow a high-pressure water mixture to be directed through cracks in the rock to release the gas inside. The rock is 'fractured' apart by the high pressure mixture. The process has attracted controversy due to the potential risks of earth tremors and environmental contamination but some industry experts claim the risks are negligible and fracking could create thousands of jobs. At present the Scottish Government opposes fracking until more research on the possible impacts has been carried out. Instead, Scotland continues to invest in renewable energy with an emissions target (The Climate Change (Scotland) Act 2009), set for the year 2050, for a reduction of at least 80% from the baseline year, 1990.

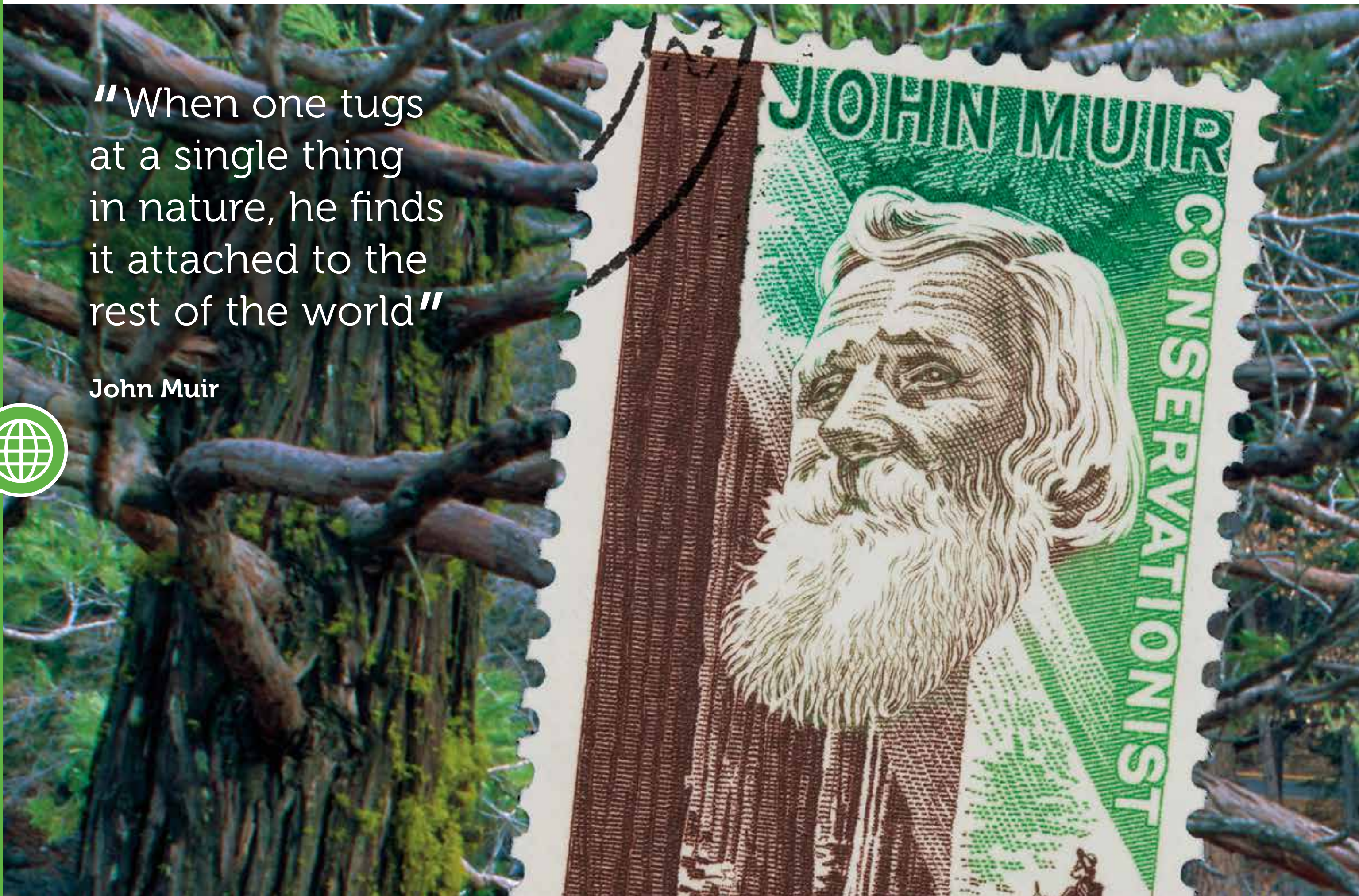


Scotland now generates over half of its electricity from renewable sources and this has contributed to a growing expertise in the sector. Renewable energy is an increasingly important industry, providing jobs, economic growth, and a way for Scotland to play its part in tackling climate change.

Tourism and Environmental Science

"When one tugs at a single thing in nature, he finds it attached to the rest of the world"

John Muir



Scotland's natural and much loved landscape has been created by a variety of different geological and environmental processes over hundreds of millions of years. Drifting continents, volcanic eruptions and a series of ice ages have all contributed to our unique foundations.

Today, we live on a northerly latitude within a temperate climate which benefits from the North Atlantic Drift, and our mountains, glens, coasts and islands attract visitors from all over the world. However, our climate is also changing and the impacts of climate change on our local environments could be far-reaching.

Our geological evolution, distinctive meteorology and climate change challenges also present opportunities for learners to engage with a variety of environmental science concepts and skills.

Learn about:

Geology p32

Meteorology p40

Climatology p44

Oceanography p47

Geology

Early Beginnings

The majority of scientists believe that Planet Earth was formed out of a huge spinning disc of gas and dust about 4.5 billion years ago. The early planet was mostly in a molten form with extreme volcanism, but over time the Earth cooled allowing a solid crust to form with liquid water on the surface.

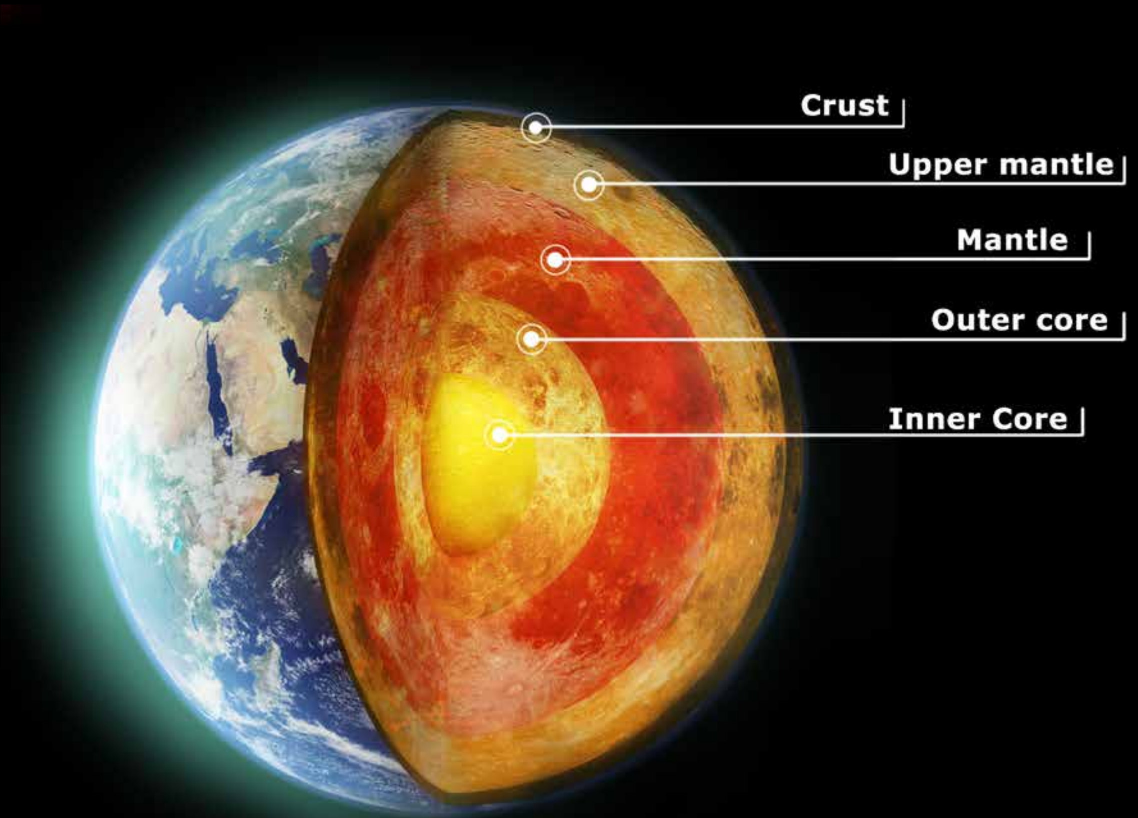
How the first land masses emerged from the Earth's crust is still debated by geoscientists, but it is accepted that the early continents have changed shape and position slowly over geological time.

At one time they formed one large 'super continent' called Pangea. A map of the world shows how well Africa and South America could fit together and investigations show that rocks of the same type and age can be found in both Brazil and Southwest Africa. Certain reptile fossils from 250 million years ago are also only found in Brazil and South Africa, helping to confirm the theory that they were once joined together but have now moved apart.

The Earth Today

Today, the continents and the sea bed sit on the outermost layer of the Earth, called the Earth's crust. This is a thin layer with a thickness of between 5 and 100 km.

Under the crust lies the Earth's mantle which is largely hot, solid rock but has small molten portions. Beneath the mantle lies the core of the Earth which is believed to consist mainly of iron with a molten outer layer and a solid centre. The iron core is thought to be the main cause of the Earth's magnetic field.



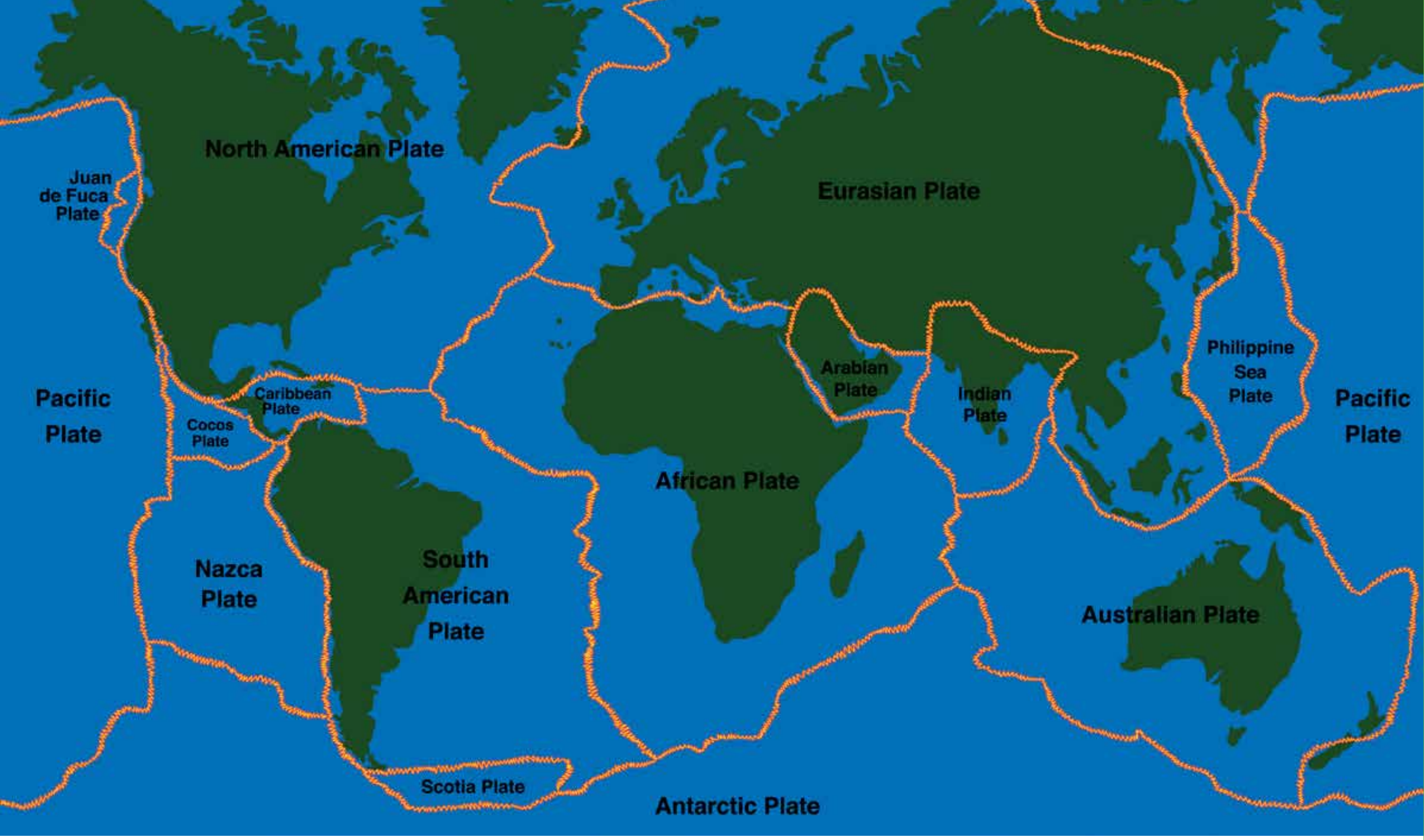


Plate Tectonics

Today we also know that the Earth's crust, along with the uppermost part of the mantle, are made up of a series of plates.

Heat rising and falling within the mantle causes convection currents that help the plates move. They can move horizontally, to cause gaps or collisions, and vertically, to pile one under, or over the other. These movements also give to rise to volcanoes and earthquakes at the plate boundaries.

Iceland, California, New Zealand and Japan all sit near plate boundaries and can feel the devastating impacts of these geological hazards.

Volcanoes and Earthquakes

Volcanoes get their name from the Roman god of fire, Vulcan. They form on the Earth's surface at weak points in the crust. This usually occurs near a plate boundary and allows magma – a mixture of molten and semi-molten rock to push up from the mantle.

Today, there are no active volcanoes in Scotland. However, some of our most famous landmarks like Ben Nevis, The Cuillin Hills on Skye and Glencoe were all formed as a result of volcanic activity that did exist in Scotland many millions of years ago.

Earthquakes occur when there is a build-up of energy within the Earth's crust. This usually happens when two of the Earth's plates have stopped moving smoothly alongside each other and have become 'stuck'. This causes a build-up of stress. When the stress is eventually released, the crust will often shake and vibrate in the form of an earthquake. The point inside the crust where the energy has been released is the focus of the earthquake, and the point on the Earth's surface, above the focus, is called the epicentre. This is where the most damage is likely to occur.

Earthquake House, Comrie

Activity

Comrie in Perthshire is sometimes referred to as the 'Shaky Toun', because the area is thought to experience more earthquakes than any other part of the British Isles.

Experts believe Comrie's close proximity to the Highland Boundary Fault is the reason for the enhanced seismic activity. Consequently, monitoring instruments have been located at Comrie for many years.

Research and investigate Comrie's 'Earthquake House'.

Write a short article (two or three paragraphs) detailing some of the theories behind Comrie's earthquakes and describing the sorts of technology used to measure earth tremors.

Earthquake House information
www.undiscoveredscotland.co.uk/comrie/earthquakehouse
http://strathearn.com/pl/earthquake.htm

Scotland and the UK are not generally associated with earthquakes, but can experience up to 300 minor tremors each year.

Although we sit a significant distance from the nearest plate boundary, our minor earthquakes probably occur when small stresses within the plate are relieved by movement along geological fault lines. These fault lines are boundaries between distinct geological zones that can be traced back to Scotland's formation – millions of years ago.

Scotland's Geology

500 million years ago, Scotland was a fragmented part of a major continent called Laurentia, which sat south of the Equator and also contained what we now call North America and Greenland. The landmass was separated from England and Wales by an ocean wider than the present day Atlantic. This ocean closed about 410 million years ago bringing Scotland and England together during a massive continental collision. The closure squeezed a series of broken and distinct geological fragments into the land that would become Scotland. This process, and the resultant journey northwards to our present location, gave our country a uniquely varied collection of rocks and minerals and a series of major fault lines.

The collision which resulted in the joining of Scotland with England also produced a massive mountain range that would eventually become the Highlands, the Cairngorms and the many famous hills and peaks that dominate Scotland's landscape of today.

Rock Types

Rocks consist of tiny grains of different minerals, sometime held together by a cement like matrix. Minerals are naturally occurring solids, with a definite structure and thus chemical composition.

Gold, salt, diamond and quartz are all examples of minerals. The grains can fit together in different ways to make the rock either soft and porous or hard and non-porous.

Rocks are normally divided into 3 categories – igneous, sedimentary and metamorphic and all 3 of these types can be found in Scotland.

Igneous rocks are sometimes referred to as volcanic rocks because they are created by heat and originally molten, but not all were erupted. Some, like granite, cooled slowly below the Earth's surface and have gradually been exposed by geological processes. They usually have big interlocking minerals and the majority of igneous rocks are hard and non-porous. Examples include granite and basalt and they do not contain fossils due to the high temperatures involved in their formation.

Sedimentary rocks are formed from compressed sediments or deposits that build up and become compacted and harder over time. They can be soft and porous and may contain fossils of plants and animals that became trapped in the sediments as the rocks form. Examples include sandstone, chalk and limestone.

Metamorphic rocks are rocks that have changed their chemical composition due to the application of heat and/or pressure. They are often found near volcanoes or in mountain building regions, where heat and/or pressure can build up under the Earth's crust. Over time, these rocks can then reach the surface. Examples include marble which has formed from limestone, and slate which has formed from shale. They can be hard or soft and may contain fossils if the rock was originally sedimentary, but the changing process usually alters the shape of the fossil.

Rocks are constantly changing on a timescale of millions of years. This is called the rock cycle.

For example igneous rocks that emerge from the earth's crust at a volcano can be broken down by a river or the weather into small pieces of sediment. As this sediment builds up and hardens, it eventually becomes a sedimentary rock. This rock can gradually become buried in the Earth's crust where high pressures and heat can change the sedimentary rock into a metamorphic rock and the cycle can begin again.

Scottish Rocks in Use

Activity

1. Have a look at the images of rocks below. Name the rocks and where you might find examples of them in buildings around Scotland.

a.

b.

c.

2. Local building materials

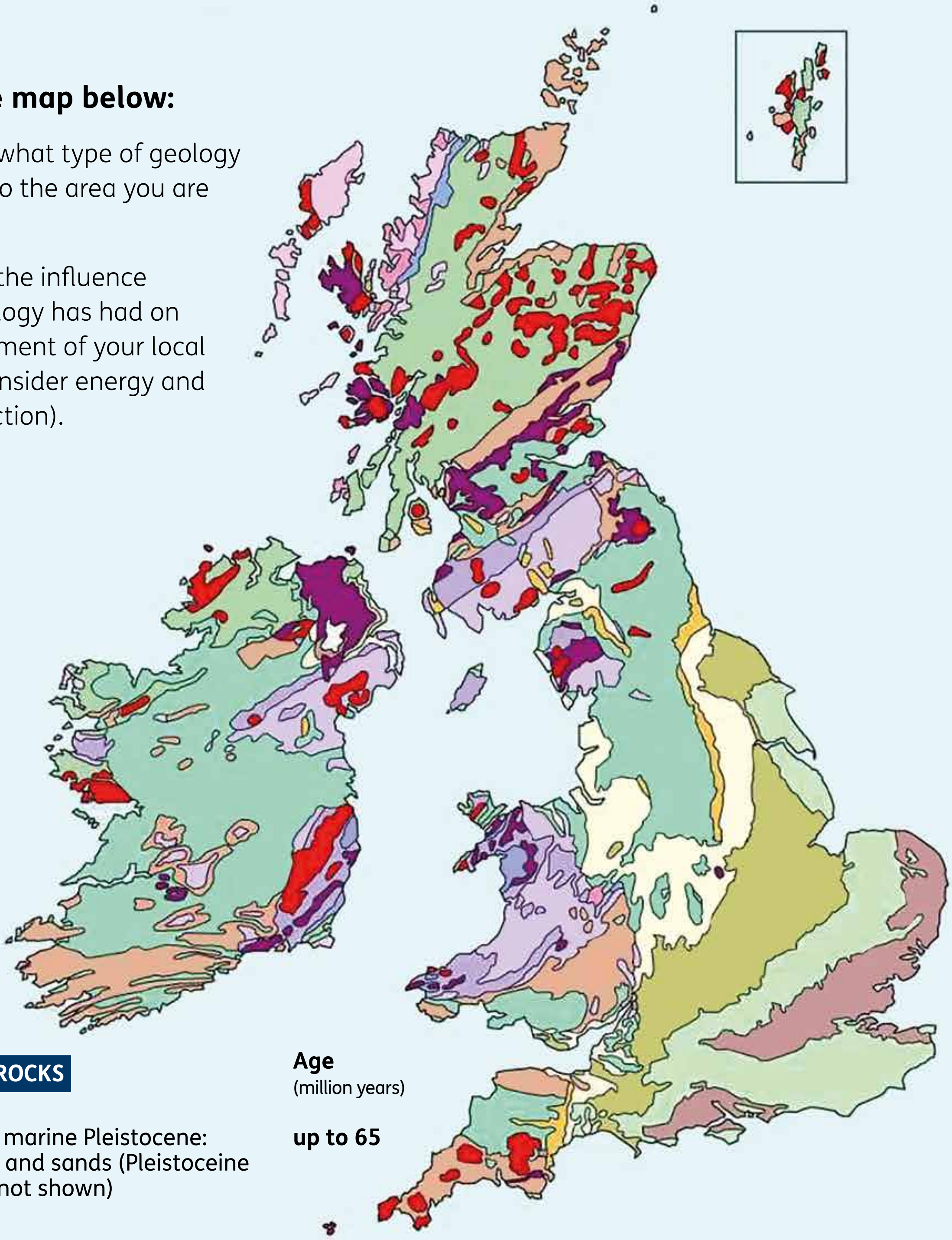
a. What materials are used to construct your home?

b. What type of stones/rocks are used in your local area?
(Check out old properties like tenement flats, churches, libraries, banks etc.)

3. Using the map below:

a. Discuss what type of geology relates to the area you are from.

b. Discuss the influence this geology has had on development of your local area (consider energy and construction).



SEDIMENTARY ROCKS	Age (million years)
CENOZOIC	
Tertiary and marine Pleistocene: Mainly clays and sands (Pleistoceine glacial drift not shown)	**up to 65**
MESOZOIC	
Cretaceous: Mainly chalk clays and sands	**65-140**
Jurassic: Mainly limestones and clays	**140-195**
Triassic: Marls, sandstones and conglomerates	**195-230**
PALAEZOIC	
Permian: Mainly magnesian limestones, marls and sandstones	**230-280**
Carboniferous: Limestones, sandstones, shales and coal seams	**280-345**
Devonian: Sandstones, shales, conglomerates (Old Red Sandstone) slates and limestones	**345-395**
Silurian: Shales, mudstones, greywacke, some limestones	**395-445**
Ordovicia: Mainly shales and mudstones, limestone in Scotland	**445-510**
Cambrian: Maily shales, slate and sandstones; limestone in Scotland	**510-570**
UPPER PROTEROZOIC	
Late Precambrian: Mainly sandstones, conglomerates and siltstones	**600-1000**

METAMORPHIC ROCKS	Age (million years)
Lower Palaeozoic and Proterozoic: Mainly schists and gneisses	**500-1000**
Early Precambrian (Lewisian): Mainly gneisses	**1500-3000**

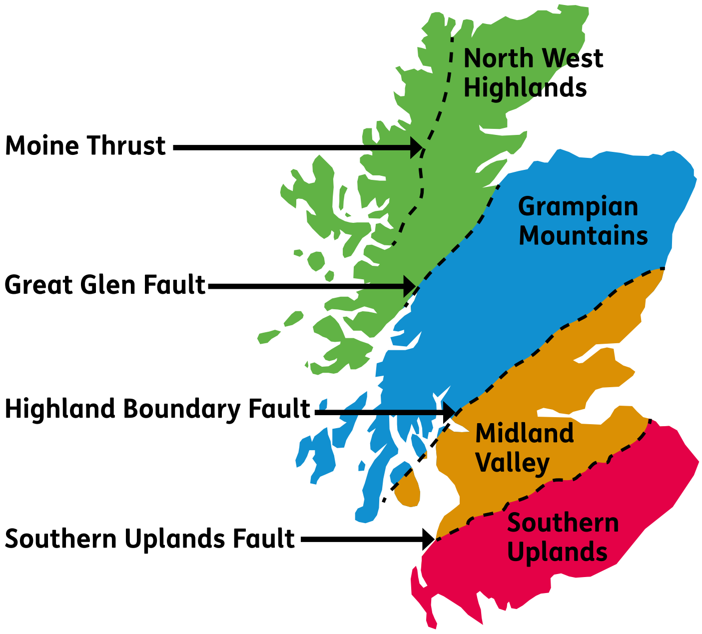
IGNEOUS ROCKS

- Intrusive: Mainly granite, granodiorite, gabbro, and dolerite
- Volcanic: Mainly basalt, rhyolite, andesite and tuffs

Scottish Rocks

Scotland has a rich and varied geology as a result of the distinct fragments that joined together millions of years ago to form the Scottish landmass. Consequently, our geology is split into 5 separate zones by 4 major fault lines. From North to South these are:

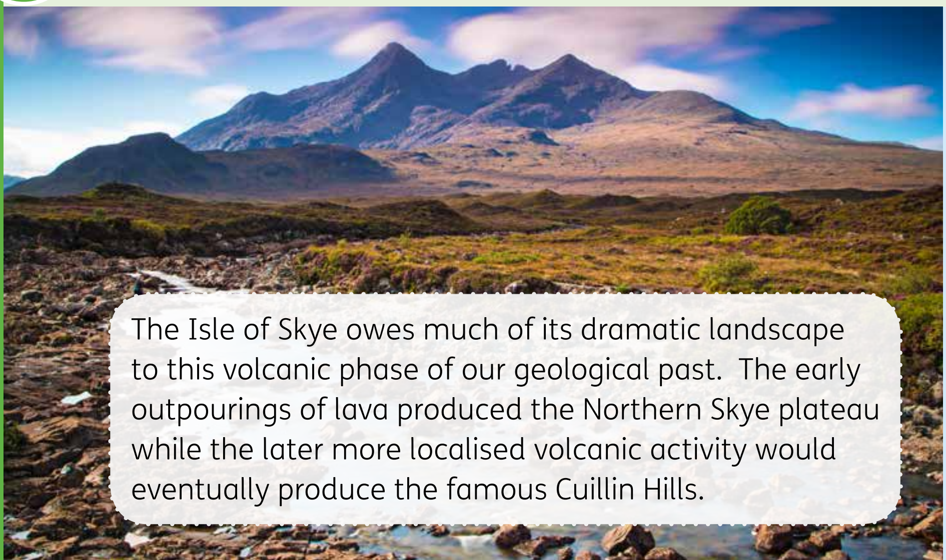
- The Moine Thrust
- The Great Glen Fault
- The Highland Boundary Fault and
- The Southern Uplands Fault.



The Great Glen Fault and The Highland Boundary Fault are the most visible landscape features today, but all the fault lines mark boundaries of major geological interest.

The Moine Thrust separates the Northwest Sea-board (Western Isles, Skye and the Northwest Highlands from Cape Wrath to Kyle of Lochalsh), from the Northern Highlands.

This Sea-board zone contains rocks from 3 different time periods including 'Lewisian rocks' which are around 3 billion years old, making them the oldest rocks in Scotland and some of the oldest rocks in the world. The Sea-board zone also experienced a spell of significant volcanic activity when the Earth's crust began to stretch and crack as North America and Greenland separated from Europe, and the Atlantic Ocean slowly formed around 65 million years ago.

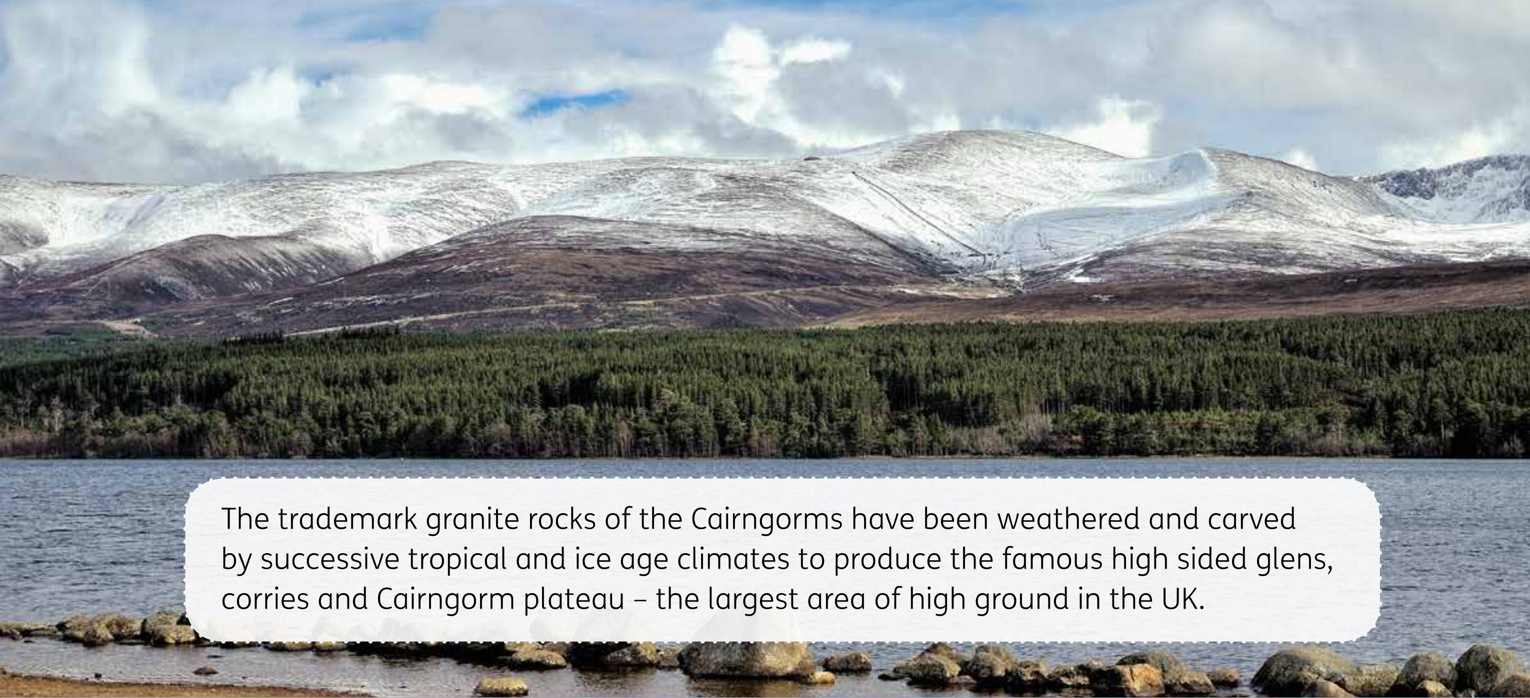


The Isle of Skye owes much of its dramatic landscape to this volcanic phase of our geological past. The early outpourings of lava produced the Northern Skye plateau while the later more localised volcanic activity would eventually produce the famous Cuillin Hills.

The mainly metamorphic and sedimentary rocks of the Northern Highlands lie between The Moine Thrust and The Great Glen Fault. Mull, Iona and Ardnamurchan are also examples of how volcanic activity has helped to shape the landscape of Scotland's northwest coast.

Between The Great Glen Fault and The Highland Boundary Fault lies a tremendous variety of geological features including Ben Nevis, Glencoe and the Cairngorms. These mountains can trace their beginnings to a continental collision that produced a massive mountain chain over 400 million years ago. The remains of this ancient mountain belt include The Appalachian Mountains of North America, the Scandinavian Mountains and our own Grampian Highlands.

The Ben Nevis and Glencoe Area is one of the most dramatic parts of the UK and after its formation via continental collision, was then influenced by volcanic activity followed by erosion and sculpting by ice age glaciers.



The trademark granite rocks of the Cairngorms have been weathered and carved by successive tropical and ice age climates to produce the famous high sided glens, corries and Cairngorm plateau – the largest area of high ground in the UK.

The Highland Boundary Fault brings us to Loch Lomond and the dividing line between the hard metamorphic rocks of the Highlands and the softer, younger sedimentary rocks of the Lowlands. This line marks a distinctive change in landscape, weather, plant and animal species.

To the south of the Highland Boundary Fault lies the Midland Valley with foundation rocks thought to be volcanic in nature. The city of Edinburgh is home to two of the most famous dormant volcanos in Scotland – castle rock on which Edinburgh Castle sits, and Arthur's Seat – the highest point in the city.

350 million years ago the Midland Valley became dominated by tropical swamps and ancient forests which eventually died and were compressed over millions of years to produce coal deposits which gave rise to Scotland's mining industry of the 20th Century.

Finally the Southern Uplands Fault divides the southwest and the Borders from the Central Belt. Southern Scotland also possesses a rich geological history responsible for granite hills, soft sandstones, dramatic cliffs and volcanic roots like the famous Bass Rock.

Scotland's varied and exceptional geology comes to an end at the 'Iapetus Suture' which follows a line close to Hadrian's Wall. This boundary fault dates back 400 million years to when Scotland and England joined together to became one landmass and continue their geological journey together.

Meteorology

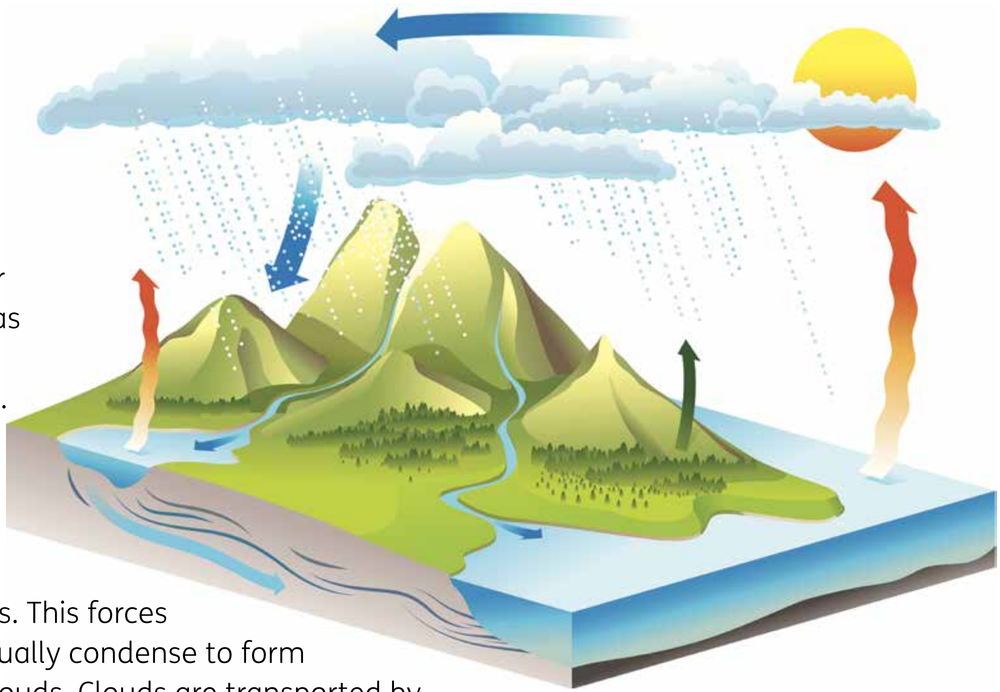
Scottish Weather

Tourists coming to Scotland are usually advised to bring a variety of clothing including wet weather gear – even in the summer months. Indeed our weather is regularly characterised by the expression – 'four seasons in one day'.

Our landscape combined with our latitude and close proximity to the Atlantic Ocean all act as major influences on our weather patterns and contribute to the varied, changeable and often wet conditions!

The Science of Weather

The term 'weather' is used to describe day to day variations in the Earth's atmosphere. These variations are complex and occur because of solar heating, the Earth's rotation and the presence of water in our atmosphere.



The Water Cycle

summarises the main processes involved in producing weather across our planet.

- The Sun warms water in the oceans and seas causing evaporation to form water vapour. Warm air can hold more water vapour than cold air.
- Warm air and water vapour rises and cools. This forces water vapour to gradually condense to form water droplets and clouds. Clouds are transported by the winds which are produced by solar heating and the Earth's rotation.
- Water droplets collide and grow within the cloud until they become too heavy, and fall to Earth as precipitation, which can be rain, hail, sleet or snow.
- Water then flows back into the oceans and seas in rivers and as ground water and the whole process starts again.

Weather is produced because water can exist in 3 different states (solid, liquid and gas) within the atmosphere and can change from one state to another when heated or cooled.

The following terms are used to describe different changes of state.

Scientific Term	Meaning	Example
Freezing	Liquid to Solid	making ice cubes in a kitchen freezer
Melting	Solid to liquid	An ice lolly on a warm summer's day
Evaporation	Liquid to Gas	Wet clothes dry outside on a sunny day
Condensation	Gas to Liquid	Water droplets appear on a cold window pane

Occasionally a gas can change directly into a solid and miss out the liquid phase, or a solid can turn directly into a gas.

Deposition: Gas to Solid (formation of hoar frost on leaves and grass).

Sublimation: Solid to Gas (Snow in the coldest parts of Antarctica does not melt, but much of it does disappear in the summer, by sublimation straight from solid to water vapour).

Water Cycle in a Bowl Experiment

Activity

What you need:

- Large glass bowl
- Glass beaker or yoghurt pot
- Clingfilm
- Two stones
- Warm water

Method:

1. Place the glass beaker or yoghurt pot in the bowl and put a stone inside it (this will keep it weighted down).
2. Pour warm (not boiling) water into the bowl but not into the beaker. The water should come to about half way up the outside of the beaker.
3. Cover the top of the bowl with clingfilm. Place the second stone on top of the clingfilm (in the centre, over the beaker) so there is a very slight 'dip'.
4. To accelerate the process – place some ice cubes alongside the stone on top of the clingfilm. This represents the colder and higher altitudes in the sky, where clouds form.
5. Place your experiment on a window sill.

? Identify and discuss the processes involved in the water cycle as you carry out the experiment.

? Observe the experiment until it is possible to see some water (rain!) dripping into the beaker/yoghurt pot.

? Draw a sketch of your experiment, label the processes happening within the bowl and explain why water has accumulated in the beaker/yoghurt pot, using the scientific terms evaporation and condensation.

Another scientific way of describing changes of state is to consider the Particle Model.

Everything on our planet is made of tiny, constantly moving particles and particles behave differently in solids, liquids and gases.

A solid, like ice, contains particles that have fixed positions and are strongly attracted to one another. The particles are closely packed but they can vibrate. When heat is continually applied to a solid, the vibrations increase until the attraction forces between the particles are weakened and the particles can roll over one another. When this happens, the solid has melted to become a liquid.

If heat continues to be applied, the particles increase their movement until some of those on the surface of the liquid break away into the air. The liquid has begun to change and evaporate into a gas. In a gas, the particles are not held together and can move randomly.

If the gas is then cooled, the particles slow down and become closer together until they start rolling over each other. The gas is condensing into a liquid. If cooled further, the particles become closely packed and stop moving freely. The liquid has frozen into a solid.

The Particle Model Challenge

Extension Activity

Read the following statements and phrases about water as a solid, liquid and gas.

the particles are very far apart

the particles are packed close together

the particles are close together but can move on top of each other

has a fixed shape and a fixed volume

has no fixed shape or volume

can be compressed

can change its shape but has a fixed volume

the particles can only vibrate

can flow

1. Research the properties of solids, liquids and gases and use your knowledge of the particle model to sort the statements into 3 groups: a group that describes solid water (ice), a group that describes liquid water and a group that describes water as a gas (water vapour).
2. Use the statements to write a short paragraph about the particle nature of water in each state.

Scotland's Weather Patterns

Scotland's prevailing wind is from a southwesterly direction. This means that most of the air masses that arrive in Scotland have travelled across the Atlantic Ocean, allowing them to pick up water in the form of water vapour.

The air masses are then forced to rise as they reach the high ground of western Scotland. This causes the air mass to cool and water vapour to condense and form clouds that often produce significant amounts of rain. As the air descends to the eastern side of Scotland, it warms slightly and there is less rainfall.

Scotland's mountains produce a variety of shelter effects depending on which way the wind is blowing.

Another example would be a cold northerly wind which can produce significant amounts of snow across the North Highlands and Grampian mountains, but by the time the air reaches the Central Belt, the southwest and the Borders, it has warmed slightly and dried out.

This phenomenon also works in reverse and is particularly evident with southerly winds during the summer months. As air travels from the Central Belt over the Central Highlands and Grampian Mountains it dries out, allowing an increase in temperature as it descends to the Moray coast area.

Local Weather Investigation

Activity

Choose 2 or 3 Scottish locations from the Met Office's Historic Data webpage:

www.metoffice.gov.uk/public/weather/climate-historic/#?tab=climateHistoric

Predict which location will be the wettest. Predict which location will be the warmest. Justify your predictions by thinking about the prevailing wind direction, shelter effects and height of the location.

Now examine the rainfall figures for the past 10 – 15 years. Calculate average rainfall for each location.

?

Which location is the wettest? Were you correct?

Examine the temperature data.

On average, which location is the warmest? Were you correct?

Discuss your findings in groups.

Predict which English locations will be the wettest and verify your theories by examining the relevant data.

Look at a map of Scotland – identify which towns are likely to have the least/most rainfall. Check your predictions by using the internet and researching climate websites.

Climatology

Climate Change

Weather is the term we use to describe daily changes in our atmosphere. Climate is the term we use to describe the average weather for an area worked out over a much longer period of time. Most climatologists use a period of 30 years.

There are 6 different climate zones around the world namely Mountainous, Polar, Arid, Tropical, Mediterranean and Temperate.

Scotland has a Temperate climate where winters are cold and summers are mild. The climate rarely has extremes of temperatures or rainfall. However, the significant majority of scientists now believe that the world's climate is changing as a result of large quantities of carbon dioxide and other greenhouse gases that we're emitting into the atmosphere.

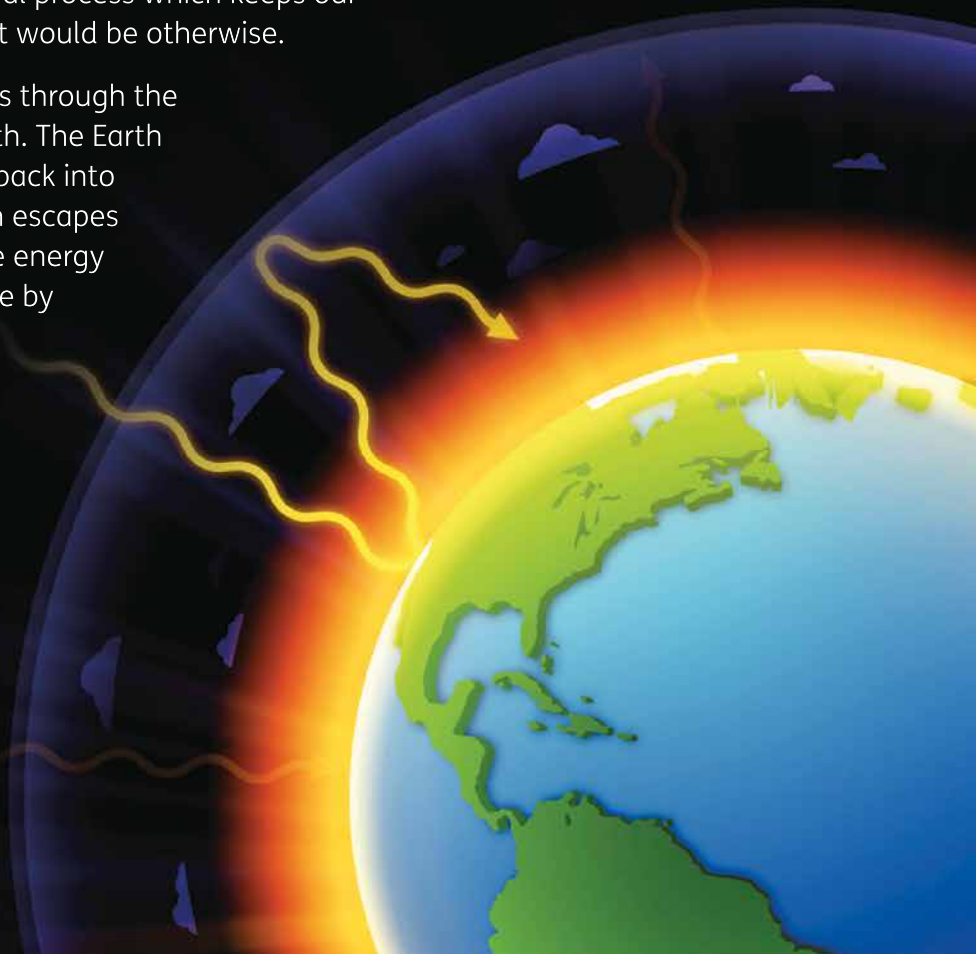
The Science of Climate Change

According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8° Celsius between 1880 and 2010. The majority of scientists believe that this warming is the result of an enhanced greenhouse effect due to increased amounts of carbon dioxide within the atmosphere.

The greenhouse effect is a natural process which keeps our planet about 33C warmer than it would be otherwise.

Heat energy from the Sun passes through the atmosphere and warms the Earth. The Earth then emits some of this energy back into the atmosphere. Some of it then escapes back into space, but some of the energy is trapped within the atmosphere by greenhouse gases.

Gases which behave in this way include water vapour, methane, ozone, nitrous oxide and carbon dioxide. Most scientists believe that increasing amounts of carbon dioxide within our atmosphere are causing man-made enhancement of the greenhouse effect and the resultant global warming.



Climate Change Impacts

The UN's IPCC (Intergovernmental Panel for Climate Change) assesses scientific, technical and socio-economic information concerning climate change, its potential effects and options for adaptation and mitigation.

The IPCC published its 5th Assessment in 2014 and concluded:

"Warming of the atmosphere and ocean system is unequivocal"

"No one on the planet will be untouched by the damaging effects of global warming"

"There needs to be a massive shift away from fossil fuels and towards renewable energy"

Global impacts identified within the assessment include drought, sea level rise, more extreme weather, visible impacts on the natural world, impacts on human health and concerns about food security.

Scottish Impacts

Scotland is getting warmer and wetter. Average temperatures have increased by just below 1.0 degree Celsius during the period 1910 to 2010. Rainfall has also increased, especially during the winter months in the North and West of the country where in 2017 there is a 67 – 69 percent increase above 1961 levels.

This increased rainfall has led to more flooding events and landslide problems in some parts of Scotland. The warmer and wetter conditions are also likely to impact on Scotland's famous wildlife and natural environment.

- Some plant species like **Diapensia, Norwegian mugwort** and **cloudberry** that live on Scotland's mountain tops, may not survive as temperatures increase. Birds such as the **Snow Bunting** may also disappear.
- Species of butterfly which prefer warm weather, such as the **orange-tip** and **peacock butterflies** are already being found further north in Scotland than before.
- Warmer and wetter conditions will bring new risks from diseases carried by ticks, midges and mosquitoes including **bluetongue disease** and **lyme disease**.
- **Invasive non-native species** already cause huge environmental damage and cost the Scottish economy as estimated £500 million per year.
- **Bees** play a vital role in pollinating much of our food but the bee populations are in serious decline and could be further affected by our changing climate.
- **Salmon** populations may also be under threat as a result of loss of spawning bed habitat due to an increase in flash flooding.
- **Soil quality** may be compromised both as a result of increased rainfall in the winter and drier warmer summer weather.

Many organisations, including the Scottish Government, the Scottish Environmental Protection Agency (SEPA) and research institutes are all working together to help Scotland reduce carbon dioxide emissions and mitigate against the damaging impacts of climate change.

Climate Change and Scottish Impacts

Activity

Work with a partner and choose two of the following topics:

1. Research the possible impacts of climate change on your chosen topics.
2. Prepare a short presentation (5-10 minutes) or write a short article (two or three paragraphs) in order to share your findings.

? Be sure to include relevant data about how changes in weather conditions are affecting species populations or businesses.

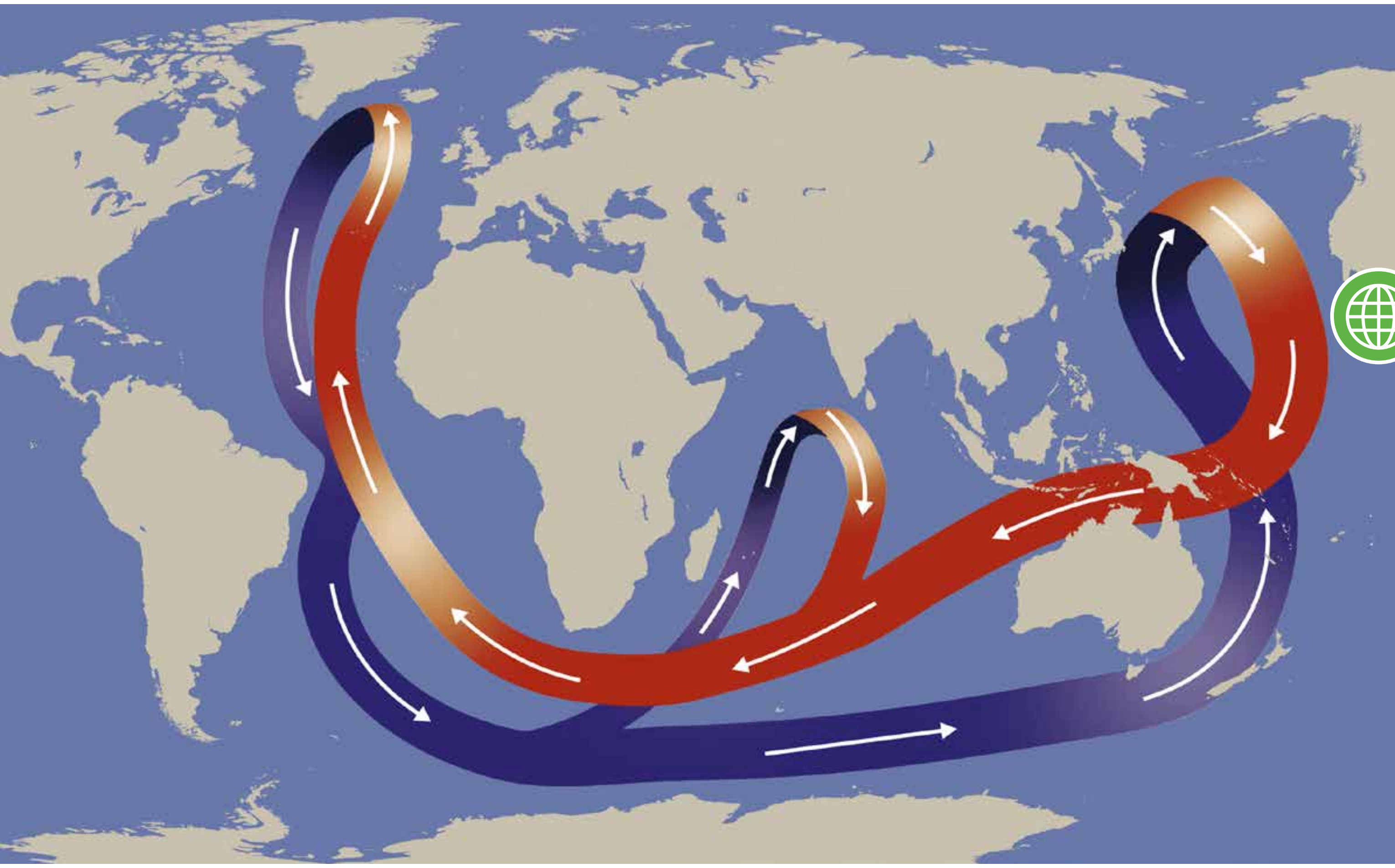
Try and link your conclusions to potential issues for Tourism in Scotland.

Oceanography

The Earth's Oceans

The oceans cover about 70 percent of the Earth's surface and play a vital role in the water cycle and global climate.

Ocean currents caused by wind patterns and differences in temperature and salinity (salt content) also help to distribute heat around our planet. These currents follow established patterns which travel around the globe and are known as the Great Ocean Conveyor Belt. Part of this conveyor includes the North Atlantic Drift which carries warm water from the tropics to the North West of Europe. This current of warm water gives Scotland its temperate climate and keeps us warmer than other parts of the world on the same latitude.

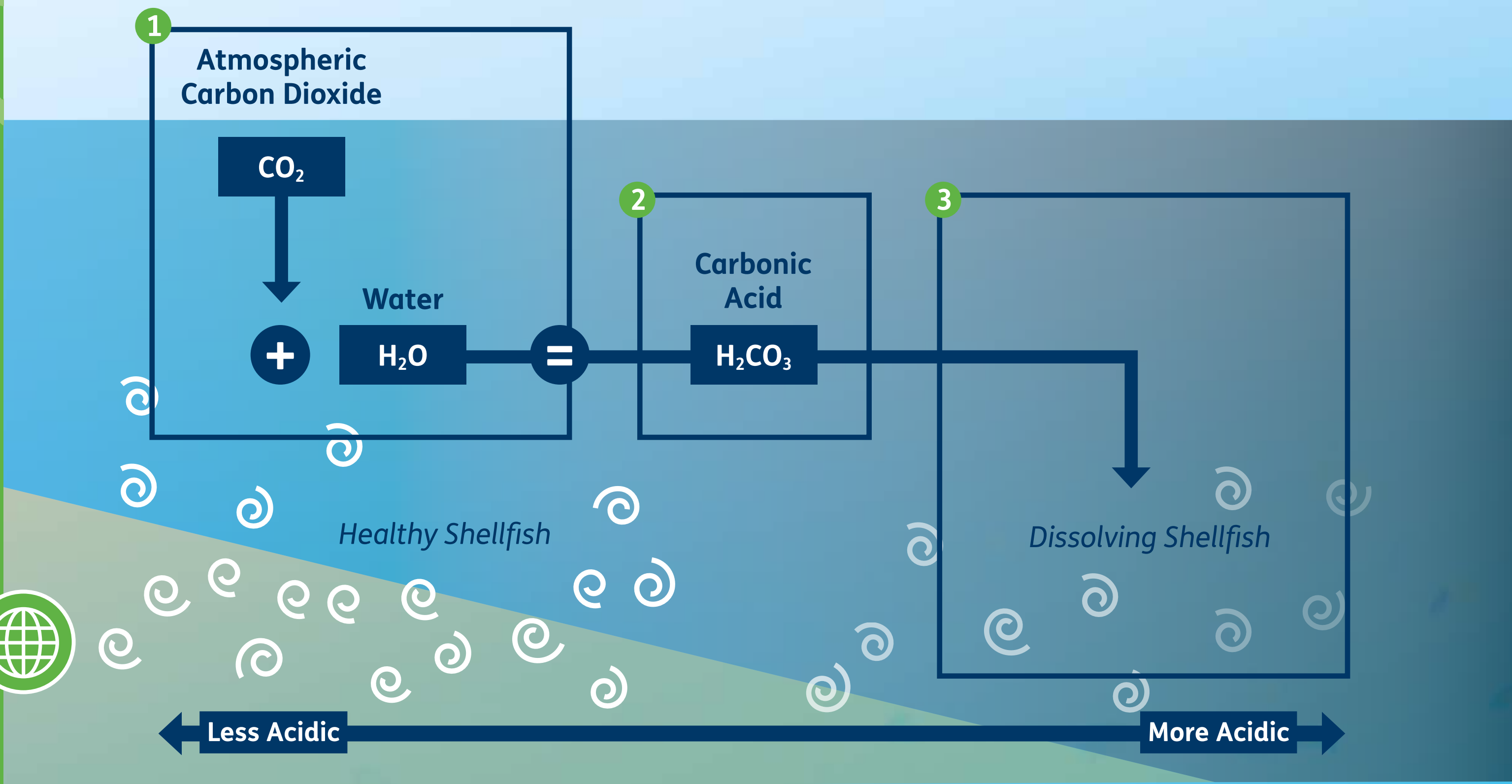


As increasing amounts of carbon dioxide trap more heat within our atmosphere, the oceans also absorb more heat. The impacts of this warming are likely to include an increase in sea temperature and rising sea levels. Furthermore as cold water from the melting Greenland icecaps enters the North Atlantic it may cause a decrease in the strength of the North Atlantic Drift or possibly even a complete shutdown of the current. Computer models suggest that a complete shutdown is unlikely and any cooling produced by a weakening of the current may be offset by the predicted warming due to climate change. Nonetheless, Scotland's climate depends on the North Atlantic Drift and any changes will have to be monitored and researched closely.

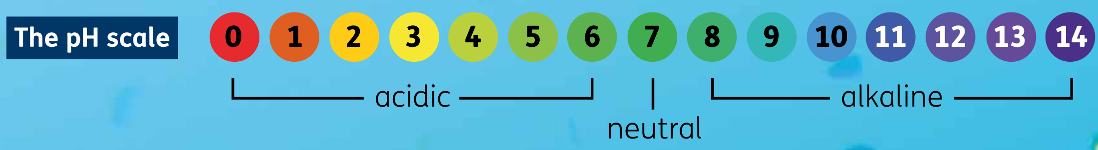
Ocean Acidification

As well as absorbing heat, the oceans also help to reduce climate change by storing large amounts of carbon dioxide. However, increasing levels of dissolved carbon are now altering the chemistry of seawater and making it more acidic.

When carbon dioxide dissolves in the ocean, carbonic acid is formed. This leads to higher acidity, mainly near the surface, which has been proven to inhibit shell growth in marine animals and is suspected as a cause of reproductive disorders in some fish.



On the pH scale, which runs from 0 to 14, solutions with low numbers are considered acidic and those with higher numbers are alkaline. Seven is neutral.



Over the past 300 million years, ocean pH has been slightly alkaline, averaging about 8.2. In 2017, the pH is around 8.1, a drop of 0.1 pH units, representing a 25-percent increase in acidity over the past two centuries.

These ocean impacts could adversely affect many of Scotland's marine ecosystems, some of which bring direct benefits for Tourism.

Scotland's magnificent landscape and wildlife continue to be a major benefit for the Tourism industry in the 21st Century. Understanding more about how our landscape, weather and climate has developed along with the environmental challenges we now face, will help all of us protect Scotland's natural assets for the future.

Ocean Acidification Experiment

Activity

The Scottish Government has identified Fishing and Aquaculture as one of the 4 sub-sectors within Scotland's Food and Drink Industry.

This covers both marine and freshwater activities. Scottish shellfish play an important role within this sector and even slight changes in seawater chemistry could impact on shellfish in the longer term.

Our oceans absorb about 30% of all man-made carbon dioxide. It does this via a chemical reaction that produces carbonic acid in water. In 2017, the oceans have a pH of 8.1. Although this is an alkaline value, the pH has reduced from 8.2 and is predicted to reach 7.8 by the end of the 21st Century. Consequently, our oceans pH is dropping at a rate not experienced by marine animals for many millions of years and is already having an impact on some ocean species.

The impact of acid on shells can be investigated with a simple experiment using vinegar – a household acid - and an egg:

1. Place an egg in a plastic beaker.
2. Pour some household vinegar over the egg until the plastic beaker is quarter filled. Add water until the beaker is almost full and the egg completely covered. Place some cling-film over the cup to contain the vinegar smell.
3. Leave for 24 hours.
4. Pour away the water/vinegar solution and place the egg on a paper towel. Gently scrape the shell and assess how easy it is to remove.

This experiment uses a strong acid to quickly highlight the destructive effect an acidic solution can have on shells. Our oceans are not turning into vinegar. However, because very small changes in pH can affect the strength and development of shell creatures, especially during their early life cycle, ocean acidification is a major concern. The UK Ocean Acidification Research Programme is currently monitoring our in-shore waters and researching the impact on several local shellfish and marine creature species.

Ocean Acidification Research Activity

Activity

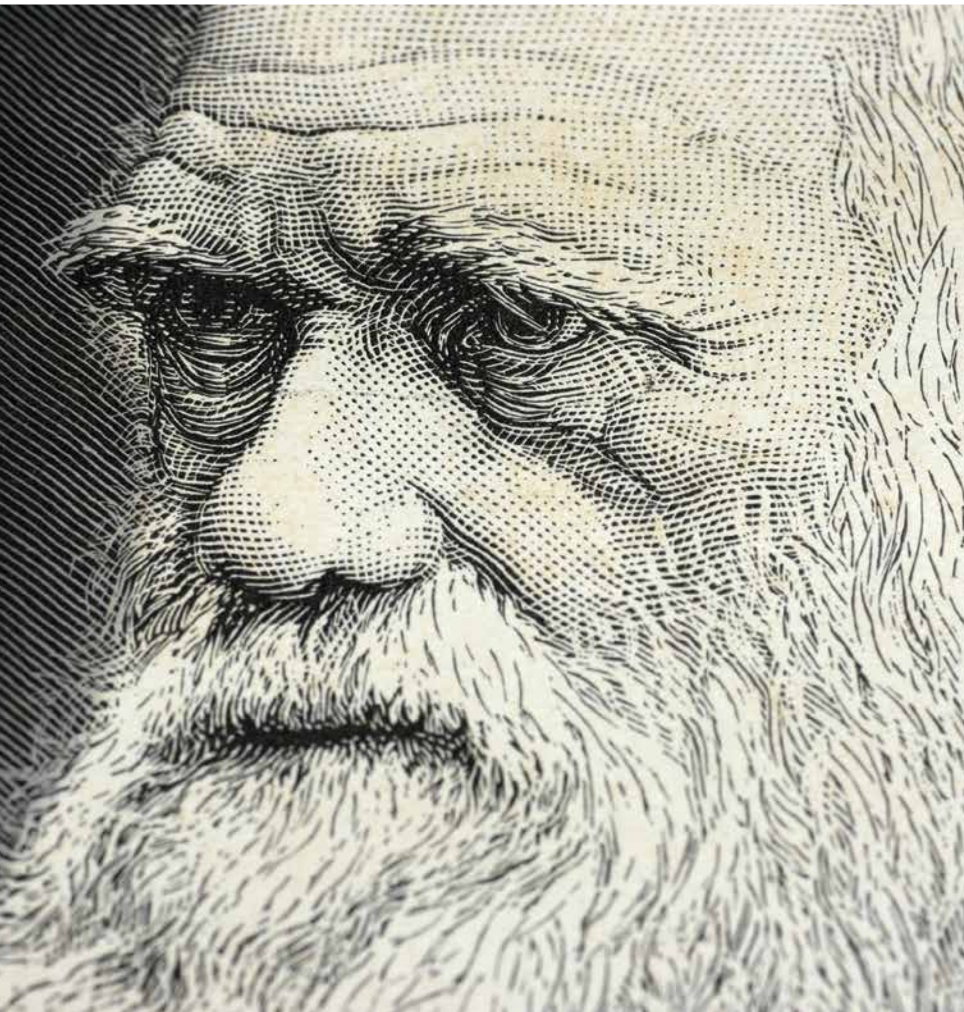
Many organisms that form the basis for the marine food chain may be affected by ocean acidification.

Scientists are concerned that ocean acidification will disrupt the food chain for a variety of marine animals, and therefore increase the impact through-out the oceans eco-systems.

Research marine food chains and find 2 examples which support these concerns.

Hint – what do whales or dolphins eat and will their food be affected? Does ocean acidification affect coral reefs and the animals that live there?

Life Sciences



"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change."

Charles Darwin

The field of Life Sciences is defined as the study of all living things, including their organisation, their environment and their relationships to each other.

Research in this area of science also helps in improving our quality of life and has applications in health, agriculture, medicine and the pharmaceutical and food science industries. Scotland is a world leader in many areas of Life Sciences and this in turn has led to a successful Life Sciences industry sector with over 640 organisations and more than 32,000 employees. (Scottish Life Sciences Strategy 2011 – Life Sciences Scotland).

This unit will investigate a range of biological concepts relating to living things, the human body, DNA, micro-organisms and health technologies. Learners will have the opportunity to increase knowledge around the Life Sciences while also developing an understanding about the importance of health and well-being and some of the ethical challenges within the sector.

Learn about:

Living Things p52

Human Body Systems p56

Health Technology p58

DNA p63

Micro-Organisms p66

Living Things

Our world contains living, non-living and once living things. Plants and animals are examples of living things while metals and plastics are examples of non-living things. Paper is an example of a once living thing, since it is made from trees which used to be alive.

This unit will focus on living things, their characteristics and how they can be classified into different groups.

Life Processes

Scientists use 7 characteristics or life processes in order to determine whether something is living or not. These processes are:

Movement – all living things move in some way or another from animals walking to find food, to plants moving to face the Sun.

Reproduction – all living things produce young. Humans give birth to babies, birds lay eggs and plants can make seeds which can then grow into new plants.

Sensitivity – all living things respond and react to changes in their environment such as light, heat and touch.

Nutrition – all living things take in and use food.

Excretion – all living thing need to get rid of waste in order to survive.

Respiration – all living things use this process to release energy from food.

Growth – all living things grow from a young state to adult size.

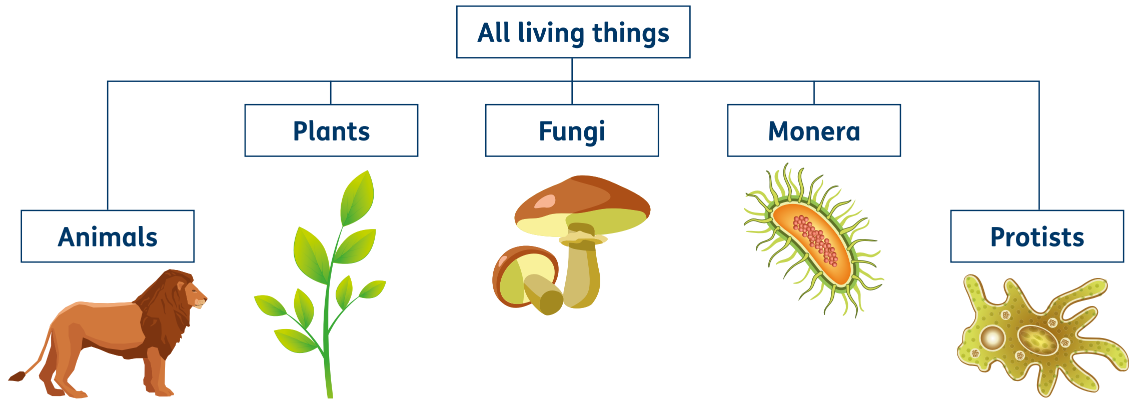
A useful way to remember these 7 Life Processes is with the term MRS NERG which is formed by using the first letter of each process.

Classification of Living Things

Scientists estimate that there approximately 9 million different types, or species of living things on Earth. These living things, which satisfy the 7 life processes already identified, are sub divided into groups depending on shared characteristics.

This makes it easier for scientists to study them and each group can then be further divided into smaller groups based on more detailed similarities. Putting different species into different groups according to their characteristics is called classification. The first major division of living things within the classification system is to sort them into one of five kingdoms. These are based on what a living thing's cells are like and how they obtain food. The cell is the basic unit of life. It is the smallest part of a living thing and carries out actions necessary to keep it alive. Some living things are made up of a single cell, like bacteria, while others, like the human body are made up of many millions of cells.

The Five Kingdoms of living things



Animals – consisting of multi-celled living things that cannot make their own food but feed on other living things. Corals, insects, birds, reptiles, fish and human beings are all examples of animals. The animal kingdom can be further classified in lots of different ways.

Plants – consisting of multi-celled living things that contain chlorophyll and make food through photosynthesis. Examples include moss, flowering plants, seaweed and trees.

Fungi – consisting of multi-celled living things which can absorb food from living or once living things. Examples include mushrooms, mould and yeast. Fungi can be useful – penicillin is made from mould, and yeast is used in baking.

Monera – consisting of simple single-celled living things with no nucleus. The nucleus is usually referred to as the 'brains' of a cell and contains important genetic information. But in these single celled living things, this information is contained within the watery gel inside the cell and it is this characteristic that makes them different from any other form of life. They can live in every habitat on Earth, including the deepest oceans and artic ice. Examples are bacteria like E.coli and some types of algae.

Protists – consisting of single celled living things with a nucleus. They are more complex than Monera single celled living things and are mostly found in water. Examples include amoebas, which are best known for having the ability to change their shapes.

A common classification within the Animal Kingdom is to sub-divide animals into vertebrates and invertebrates. Vertebrates have a backbone, and invertebrates do not have a backbone.

Classification is a useful technique to help scientists organise the huge number of different types of living things. It also allows researchers to make links between different species which leads to a deeper understanding of their characteristics.

Evidence also shows that many living things have had to evolve (change over time) to survive and avoid extinction. Extinction is the term used to describe the loss of living things. Fossils can be used to understand how the living things of today have evolved, and how they relate to living things of the past. The long neck of a giraffe, the high speed of a running cheetah and the camouflage of a chameleon have all evolved in order for these living things to survive.

Life Processes and Classficiation

Activity

Scientists use 7 characteristics or life processes to decide whether something is living or not.

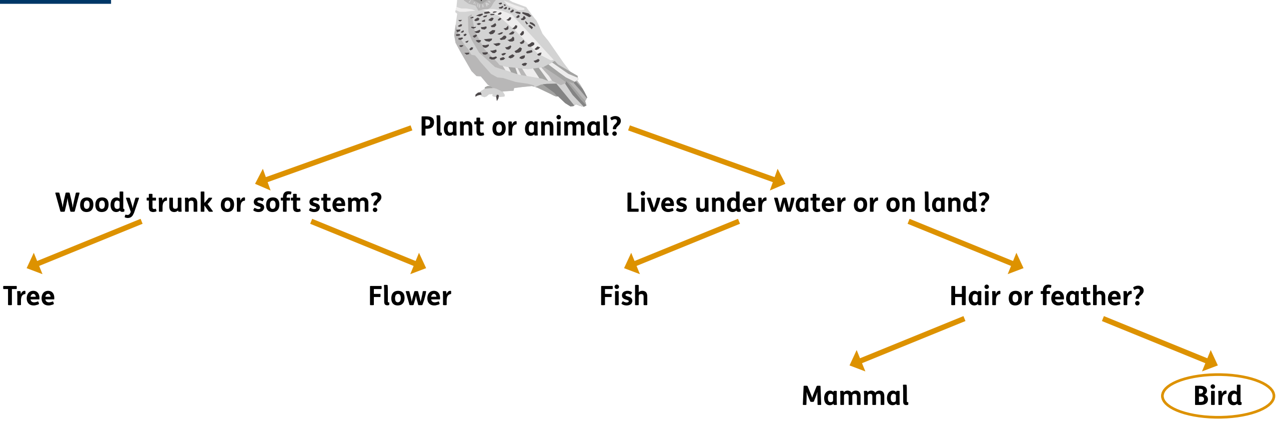
1. Match the 7 life processes with the correct statement.

Movement Sensitivity Nutrition Growth Respiration Reproduction Excretion

Life Process	Statement
	All living things use this process to release energy from food.
	The act of getting rid of waste in order to survive.
	Animals do this in order to find food.
	Birds lay eggs to carry out this life process.
	All living things need food.
	Responding and reacting to environment changes e.g. light, heat.
	Changing from a young state to adult size.

Classification is a useful technique to help scientists organise the huge number of living things into different groups depending on shared characteristics. This is often represented in the form of a branching or 'dichotomous' key. Dichotomous means divided into 2 steps, so this type of key always gives two choices at each step, as shown in figure 1.

Figure 1

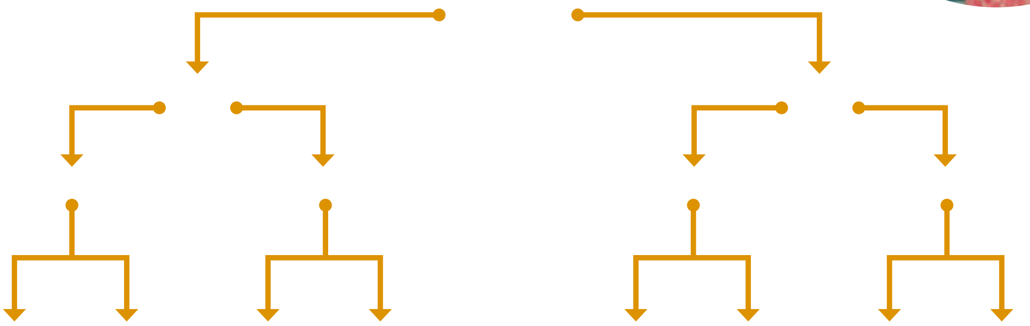


Group Activity

Work in a group to construct a variety of dichotomous keys.

1. Produce a key that will help sort a pack of liquorice allsorts into different groups with shared characteristics.

Hint – questions like ‘is it round?, does it have more than one colour? May be helpful.



2. Produce a key that will sort a group of friends into different sub-groups depending on different characteristics like male/female, eye colour, hair colour. Use your key and check if it needs any further modifications or additional steps.
3. Choose either the Plant or Animal kingdom and produce a key that will help produce a useful set of sub-groups. Think carefully about the questions at each step within your key and identify examples within each grouping.

Biodiversity

Biodiversity is defined as the variety of living things that is found in a particular place. The greatest variety of living things on our planet is found in the tropical rainforests.

Biodiversity is considered important because all life depends on it. The United Nations estimates that at least 40% of the world’s economy and 80% of the needs of the poor come from biological resources. It is generally accepted that greater biodiversity provides greater opportunities for economic development, medical advances and solutions to global challenges such as climate change.

Human Body Systems

Fish, reptiles, birds, amphibians and mammals are different sub-groups of vertebrates within the Animal Kingdom. Human beings are part of the mammal sub-group.

Mammals' characteristics include being able to suckle their young and having hair or fur on their bodies.

The human body is a complex biological system which is made up of several different systems that depend on each other and contribute to our health and well-being.

Body systems

The Skeletal System

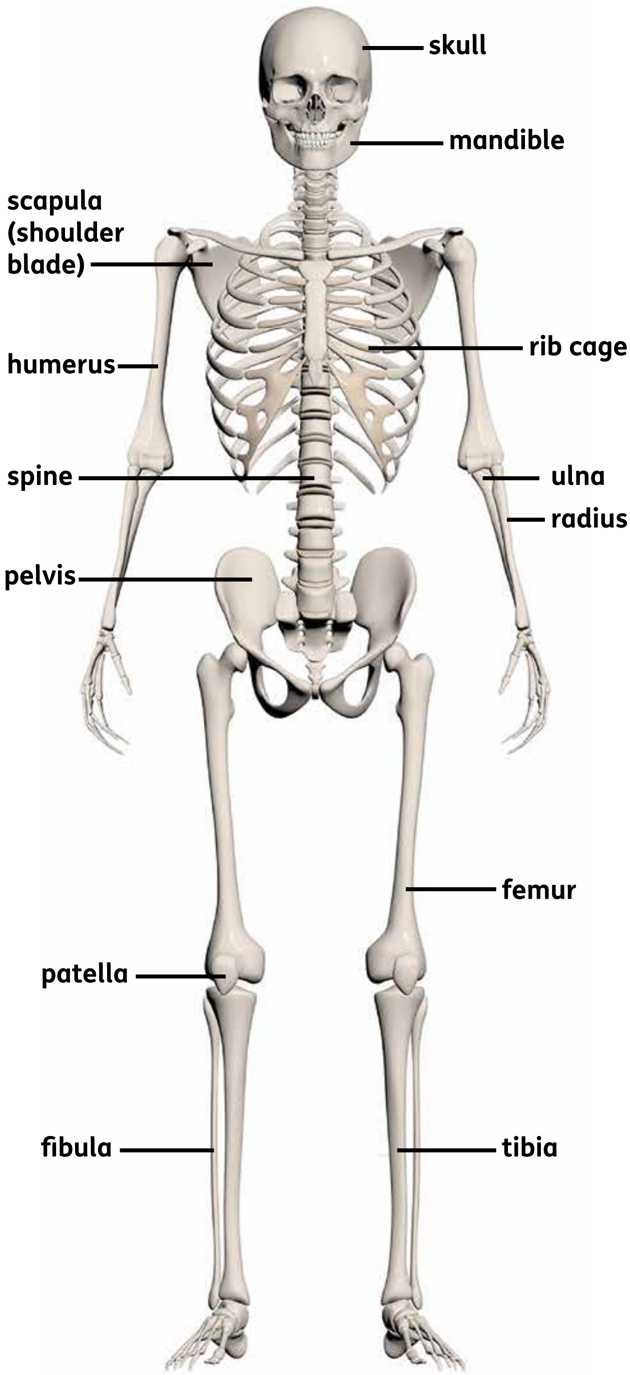
The skeleton supports and protects the human body and includes bones, ligaments and tendons. There are 206 bones within the system. The longest is the thigh bone or femur, and the shortest can be found within the middle ear. Some of the bones contain marrow which is essential for the production of red and white blood cells.

The Respiratory System

The respiratory system allows the human body to breathe. It includes the nose, mouth and windpipe. The system carries air in and out of the lungs and also includes the diaphragm, the rib-cage and the surrounding muscles.

The Digestive System

This system includes the mouth, oesophagus (food pipe), stomach, pancreas, liver and intestines. It breaks down food into soluble nutrients firstly, by breaking the food into tiny pieces and then using a variety of chemicals so nutrients can be extracted and sent around the body.



The Cardiovascular System

The cardiovascular system works with every other system as it transports blood around the body. The blood carries food, heat, oxygen and hormones to various locations within the human body. It also removes waste substances like carbon dioxide. The system includes the heart, arteries, veins and capillaries. Arteries carry blood away from the heart, while veins carry blood back to the heart and the tiny capillaries carry blood through the body's organs.

The Nervous System

The nervous system is a communications system which collects and transfers information by using electrical signals between every part of the body and the brain. The central nervous system consists of the brain and the spinal cord and is connected to the sensory organs like the skin, nose, eyes and ears.

Other Body Systems

The Muscular System helps the body move.

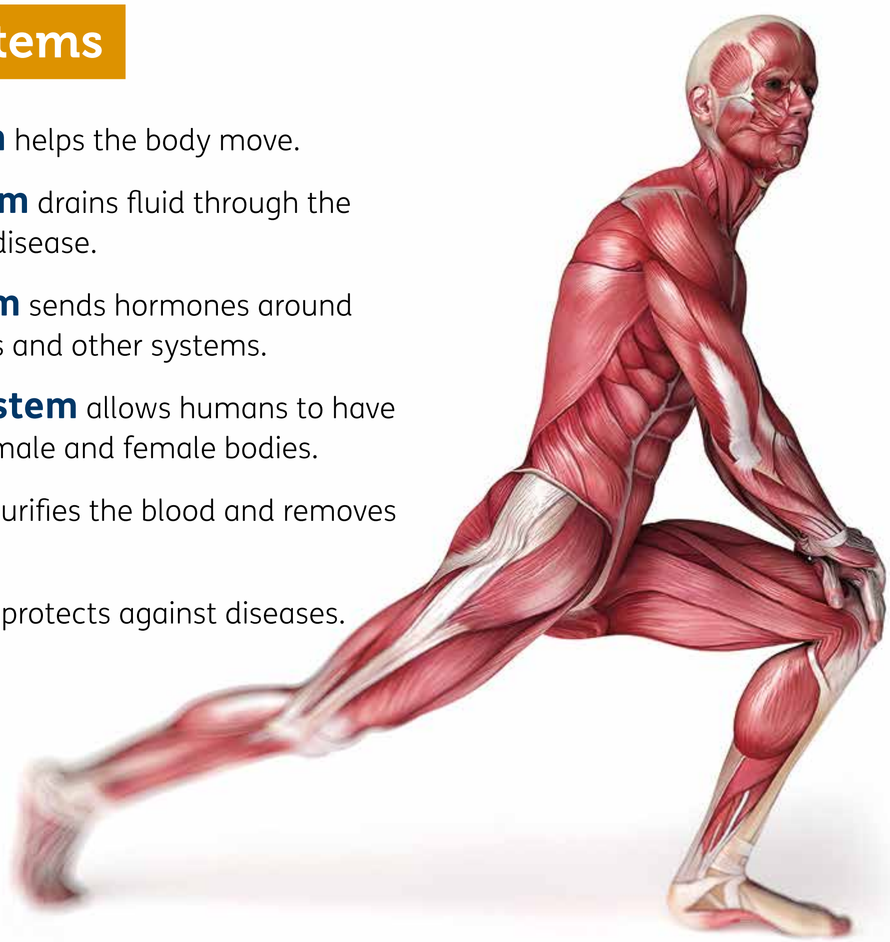
The Lymphatic System drains fluid through the body and protects against disease.

The Endocrine System sends hormones around the body to regulate organs and other systems.

The Reproductive System allows humans to have children and is different in male and female bodies.

The Urinary System purifies the blood and removes waste from the body.

The Immune System protects against diseases.



All of these biological systems are essential for our health and well-being.

Today, thanks to advances in science and technology, many diagnostic tools exist to help doctors monitor the state of our body systems and draw conclusions about our health. Research has also led to the manufacture of many life-saving technologies that allow complex operations like organ transplants, the attachment of artificial limbs and the use of lasers to remove cancerous growths. Scotland is a major contributor in the field of health technologies with cutting-edge research taking place in our universities and life sciences industries.

Health Technology

Scotland has a proud history in developing diagnostic technology. Both ultrasound and MRI (Magnetic Resonance Imaging) were invented here.

Ultrasound was developed by Professor Ian Donald at Glasgow University in the 1950s and involves bouncing "ultrasonic" sound waves which are above the audible range of human hearing, at body structures or tissues, then detecting the echoes that bounce back. This type of technology is now common place in hospitals around the world.

Magnetic Resonance Imaging (MRI) is a type of scan that uses strong magnetic fields and radio waves to produce detailed images of the inside of the body.

In 1980, Professor John Mallard and his research team at Aberdeen Royal Infirmary were the first to obtain a clinically useful image of a patient's internal tissues using MRI. Mallard's team then went on to make the technological advances that led to the widespread introduction of MRI.

Monitoring Health

Today technology continues to play an increasingly important role in medicine and health-care. Doctors have a vast of array of equipment for monitoring health and diagnosing medical conditions.

Heart rate and blood pressure are two of the most common measurements taken at GP medical centres. The adult heart at rest ranges from 60 to 100 beats per minute. Athletes usually have a slower heart rate because their training exercises the heart muscle. Many modern watches, such as a Fitbit, come with a heart rate monitor which can measure the electrical signals transmitted through the heart muscle in order for it to contract.

Blood pressure is a measure of the force of the blood flowing through blood vessels after a heartbeat. Doctors use a sphygmomanometer (commonly referred to as a sfig) to assess blood pressure and gain an insight into the health of the heart. High or low blood pressure could lead to recommended changes in diet or exercise, or possibly the taking of medication to restore blood pressure to healthy readings.

Doctors use X-rays to see inside our bodies and diagnose damage to bones. They can also look inside our bodies using an instrument called an endoscope. An endoscope is a flexible tube with a light source and a tiny camera that can be fed into internal organs like the intestines and stomach to investigate the health of these organs by taking photographs. Endoscopes can also have surgical instruments attached to them for the purpose of key-hole surgery which is less invasive and allows for quicker recovery times.

Blood testing also allows doctors to detect medical conditions and potential health disorders. Blood-glucose monitoring kits allow patients with diabetes to monitor their own glucose (or sugar levels) in their body at any time of day. This sort of technology helps people to take responsibility for and care for their own health and hopefully reduce the risk of diabetes related complications such as eye and nerve damage.

Monitoring Health

Activity

Monitoring heart rate

The adult heart at rest normally ranges from 60 – 100 bpm (beats per minute).

This is also commonly referred to as a pulse rate. This can vary, depending on what you're doing. For example, your heart rate will be slower if you're sleeping and faster if you're exercising. Caffeine, alcohol and stress can also cause an increase in heart rate.

Apparatus:

- Stopwatch or watch with second hand
- Paper and pen
- Space to exercise

Step 1: Finding your pulse

You can find your pulse in places where an artery passes close to your skin, such as your wrist or neck.

To find your pulse in your wrist:

- hold out one of your hands, with your palm facing upwards and your elbow slightly bent
- put the first finger (index) and middle finger of your other hand on the inside of your wrist, at the base of your thumb
- press your skin lightly until you can feel your pulse – if you can't feel anything, you may need to press a little harder or move your fingers around

To find your pulse in your neck, press the same two fingers on the side of your neck in the soft hollow area just beside your windpipe.

When you find your pulse, use your stopwatch to count the number of beats you feel for one full minute.

___________________________ beats per minute.

This is your resting heart rate.

Continued on page 60 →

Monitoring Health - *continued*

Activity

Step 2: Measuring pulse after exercise

This is best done with a partner who can help with timing and recording of results.

In order to increase your heart rate, gently jog on the spot for at least 2 minutes, then repeat step 1 and measure your pulse in order to record your increased heart rate. Get your partner to write down the result while you continue to monitor your pulse every minute for 5 minutes.

Heart rate after exercise: ___________________________ beats per minute

1 minute later: ___________________________ beats per minute

2 minutes later: ___________________________ beats per minute

3 minutes later: ___________________________ beats per minute

4 minutes later: ___________________________ beats per minute

5 minutes later: ___________________________ beats per minute

?

Has your heart rate returned to its resting rate?
If not, keep recording until it does so. How long does this take?

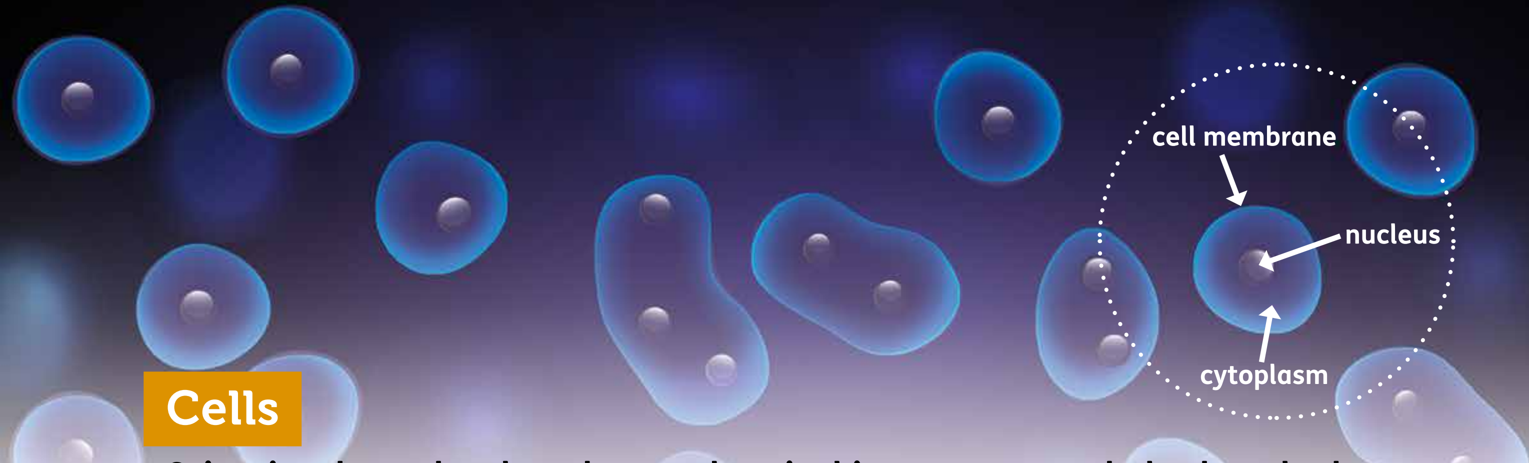
Choose suitable scales and plot a graph of your heart rate (y axis) against time (x axis).

The time it takes for your heart rate to return to its resting value after exercise is called your heart's 'recovery time'.

Health and medical technology inventions

Technology continues to play an increasingly important role in medicine and healthcare. Doctors and nurses now have a vast selection of equipment for monitoring health and diagnosing medical conditions.

Research a range of medical and health technologies and decide, in your opinion, what is the most significant invention of the last 150 years. Write a paragraph or give a short talk to justify your choice with some evidence, like how many lives it has saved, or how lives have been improved, or how commonplace this technology now is in hospitals. If you are using the internet try and use a variety of sources to double check your evidence.



Cells

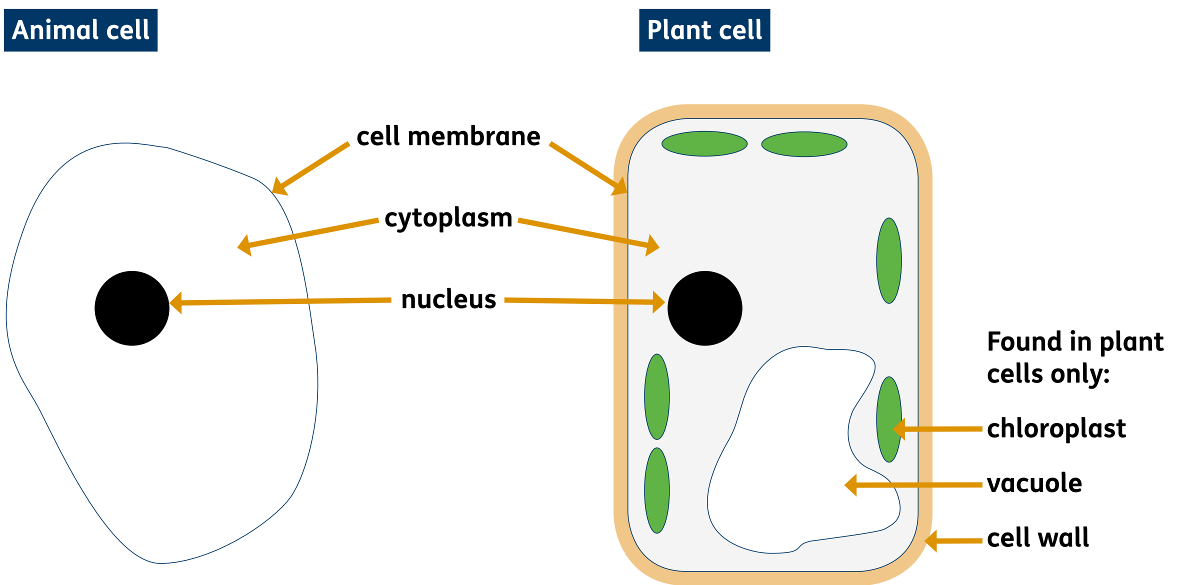
Scientists have developed several optical instruments to help them look more closely at different parts of the body. One of the most commonly used instruments is the microscope. A microscope can be used to view cells. The cell is the basic unit of life. It is the smallest part of all living things and carries out actions necessary to keep it alive. Some living things are made up of just a single cell, like bacteria, while others, like the human body, are made up of many millions of cells.

Huge numbers of different types of cells exist and they each have different appearances but they also have some things in common.

Most cells have a thin covering around them called a cell membrane. Inside the cell is a watery gel called the cytoplasm where most of the cell's chemical reactions take place. Within the cytoplasm is usually found a cell nucleus which contains genetic information within structures called chromosomes. It's the nucleus which controls the cell's activities and function.

One of the main differences between animal and plant cells is the addition of structures within the cytoplasm of plant cells called chloroplasts. Photosynthesis - the process used by plants to convert light energy into chemical energy that helps the plant grow - takes places inside the chloroplasts. Some plant cells may also have an area inside the cytoplasm where the plant stores water and salts. This structure is called a vacuole.

All plant cells also have an outer wall which surrounds the cell membrane helping to the make the cell more rigid than an animal cell. The cell wall is made from a substance called cellulose. We use cellulose in a number of commercial applications from cellophane to stabilisers in processed foods.



All About Cells

Activity

Use the words and terms in the word box to complete the information about plant and animal cells.

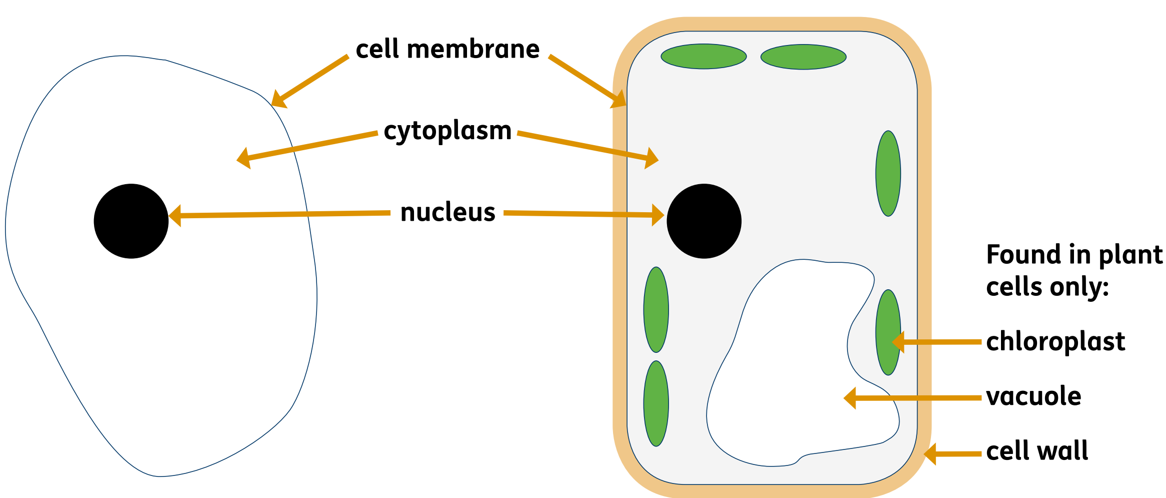
cell wall	cytoplasm
cellulose	chloroplasts
chromosomes	vacuole
nucleus	cell membrane

The cell is the basic unit of life. It is the smallest part of all living things and carries out actions necessary to keep it alive. Most cells have a thin covering around them called a ________________. Inside the cell is a watery gel called the ________________ where most of the cell's chemical reactions take place. The cell ________________ is usually found within this watery gel. This normally contains genetic information within structures called ________________.

One of the main differences between animal and plant cells is the addition of structures within plant cells called ________________ where photosynthesis takes place. Some plant cells may also have an area within the cell which stores water and salts called a ________________.

All plant cells also have a ________________ which helps to the make the cell more rigid than an animal cell. This is made from a substance called ________________.

Animal cell **Plant cell**



DNA

DNA, or deoxyribonucleic acid is a molecule that carries the genetic instructions used in the growth, development, functioning and reproduction of all known living things. It is mainly found in the cell nucleus. The discovery and subsequent extraction of DNA has led to several medical advances, especially within agricultural sciences and the field of forensic medicine.

DNA contains just a few chemical elements, namely carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and phosphorus (P).

DNA is the essential ingredient within our genes. Genes dictate our appearance, like eye colour and height, and also tell cells how to make a specific protein that then can be used by the cell to perform certain functions so living things can grow, and survive.

Thousands of genes joined together in a certain order make chromosomes.

All living things have a characteristic number of chromosomes. Human beings have 46 chromosomes arranged in 23 pairs with 30, 000 genes between them. Polar bears have 74 chromosomes, a lion has 38 and barley has 14.

To summarise, all living things have a certain number of chromosomes. Chromosomes are made of thousands of genes, which in turn are made of DNA.

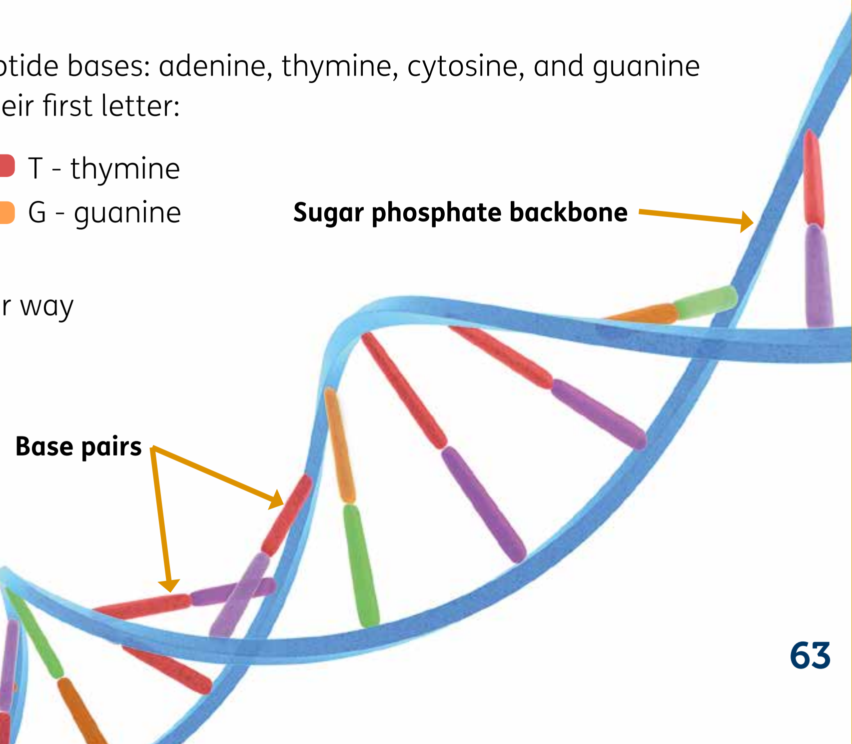
The Structure of DNA

DNA has a famous double helix structure that was first discovered by James Watson and Francis Crick at Cambridge University in 1953. They subsequently were awarded the Nobel Prize for Medicine in 1962.

The structure looks like a ladder that has been twisted into a spiral. The outside of the ladder is made from sugar phosphate and each rung in the ladder is held together by a pair of chemicals called nucleotide bases.

There are four different types of nucleotide bases: adenine, thymine, cytosine, and guanine and they are usually represented by their first letter:

A - adenine
T - thymine
C - cytosine
G - guanine



The bases always pair up in a particular way – thymine with adenine and guanine with cytosine – and the way these base pairs are then arranged within the DNA of a living thing is called its genetic code.

The code carries a genetic map and contains the plan for everything about the living thing including whether it will be a human, a polar bear, a plant or a bacteria. The genetic code can be found in every cell of a living thing.

The discovery of the structure of DNA has given scientists a greater understanding into the way that living things work, and develop and grow. This has led to further research in the fields of molecular biology and genetics including the Human Genome Project.

The Human Genome Project

"The Human Genome Project is the largest international collaboration ever undertaken in biology. Between 1990 and 2003, thousands of scientists world-wide undertook the immense task of sequencing the 3 billion bases of genetic information that resides in every human cell."
(The Wellcome Trust)

The success of the Human Genome Project meant that for the first time, scientists were able to create a map that showed the exact location of every gene on human chromosomes. One of the main aims of the project is to use this information to help improve human health by fixing faulty genes that can pass on diseases and certain cancers. Through gene therapy, it is hoped that scientists will be able to remove faulty genes from chromosomes and replace them with normal copies to help prevent genetically inherited diseases. However, altering the genetic make-up of living things can also prove controversial.

DNA and Animal Cloning

Dolly the sheep was born in 1996 in Edinburgh and was the first mammal to be successfully cloned.

Scientists took an egg cell from the ovary of an adult sheep and removed its nucleus. They then took the nucleus from an udder cell in a donor sheep and inserted it into the empty egg cell. The cell then developed using the genetic information from the donated DNA. Dolly was genetically identical to the donor sheep. This technique may in the future allow desirable features from certain animals, like a cow that produces lots of milk, to be duplicated many times. However, some people view this as ethically questionable and have concerns about the same procedures extending to the cloning of animals.

DNA and Genetically Modified Foods

Scientists are also researching the applications of gene modification on plants and crops.

By inserting genes for drought resistance it is hoped to increase food production in dry countries around the world, often in areas prone to famine. Similarly genes for disease resistance can help to reduce the use of pesticides, and increase crop yield, especially as the human population continues to increase. However many people are against the idea of GM crops and have concerns that cross-pollination between GM crops and wild plants may impact biodiversity.

Discoveries involving DNA have also made considerable impact in the fields of cancer research, genetically modified medicines, DNA fingerprinting and forensic science. However, at the same time, many of these advances also give rise to important ethical questions for both scientists and society to address.

DNA and its applications

Activity

Complete the following paragraphs about DNA using the terms below.

instructions	**humans**	**function**
deoxyribonucleic acid	**chromosomes**	**molecule**
double helix	**nucleus**	**genes**

DNA is a _________________ that is essential for life. It is in the shape of a _________________ and carries the genetic _________________ that tell our bodies how to develop and _________________. DNA stands for _________________ and is mainly found in the cell _________________.

_________________ are short sections of DNA and influence how we look and how our body works. Thousands of genes join together to make _________________. All living things have a characteristic number of chromosomes. _________________ have 46 chromosomes arranged into 23 pairs.

As the human population continues to increase, it is predicted that this may lead to global food shortages. Scientists have proposed to introduce the gene for drought resistance into some crop plants' genome in order to grow genetically modified (GM) plants in dry countries and increase food production in areas with shortages.

? Do you find the idea of eating GM crops unacceptable?

Research both sides of the arguments for and against GM crops to investigate whether this leads you to change your mind.

Take part in a debate with fellow learners and share your views.

Micro-Organisms

The term micro-organism is used to describe tiny, microscopic living things. They are found everywhere on Planet Earth from the highest mountains to the deepest oceans and can also be found throughout the human body. The scientific study of micro-organisms is called microbiology.

Micro-organisms impact on almost every aspect of our daily lives. Many provide benefits, but some micro-organisms also present serious challenges.

Benefits of Micro-Organisms

Micro-organisms play an essential role in the cycle of life. They break down and recycle the nutrients of once living things which allows the release of nitrogen into the air. Only certain groups of bacteria can then capture nitrogen from the atmosphere and convert it into the sorts of nitrates which are essential for plants to manufacture food. Plants in turn then provide food for all other living things, including humans.

The food and drinks industry makes frequent use of the micro-organism yeast – a single-celled fungus which can turn sugar into carbon dioxide, alcohol and heat. The carbon dioxide can make bread rise while alcohol is used in the brewing process.

Micro-organisms are also used by biotechnology companies in the production of antibiotics. Antibiotics are substances that kill bacteria or prevent their growth. The first antibiotic, penicillin, was discovered by the Scottish scientist Alexander Fleming in 1928. Since then, many other antibiotics have been developed. However, over time, bacteria can become resistant to certain antibiotics. This occurs when a small minority of the bacteria population is not affected by the antibiotic. They survive and reproduce, thus establishing more bacteria that are resistant. To slow down or stop the development of other strains of resistant bacteria it is important to avoid the unnecessary use of antibiotics.

Disease and Illness Causing Micro-Organisms

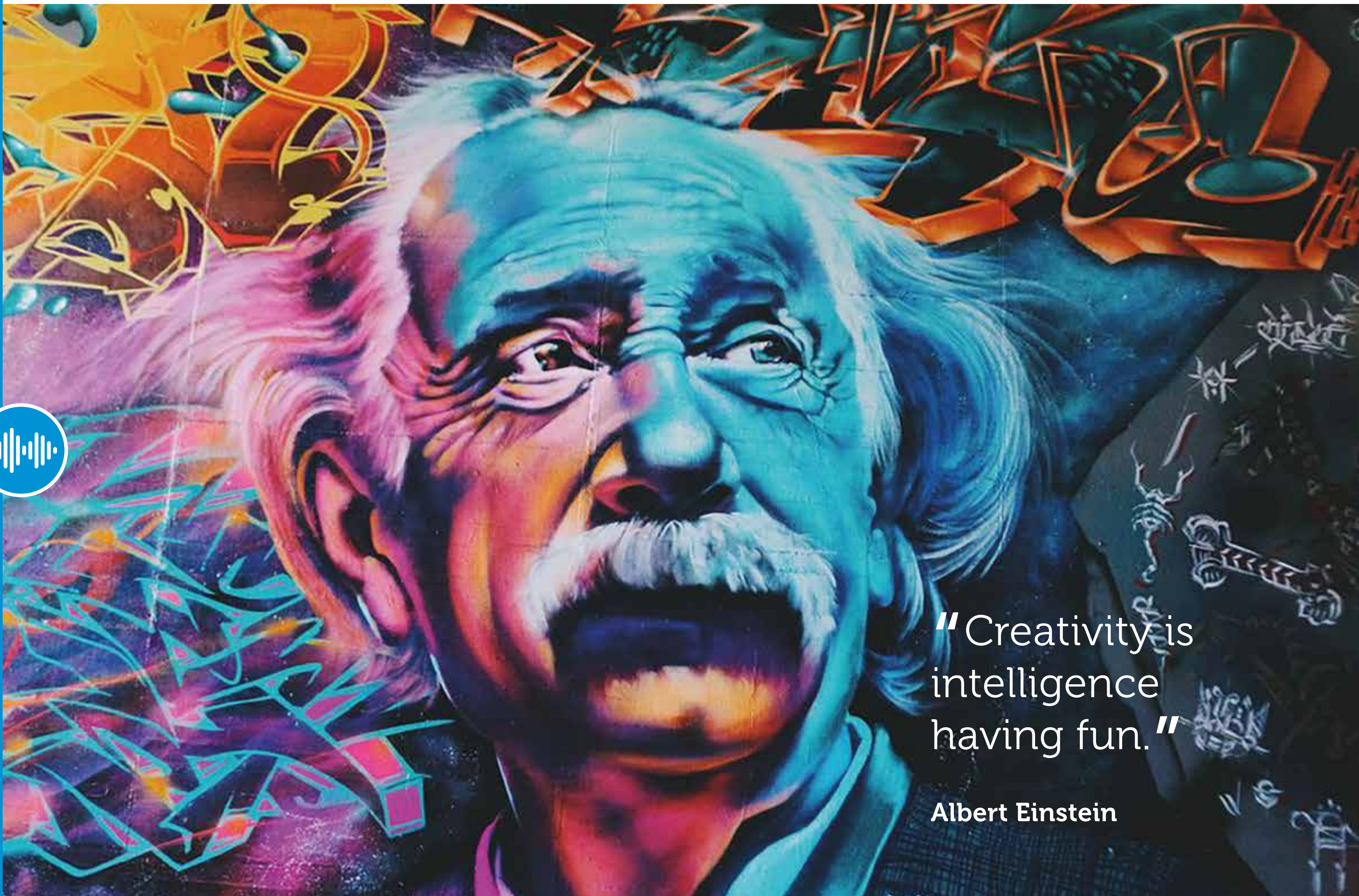
Bacteria, Germs, Viruses, Fungi and Parasites are all micro-organisms that can cause diseases and illnesses including typhoid, meningitis, tuberculosis, cholera and food poisoning. Viruses cause illnesses such as the common cold and chicken pox while fungi lead to infections such as athlete's foot and dandruff.

Understanding the role micro-organisms play in the cause and spread of disease has greatly helped in disease prevention world-wide. Improvements in public water supplies and the control of bacterial contamination within the food industry are two key factors in the reduction of infectious diseases.

And once again, Scotland played an early and important role in this area of science when Joseph Lister pioneered antiseptic surgery at Glasgow Royal Infirmary in 1867. His use of a carbolic acid spray during hospital operations significantly reduced the spread of germs and consequently the likelihood of wound infections. Since then, the control of micro-organism growth has saved millions of lives and developed into a large and profitable industry.

Today, the field of Life Sciences continues to be a major contributor to the Scottish economy. At the same time, scientific research and technological advances in this area are making invaluable contributions to the health and well-being of people in Scotland, and around the world.

Creative Industries



"Creativity is intelligence having fun."

Albert Einstein

The Creative Industries are defined as those that have their origin in individual creativity, skill and talent. In the UK, the sector is generally regarded as being made up of 13 distinct industries, namely – Advertising, Architecture, Art and Antiques, Crafts, Design, Designer fashion, Film, Interactive Leisure Software, Music, Performing Arts, Publishing, Software and Computer Services and TV and Radio.

Many of these areas have close associations and dependence on science and technology. Light, sound and electricity are essential ingredients in Film, Music, TV and Radio. Material science is a major influence on Designer Fashion and Architecture while modern technology underpins Advertising, Design, Interactive leisure software and Computing Services.

Scotland is widely recognised as a creative nation, rich in cultural heritage, while also maintaining an international reputation for excellence in the sciences.

Consequently, the Creative Industries have steadily grown over the past ten years and now contribute £3.7bn to the Scottish economy each year, supporting 71,800 jobs (Scottish Government Creative Industries Growth Sector Statistics, 2015).

The overlap between science and the Creative Industries also presents exciting opportunities for learners to engage with a variety of physics and chemistry concepts set within relevant, modern and interesting contexts.

This unit will investigate the science of sound, the science of light and the science of materials. Concepts will be developed with examples and references from the Creative Industries sector.

Learn about:

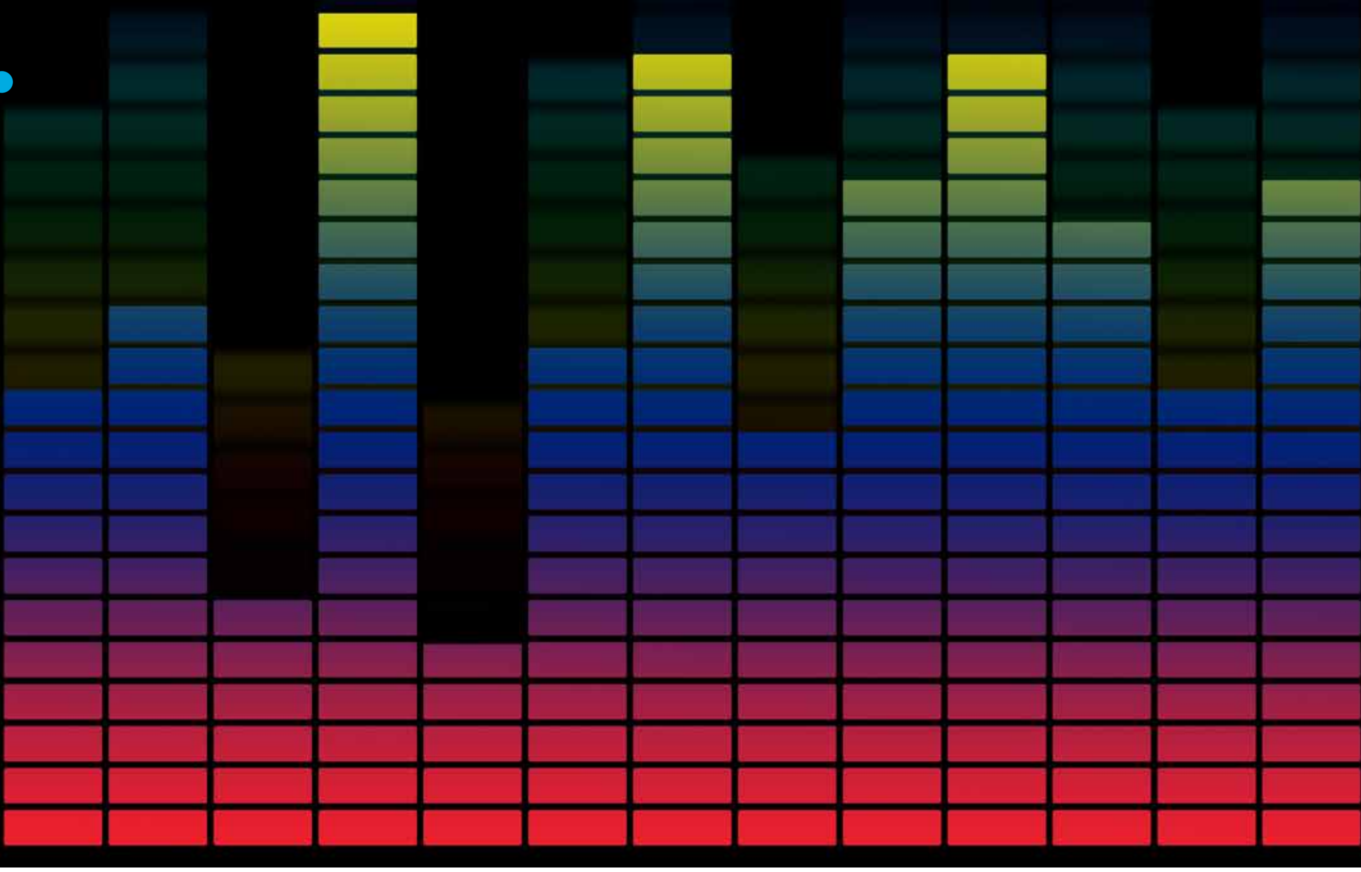
The Science of Sound p70

The Science of Light p75

The Science of Materials p80

The Science of Sound

Sound plays an important role in our lives – from talking at work to listening to music, from hearing a fire alarm, to listening to bird calls in the forest. Humans and animals use sound to communicate in a variety of ways, and the science of sound also plays an essential role in the Creative Industries, especially in TV, Radio, the Performing Arts, Music and computer games.



Sound is produced by vibrations. For example, when someone plucks a guitar this causes a vibration of air particles next to the guitar string. The vibrations then spread from particle to particle causing the sound to travel as a wave until it reaches your ear. The ear takes the vibrations and turns them into electrical signals for the brain to understand.

Sound vibrations can travel through a variety of different materials like metal, water and air. Some materials are better than others at transmitting the vibrations. Sound travels faster in water than in air. However, sound cannot travel through completely empty space (a vacuum) – it needs particles, like air or some kind of 'matter' to vibrate in order to produce the sound. In dry air, the speed of sound is 343 metres per second. We can use the relationship

Distance = Speed x Time

to calculate how long it will take for sound to travel from an open-air concert to a variety of locations at set distances from the stage.

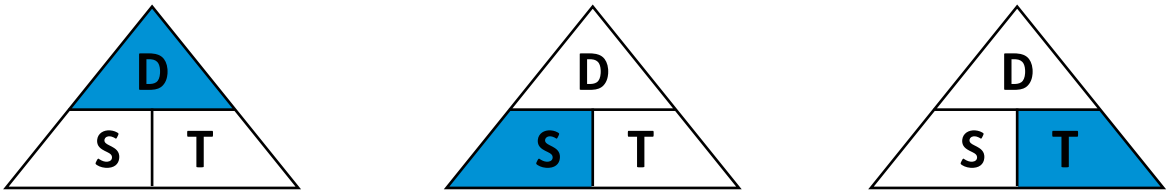
Science and Numeracy

Activity

Distance, Speed and Time are related by the equation:

Distance = Speed x Time

One way to remember this equation is to put the first letter of each term into a triangle.



Distance = Speed x Time

Speed = $\frac{\text{Distance}}{\text{Time}}$

Time = $\frac{\text{Distance}}{\text{Speed}}$

It is also important that, for all of these calculations, the units are consistent. For example, if a speed is given in kilometres per hour, the distance used in the equation must be in kilometres and the resulting time will be in hours. You may need to convert minutes to hours, or metres to kilometres before using the equation.

Using the Distance, Speed, Time equation, solve the following problems:

1. Jenna cycles at an average speed of 7 kilometres per hour. How far will she have travelled if she cycles for 4 hours?

2. Miles runs for 30 minutes at a speed of 10 kilometres per hour. How far has he run?

3. A train travels 250 kilometres in 2 hours. At what speed is it traveling?

4. Daniel drives for 480 kilometres at an average speed of 80 kilometres per hour. How long did this journey take?

5. A lorry drives with a constant speed of 32 miles per hour. How long will it take to drive 24 miles?

6. A plane is travelling at 600 kilometres per hour. How far has it travelled in 6½ hours?

7. Sound travels at 343 metres per second. How far does it travel in 1 minute?

Pitch and Frequency

Pitch is the term used to describe whether a sound is 'high' or 'low'. The pitch of a sound is related to its frequency. This is a measurement of the number of complete back and forth vibrations of a particle per unit time. The faster the particles vibrate, the higher the frequency and the higher the pitch.

On a guitar, a thin, light string will vibrate quickly and produce a high pitch sound. Whereas a big, heavy string will vibrate slowly and create a low pitch sound.

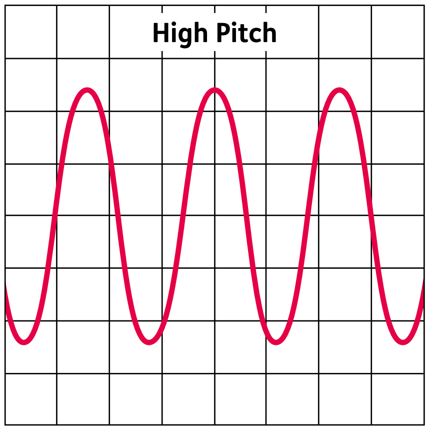
If a particle of air makes 1000 complete vibrations in 2 seconds, then the frequency of the sound would be 500 vibrations per second. A commonly used unit for frequency is the Hertz (Hz) where

1 Hertz = 1 vibration / second

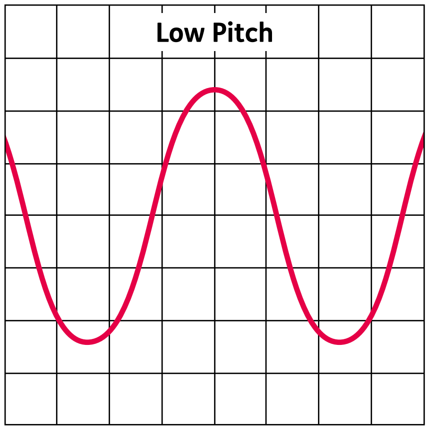
So in the example given, the frequency would be 500 Hz.

Human beings can normally hear sounds as low as 20 Hz and as high as 20,000 Hz. Sound with a frequency of more than 20,000 Hz is called ultrasound which has many applications, especially in medicine.

High Frequency



Low Frequency



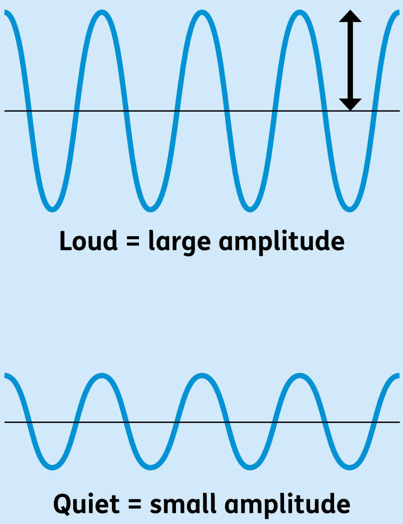
Loudness and Amplitude

The loudness of a sound depends on the size of the vibration. The bigger the vibration – the louder the sound. This can be demonstrated when hitting a drum. Gentle hits produce small vibrations and are quiet. When the drum is hit hard, the vibrations are bigger and the sound is louder.

The size of the vibration is called the amplitude and the bigger the amplitude, the louder the sound.

A common way to measure loudness is to use the decibel scale. A soft sound, like a whisper will measure around 15-20 decibels. Listening to an iPod at full volume is around 100 decibels. 120 decibels or above can lead to instant hearing damage. There are careful guidelines in place for sound levels at concerts and open air performances.

Amplitude of waves



Acoustics

Acoustics is the study of how sound travels and behaves. It's particularly important in designing buildings where good sound quality is required like concert halls, conference centres and theatres. Proper consideration of acoustics will help everyone in the building, even those in the back seats, hear the musician, actor or lecturer.

The acoustics are usually controlled by considering how sound will reverberate (bounce off things) or be absorbed by certain materials within the building. Carpets and curtains usually absorb sounds while tiles and glass help sounds to reverberate.

Loudspeakers, Microphones and Amplifiers

Modern technology has not only allowed our voices and our music to be transmitted around the globe, but also to be stored for future generations to enjoy.

Electrical microphones were invented in the late 19th Century and now make it possible to send sounds to other places by using the relationship between electricity and magnetic fields to convert the sound energy into electrical signals.

1. Sound causes the air to vibrate. This makes the microphone's diaphragm vibrate.
2. This in turn causes a wire coil to move up and down within a magnetic field.
3. This generates an electrical current within the coil.
4. Changes in the sound result in changes in the current.

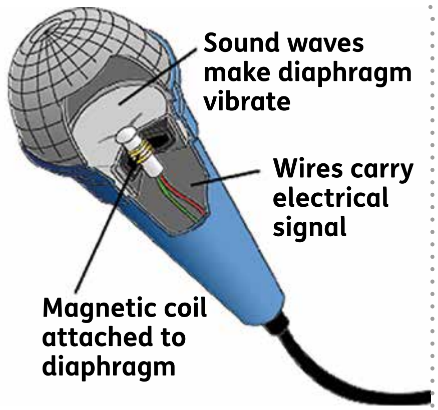


Image used with permission from the Concord Consortium (https://concord.org).

Today microphones can be found in mobile phones, hearing aids, public address systems, music recording studios, two way radios, radio and television broadcasting and computers.

Amplifiers are often used to increase the electrical signals before loudspeakers convert the electricity back into sound energy. Loudspeakers work like a microphone except in reverse, with the electrical signals driving magnetics that make a paper cone vibrate to produce sound.

Our scientific understanding of the physics of sound has allowed these electrical devices to be developed and become modern mainstays within the Creative Industries.

Science of Sound

Activity

1. Complete the following two paragraphs using the terms:

decibel scale	**pitch**	**vibrations**
frequency	**Hertz**	**loudness**
120 decibels	**vacuum**	**loud**

Sound is produced by ________________ and cannot travel in a ________________. ________________ is the term used to describe whether a sound is 'high' or 'low' and is related to a sounds ________________. A commonly used unit for frequency is the ________________.

The ________________ of a sound depends on the size or amplitude of a sounds vibration. Large vibrations produce ________________ sounds. Loudness can be measured using the ________________ and ________________ or more can cause instant hearing damage.

2. The speed of sound is 343 metres per second. Two music fans attend an open air concert. One is standing 50 metres from the stage and one is standing 250 metres from the stage. How much longer does it take the sound to reach the music fan at the back compared to the fan standing only 50 metres from the stage?

____

____

____

3. Make a list of common sounds ranging from very quiet to very loud. Research how many decibels each sound produces.

? **Loudspeakers convert electrical signals into sound.**

Research how loudspeakers do this, and produce a labelled diagram to help explain the process.

The Science of Light

Almost everything we do depends on light. From photosynthesis, where light is necessary for the existence of life itself, to the many applications of light which have revolutionized society through medicine, communications, entertainment and culture.

Light is an essential ingredient for many of the Creative Industries. From lighting a theatre stage or rock concert to creating atmosphere within paintings – from producing photographs and film to the beauty of stained glass windows. Also, our understanding of the science of light allows us to use it in an increasing number of exciting and creative ways.

Light Energy

Light is a type of energy and has the unique property that it can be described in physics as both a wave and as a stream of particles called photons. Light is also the fastest thing in the Universe and has a speed of 300,000,000 (3×10^8) metres per second. This means that light from the Sun, which is almost 93 million miles from the Earth, only takes around 8 minutes to reach us.

In the 1867, James Clerk Maxwell, a famous Scottish physicist, was the first to realise that light can travel as waves in the form of changing electrical and magnetic fields. He called this an electromagnetic wave. He also realised that visible light was almost certainly just one part of a wide range of electromagnetic waves, all travelling at the speed of light. This was confirmed twenty years later by Heinrich Hertz who discovered radio waves.

The Electromagnetic Spectrum

Visible light sits within a spectrum of electromagnetic waves. The waves all travel at the speed of light but occur in different parts of the spectrum depending on their wavelength and frequency.

Frequency is the term used in physics to describe how many waves are produced every second. If one complete wave is produced every second, then the frequency is one Hertz, or 1 Hz.

Wavelength is the length of one complete wave, and is usually measured in metres (m).

Frequency and wavelength are related by the equation

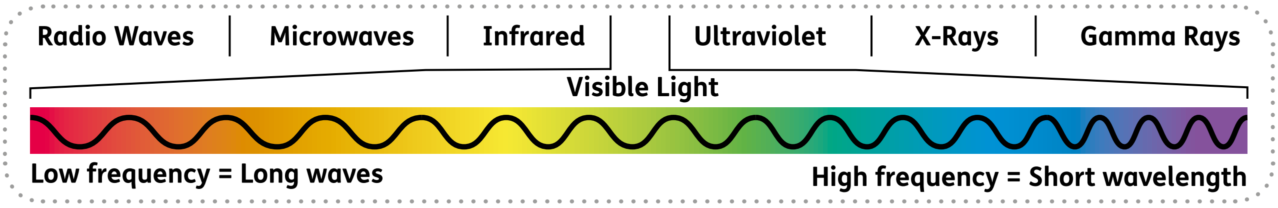
Speed = Frequency x Wavelength

The Electromagnetic Spectrum contains waves of both high and low frequency.

Since the speed of the waves is constant (the speed of light), the equation tells us that high frequencies must correspond to short wavelengths, and low frequencies correspond to long wavelengths.

The complete list of the Electromagnetic Spectrum from lowest to highest frequency is Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-Rays and Gamma Rays.

The waves are grouped into bands and make up the Electromagnetic Spectrum below.



Visible light is made of different colours. Each colour has a different wavelength and frequency. The different bands of waves that make up the Electromagnetic Spectrum can all be thought of as different types of light and they all have different properties. Scientists use the waves and their properties for different purposes. Gamma Rays, X-Rays and Ultraviolet all have medical applications, while Infra-Red is used in thermal imaging and microwaves are used in cooking.

Radio Waves

Radio waves have the lowest frequency and longest wavelength. They were first used for communication purposes in the late 1890s. Today, they are used to transmit radio and television programmes. Television uses higher frequencies than radio.

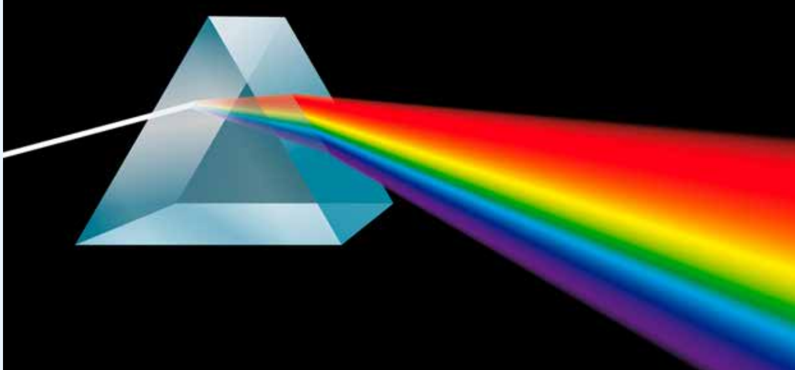
Radio waves are produced (or transmitted) by making charged particles move in an aerial. They can then be detected because they make charged particles in another aerial move. Different radio and TV stations transmit on different frequencies and your radio or television tuner can select these frequencies individually to allow stations to be decoded and watched or listened to.

Visible Light

Visible light is the most well-known part of the Electromagnetic Spectrum and is made up of different colours which all have different wavelengths and frequencies.

In 1662, Isaac Newton passed sunlight through a glass prism and observed the splitting of the light beam into different colours. He came to the conclusion that visible, or white light must contain a mix of light rays, each with a different colour. He also understood that white light could be separated into its individual components because each ray of colour is deviated by the glass of the prism by a different amount. We call this change of direction – refraction.

The fact that white light is made up of all the colours of the rainbow is particularly useful for a variety of lighting systems within the Creative Industries.



Colour

We don't need to use a prism to see a red T-shirt or a green leaf. Instead, the object itself is responsible for how we see a particular colour. The white light is separated because some of it is absorbed by the object and some of the light reflects off it.

The red T-shirt is absorbing all of the colours that make up white light except the red. The red colour reflects off of the T-shirt and travels to our eyes allowing us to see it as red.

A green leaf absorbs all colours except green which reflects off and we see a green leaf.

An object appears white when it reflects all colours of light, and black when it absorbs all the colours.

Different Colour Systems

The colour system used by scientists and lighting engineers is different to the system used by artists. An artist will mix blue and yellow paint to make green while a scientist will mix beams of green and red light to create yellow. Mixing colours of light and mixing colours of paint are different processes and consequently, produce very different results.

Scientists identify Red – Green – Blue (RGB) as primary colours. When combined, red and green light rays produce yellow, blue and green produce cyan, red and blue produce magenta.

Red, green and blue will mix to create white light.

This RGB lighting system is used in theatres to create a variety of different effects relating to mood, time of day and plot.

This colour model is also used in computer monitors, television sets and devices that use light to create images. On a television screen, red, green and blue dots of light create the image and overlap to produce the other colours.

In Art, it's different, and most artists recognise red, yellow and blue as the 3 basic primary colours. These primaries are the pure colours which cannot be created by mixing any other colours. Secondary colours are created by mixing any of the two primaries. Tertiary colours result from mixing the secondary ones.

The print industry uses yet another different colour system where cyan, magenta, yellow and black represent the four inks used in colour printing.

Lasers

Lasers also play an important role within the Creative Industries, from light shows at concerts to DVDs, CDs and movie special effects.

Laser beams can be made from visible light, x-rays, ultraviolet light or infrared light and the term laser stands for Light Amplification by Stimulated Emission of Radiation. Lasers require excited atoms that emit ‘packages of light’ called photons. A powerful laser then uses its photons to excite even more atoms.

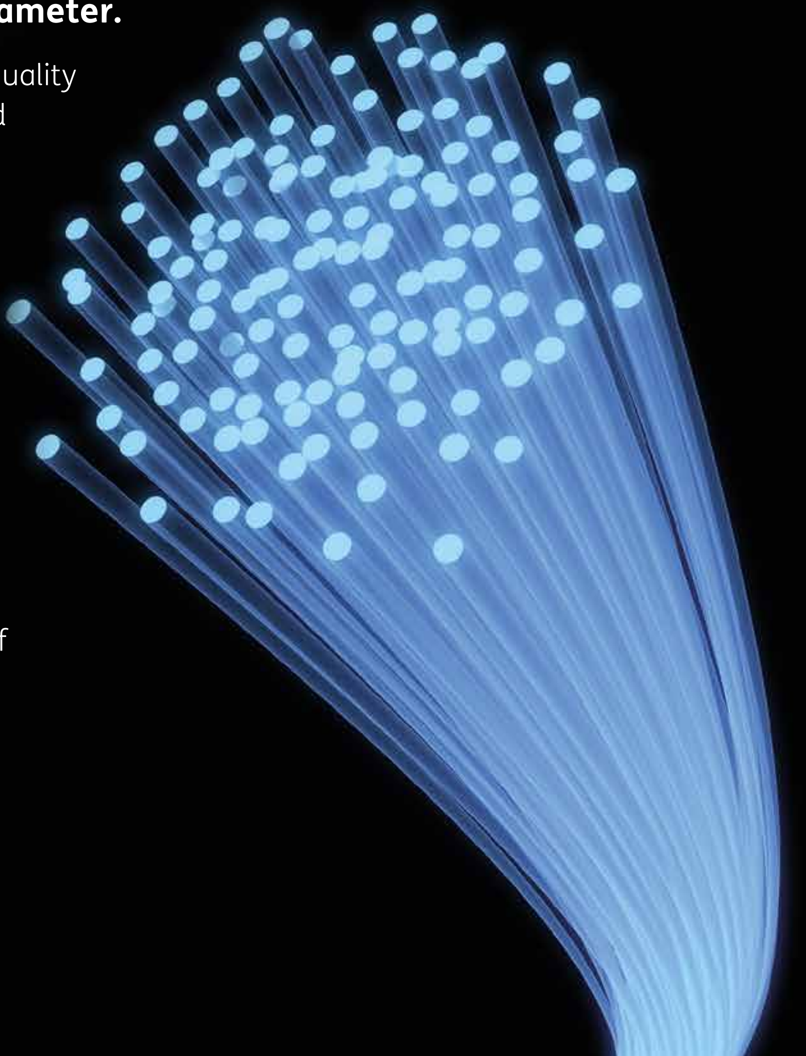
Optical Fibre

One of the most ground breaking applications of light is the use of ‘optical fibres’ to transmit telephone signals, Internet communication, and cable television signals. Optical fibres can carry information coded in light. They can carry more information than electrical signals in an ordinary cable of the same diameter.

An optical fibre is a thin rod made of high-quality glass. Light enters one end of the cable and undergoes internal reflections within the fibre before emerging at the other end. The glass absorbs very little of the light, allowing the signal to maintain a higher intensity, compared to electrical signals in ordinary cables.

The arrival of fibre optic broadband and its large data carrying capacity now makes the streaming of movies online commonplace.

Light and its many applications continue to play a key role in the on-going success of the Creative Industries in the 21st Century.



Science of Light

Activity

White light is made up of a spectrum of 7 different colours – red, orange, yellow, green, blue, indigo and violet.

1. **Carry out this simple experiment to demonstrate how water can be used to split white light into its spectrum of colours.**

What you need:

- a shallow bowl
- water
- a mirror
- tape
- a bright torch
- white paper

Method:

- Fill the shallow bowl half full of water.
- Place the mirror in the bowl and rest it on the side of the bowl. It should be half immersed in the water and sitting at an angle of 45 degrees. Tape the mirror to the side of the bowl.
- Shine the light into the bowl and onto the mirror under the water.
- Hold the white paper above the mirror and adjust its position until you see the bright light on the paper, containing an outline of a rainbow. This works best in a dark room.

? **Draw a labelled sketch of your experiment and write a short paragraph explaining how your 'rainbow' forms. Be sure to mention the terms wavelength, refraction and reflection.**

2. **Complete the following paragraph about the electromagnetic spectrum using the terms:**

visible	**Hertz**	**metres**	**waves**	**frequencies**	**wavelengths**
second	**light**	**Gamma Rays**	**colours**	**Radio Waves**	**TV programmes**

Electromagnetic ________________ travel at the speed of ________________.
Different parts of the spectrum have different ________________ and ________________. Frequency is the term used to describe how many waves are produced every ________________ and is measured in ________________. Wavelength is the length of one complete wave, and is usually measured in ________________. Waves of the lowest frequency are ________________. Waves of the highest frequency are ________________. The Electromagnetic Spectrum has many applications. Radio waves are used for broadcasting ________________. ________________ light is made up of seven different ________________.

3. **Research one of the following applications of light:**

Fibre optics **Television images** **Lasers**

Explain to a group, or write a short report, on how your chosen application of light is used within the Creative Industries.

The Science of Materials

Materials science is an interdisciplinary field which involves the discovery and design of new materials. Many of these materials can then be used within the Creative Industries, especially in the fields of Architecture, Crafts and Designer Fashion.

Materials have different properties that make them suitable for different purposes. Materials can be waterproof, absorbent, strong or weak, transparent or opaque, flexible or rigid, hard or soft, magnetic, conductors or insulators.

Common materials are metals, glass, plastics, wood and fabrics. However, material scientists have also developed a whole range of smart or modern materials for the 21st Century. Examples include 'Potatopak' which is made from potato starch and used for biodegradable, disposable products, or 'Precious Metal Clay' which is made from gold or silver with 1% clay and used in jewellery making.

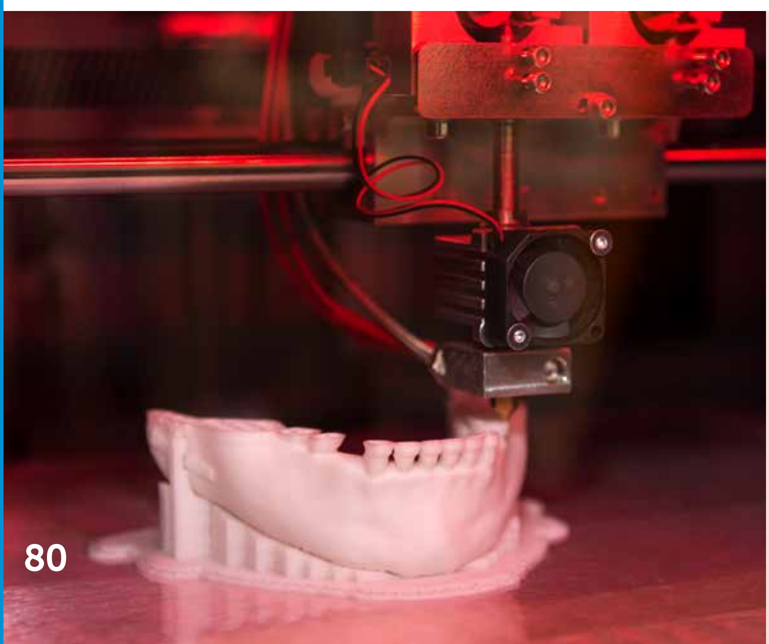
Architecture

In architecture, glass, brick, steel and concrete remain the dominant building materials. However, society increasingly desires buildings which are more energy efficient and interactive while looking attractive and individual.

Modern materials can help an architect deliver on these goals. For example:

- Self-cleaning exterior coatings, such as titanium oxide coated concrete and glass are increasing in importance.
- Innovative glass coatings in the infra-red range have been developed for the insulation of glass clad buildings.
- Electroluminescent materials which give out light when an electric current is applied to them can be incorporated in buildings.

Ultimately advances in materials science aim to make buildings safer, more sustainable and more affordable while appearing attractive and individual.



3D Printing

3D printers are having a growing impact in the areas of design, architecture and jewellery.

The technology allows the manufacture of a three dimensional object in which successive layers of material, like plastics or ceramics, to be formed under computer control to create an object.

Textiles

Science has played a key role in textile development and production throughout history. Industrialisations, the introduction of modern manufacturing techniques, and modern materials have all contributed to a successful creative industry. From synthetic fibres to chemical dyes and the weaving loom – science and technology have played an essential part.

Today, textiles manufacturers use new technological developments to improve fabrics by giving them new properties. One area of development is in healthcare where wound dressing is an important application for new materials, especially if they can affect the rate of healing, protect from infection, and mask odours. Clothes that administer doses of medication and monitor wound healing are also being researched. The use of electronics into clothing to provide mobile computing and energy generation are also of growing importance to the fashion and sports industries.

These new materials and their many applications within the Creative Industries continue to benefit science, the economy and society.

Science of Materials

Activity

3D printing

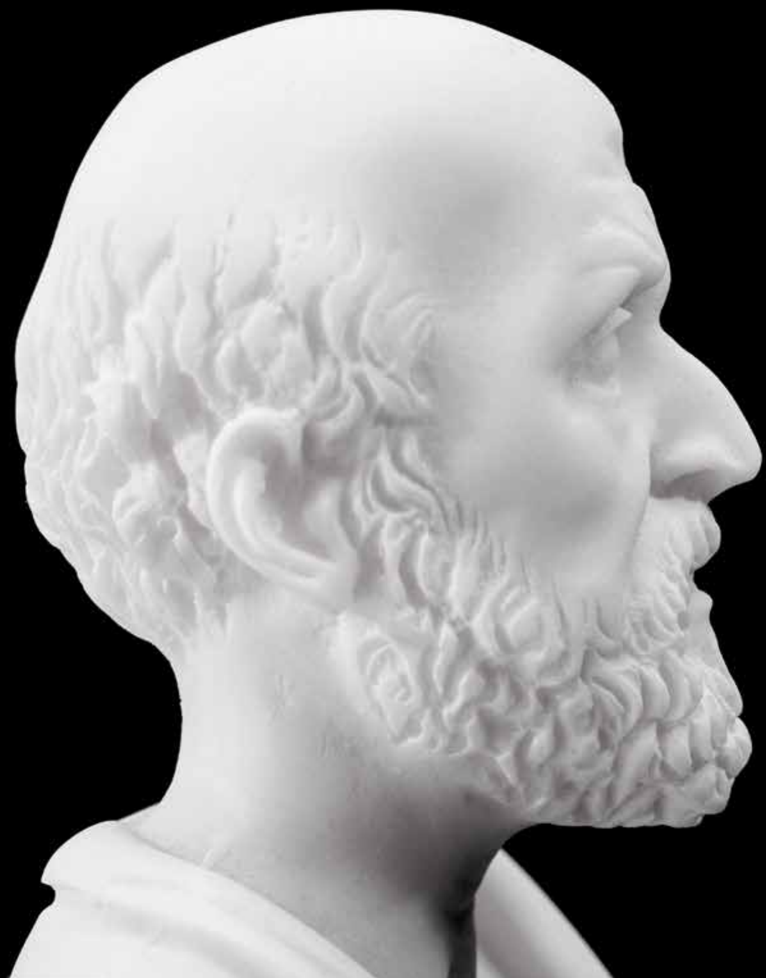
3D printers are having a growing impact in the Creative Industries. The technology allows the manufacture of a three dimensional object in which successive layers of material, like plastics or ceramics, are used under computer control to create an object.

1. **Research the impacts of 3D printing in a Creative Industry of your choice e.g. Architecture or Jewellery making. Prepare a short presentation to summarise the advantages and disadvantages of this manufacturing process.**
2. **What are smart materials? Give 2 examples and list the benefits they can bring to society.**

Where next? Can you think of a potential future application of smart materials or 3D printing within the Creative Industries? How would you 'pitch' this idea to a Dragon's Den type audience?

Write down a list of benefits/impacts that you could present to convince fellow learners that your idea is worth considering.

Food and Drink



"Let food be thy medicine and medicine be thy food."

Hippocrates

The Food and Drink Industry is very important to Scotland. It is the largest manufacturing sector in the country and supports over 100,000 jobs while also impacting on health and sustainability. Our salmon-filled rivers, world renowned whisky distilleries and fresh natural produce also help attract many visitors to Scotland.

The Scottish Government has identified four sub-sectors within the Food and Drink Industry, namely:

- agriculture: including the activities associated with growing crops, raising animals, and hunting.
- fishing and aquaculture: covering both marine and freshwater activities.
- food manufacturing: covering all activities associated with the processing, preservation and manufacture of food.
- drinks manufacturing: including the manufacture of soft drinks, mineral waters and alcoholic beverages.

Today, the industry relies on several different areas of science, engineering and technology, especially in new product development, food and drink manufacturing, packaging and crop research. Food science and nutrition also form an important part of the Health and Wellbeing curriculum within Scotland's schools.

Our universities, along with The Rowett Institute and The James Hutton Institute are world leaders in various aspects of food and drink research. They provide us with an increased understanding of food inequalities, obesity, food security and the environment, along with support for the sustainable development of Scotland's food industry crops, soils and land use.

This unit will investigate a range of science concepts relating to food and drink, including mixtures and solutions, the role of acids, alkalis and micro-organisms and the importance of good nutrition.

Learn about:

Mixtures and Solutions p84

Acids and Alkalis p88

Micro-Organisms in Food and Drink p92

Food and Nutrition p94

Mixtures and Solutions

Mixtures and solutions are involved in many food and drink processes, from baking a cake to cleaning utensils, whisky production or fertiliser use on farms. Understanding how different mixtures and solutions are created, and how potentially they can be separated, will allow learners to make relevant links between these scientific processes and the Food and Drink Industry.

Mixtures

A mixture is when two or more substances are combined and do not react chemically to form a new substance.

The substances within mixtures maintain their original properties and can be separated into their constituent parts. For example flour and peas can be added together to create a mixture and then separated again with a sieve. Iron filings and sawdust can be mixed together and then separated from each other by using a magnet to attract the iron filings out of the mixture. No chemical reactions are needed to produce the separation. Mixtures can be made with solids, liquids and gases. For example, fizzy drinks are a mixture of gases in liquids. Just about everything we eat and drink today is a mixture.

Mixtures are normally divided into two categories:

Homogeneous mixtures

Substances are evenly distributed throughout the mixture. Examples include air, a cup of coffee and salt water.

Heterogeneous mixtures

Substances are unevenly disturbed throughout the mixture. Examples include chocolate chip biscuits and salad dressing.

Solutions

A solution is a special type of mixture when one or more substances dissolve or 'disappear' in a liquid.

In science, the substances are called the solutes and the liquid into which the solids dissolve is called the solvent. For example, when salt dissolves in water, we call salt the solute and water is the solvent. When a substance does not dissolve, it is called insoluble. When a substance does dissolve it is called soluble. The extent to which a solute can dissolve in a solvent is called its solubility. A solution is said to become saturated when the solute stops dissolving in the solvent. The solvent is unable to accept any more of the solute and has reached its saturation point.

Solutions are used extensively throughout the Food and Drink Industry from whisky-making and Irn-Bru to hygiene methods and farming techniques.

The Science of Dissolving

When a solute dissolves in a liquid to form a solution, the solute breaks up from a structure with a large crystal of molecules into much smaller groups or individual molecules. This allows the solute to fit into the spaces between the liquid molecules making it appear to disappear.

This break up is caused by the solute coming into contact with the liquid. The temperature of the liquid will also affect the amount of solute that can be dissolved. Higher temperatures mean a greater amount of solute can be added before the solution is saturated. Other factors like particle size and stirring can affect the speed at which the solute will dissolve.

Sometimes a mixture can contain very small insoluble particles that are just big enough for us to see. This mixture is called a suspension.

Mixtures and Solutions - Scientific Terminology

Activity

Match the following terms to the correct definitions below.

Solute **Solution** **Saturated Solution** **Soluble** **Solvent** **Insoluble**

Term	Definition
	A liquid with a substance dissolved in it
	A solution in which the maximum amount of solute has been dissolved in a solvent
	A substance which creates a solution when dissolved in a solvent
	A substance which does not dissolve in a liquid
	Normally a liquid in which another substance is dissolved
	A substance which does dissolve in a liquid

Mixtures and Solutions - Experiments

Activity

Dissolving experiment

Fill 6 plastic cups with lukewarm water. Predict whether the following 6 solids will dissolve in the water to form solutions.

Sand	**Salt**	**Coffee**
Sugar	**Flour**	**Pepper**

? Now test the solids by adding one teaspoon to each of the cups of water.

Were your predictions correct?

Continue adding teaspoons of salt to your salt and water solution. How many teaspoons can you add until the salt can no longer dissolve?

We say this is the solution's ________________ point.

Factors affecting dissolving

Design your own set of experiments to investigate how solute particle size, stirring and the temperature and volume of the solvent can affect dissolving.

? For example, you may wish to compare the speed at which granulated sugar or sugar cubes dissolve in cups of water.

Can you dissolve more teaspoons of table salt in 100 ml of warm or cold water? Can you dissolve more salt in 100 or 200 ml of water?

Once you have carried out your experiments, answer the following questions.

1. **If the volume of a given solvent (e.g. water) increases, does the amount of a substance like salt that can be dissolved within the solvent increase or decrease?**
2. **Will salt dissolve quicker or slower if the temperature of water increases?**
3. **Will sugar dissolve quicker or slower in water if the particle size is increased? Explain your answer in terms of surface area.**
4. **Does stirring speed up, or slow down dissolving?**

Separation Techniques for Mixtures and Solutions

Methods to separate insoluble solids from a liquid include:

- **using a sieve if the insoluble solid particles are large enough to be collected in the sieving mechanism**
- **using a filtration system where the filter is of sufficient resolution to prevent any insoluble solids passing through the filter with the solvent**

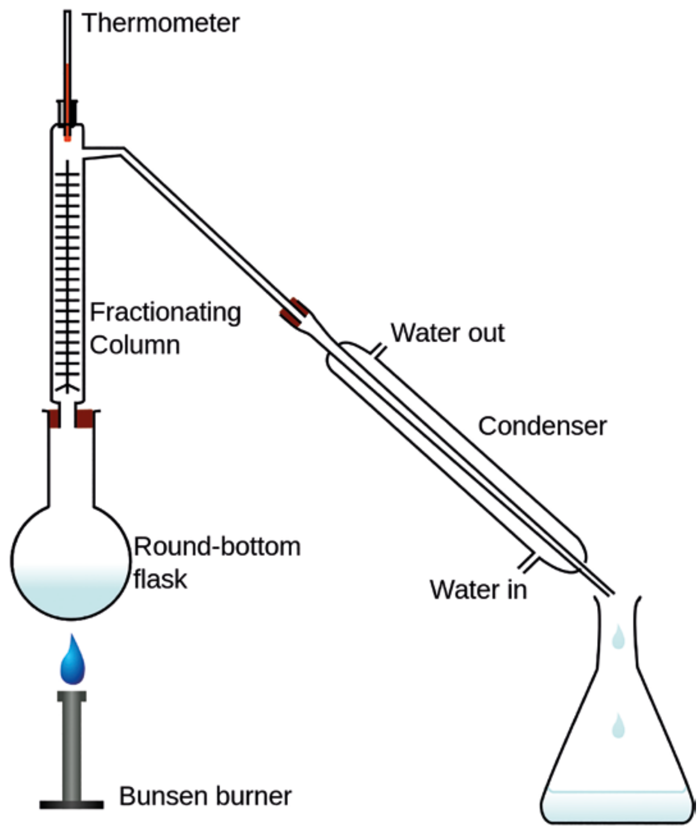
Evaporation is a good method for separating a soluble solid from a liquid.

For example salt crystals can be separated from a water and salt solution using evaporation. The water evaporates away, leaving behind the salt.

Distillation – If we want to recover the water from the solution we use a technique called distillation where the evaporated water is collected in a condenser where it is cooled and allowed to condense from a gas back into water and collected.

This technique is normally used to separate mixtures of liquids which have different boiling points. If the mixture is heated, the liquid with the lower boiling point boils first and then can then be condensed and collected, thus separating it from the original mixture. This technique is called fractional distillation and is used during whisky production. The technique is so important to whisky production, we call the place where whisky is made – a whisky distillery.

Distillation



Chromatography is an effective method for separating dissolved substances that have different colours, such as inks or food colourings. Black ink is made of inks of different colours. The individual colours are made of different chemical dyes which dissolve at different rates. Consequently they can spread through wet filter paper at different rates.

Gas chromatography is another separation technique often used in the food and drink industry, especially within food testing. The substance to be separated is vaporised and separation occurs depending on the rate of absorption of the constituent gases.

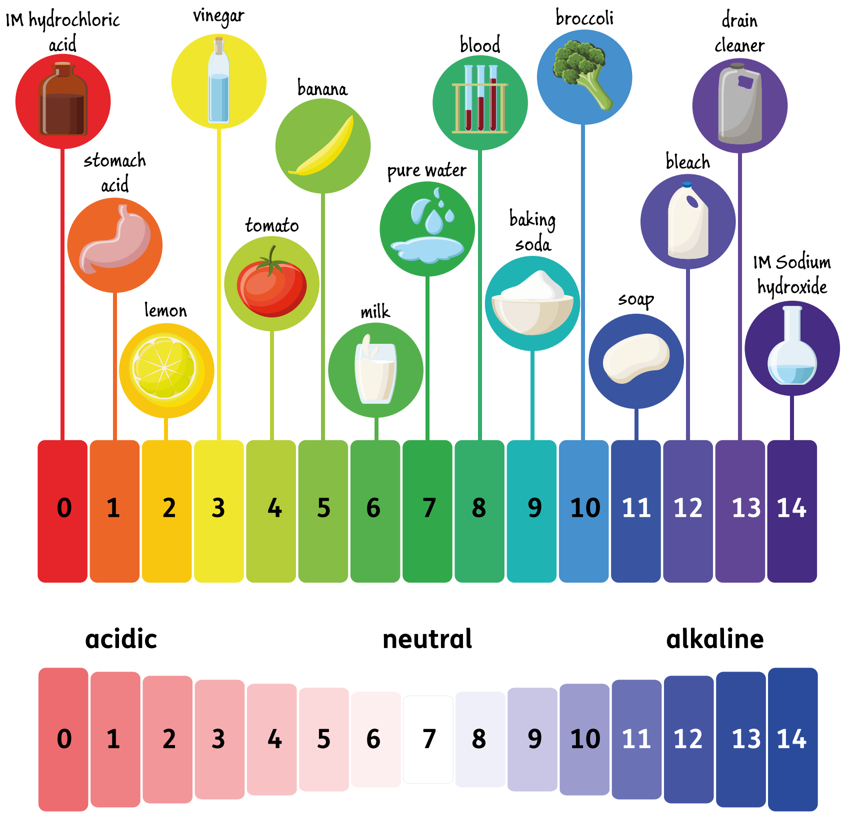
Acids and Alkalis

Many everyday substances can be classified as acids or alkalis, and these special kinds of chemicals play an important role within the Food and Drink industry. Whether a substance is acid or alkali depends on its pH.

The pH Scale

pH is measured on a scale from 0 to 14 where:

- Neutral solutions (not acidic or alkaline) are pH 7 exactly
- Acidic solutions have pH values less than 7
- Alkaline solutions have pH values more than 7
- The closer to pH 0, the more strongly acidic a solution is
- The closer to pH 14, the more strongly alkaline a solution is



The pH of a solution is determined by the way hydrogen behaves within the solution.

The chemical formula for water is H_2O and it can separate to form hydrogen (H+) and hydroxide ions (OH–). Ions are atoms with an uneven number of protons and electrons resulting in an electric charge denoted by a – or + sign.

In acids there is an excess of hydrogen ions (H+).

In alkalis there is an excess of hydroxide ions (OH–).

Solutions can be tested for their pH by using a pH indicator which is a chemical that can change colour to give information about a substance.

Acids and Alkalis at Home

Many foods and drinks are acidic. Examples include lemons that contain citric acid, fizzy drinks that contain carbonic acid, tea that contains tannic acid and vinegar that contains ethanoic acid.

Alkalis can react with oils and fats and are commonly used in household cleaners. Examples include sodium hydroxide in oven cleaner and ammonia solution.

Acid or Alkali Experiment

Activity

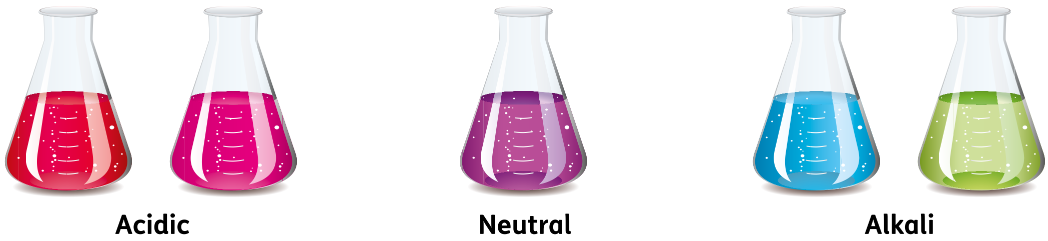
You will need:

- Red cabbage indicator – one jug or bottle of indicator per group
- 8 small plastic cups per group (2 are spare in case of spillage or mistakes)
- One experiment recording sheet per group (included on page 90)
- Sticky labels
- A variety of household liquids such as washing up liquid, apple juice, vinegar, bicarbonate of soda solution, juice from a lemon, handwash, water

Making red cabbage indicator

Red cabbage juice indicator is easy to make and contains a natural pH indicator that changes colour according to the acidity of a solution.

Very acidic solutions will turn the indicator a red colour. Neutral solutions result in a purplish colour. Alkali (opposite of acid) solutions appear blue-green. Therefore, it is possible to determine if an unknown solution is acidic or alkaline by adding red cabbage juice and watching the colour change.



This indicator is very useful for experiments about ocean acidification as part of climate change topics, or as an introduction to simple chemical reactions.

To make the red cabbage indicator, you will need – one red cabbage, one large bowl, two cups, some boiling water, and one sharp knife.

Method:

1. Chop the cabbage into small pieces until you have about 2 cups of chopped cabbage. Place the cabbage in a large bowl and add boiling water to cover the cabbage. Allow to stand for at least ten minutes for the colour to leach out of the cabbage. (Alternatively, at home, you can place about 2 cups of cabbage in a pot, cover the cabbage with boiling water, and boil for 10 minutes.)
2. Drain the liquid from the cabbage and leave to cool. Store in a flask or empty drinks bottle. Your indicator is now ready to use.

Continued on page 90 →

Acid or Alkali Experiment - *continued*

Activity

Method:

1. Pour a small amount of each household liquid into each of the plastic cups and use the labels to identify the name of the liquid in each cup. The liquid should only fill the bottom 2 – 3cm of each cup.
2. Add a little water to each cup until they are all half full.
3. Predict in groups which of the liquids are the acids and which are alkalis.
4. Add the red cabbage indicator to each household liquid and note the colour of each solution. Pink/red indicates as acid, blue/green indicates an alkali.

Acid or Alkali? – recording sheet

Household liquid	Tick if you predict it is an acid	Colour with indicator added	Tick if pink or red

?

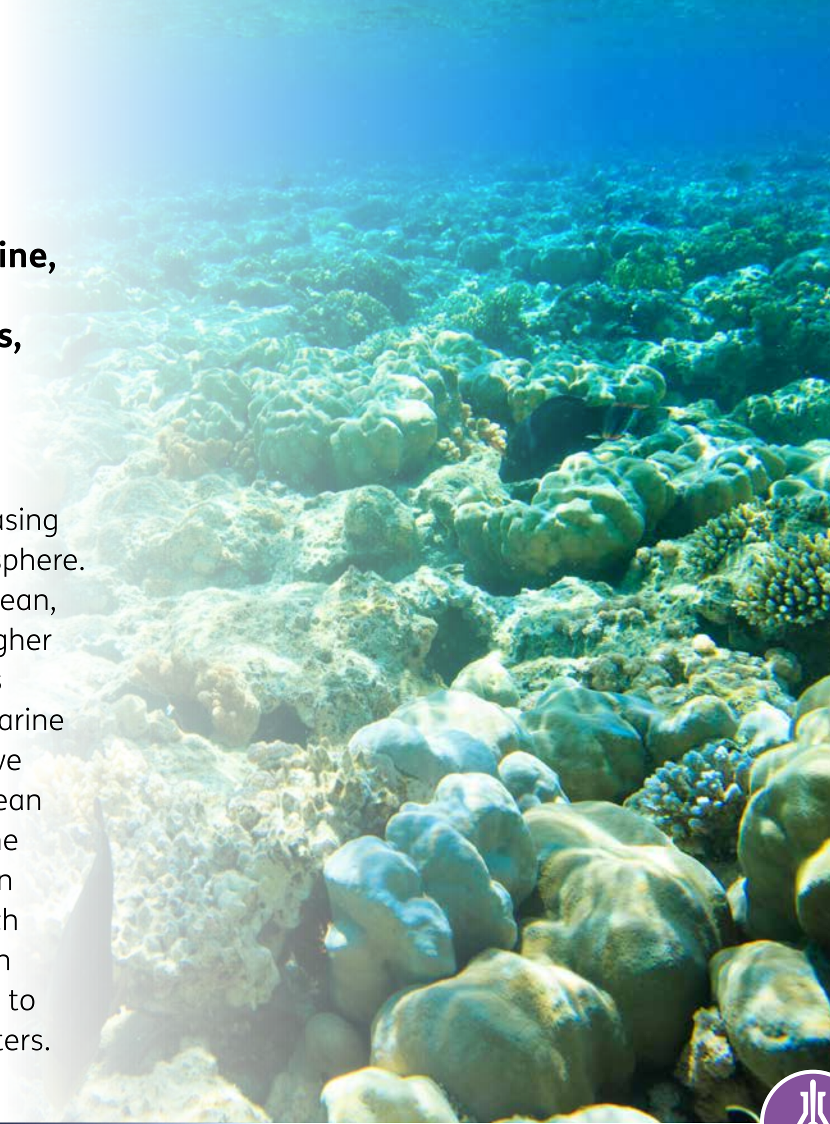
Were your predictions correct?

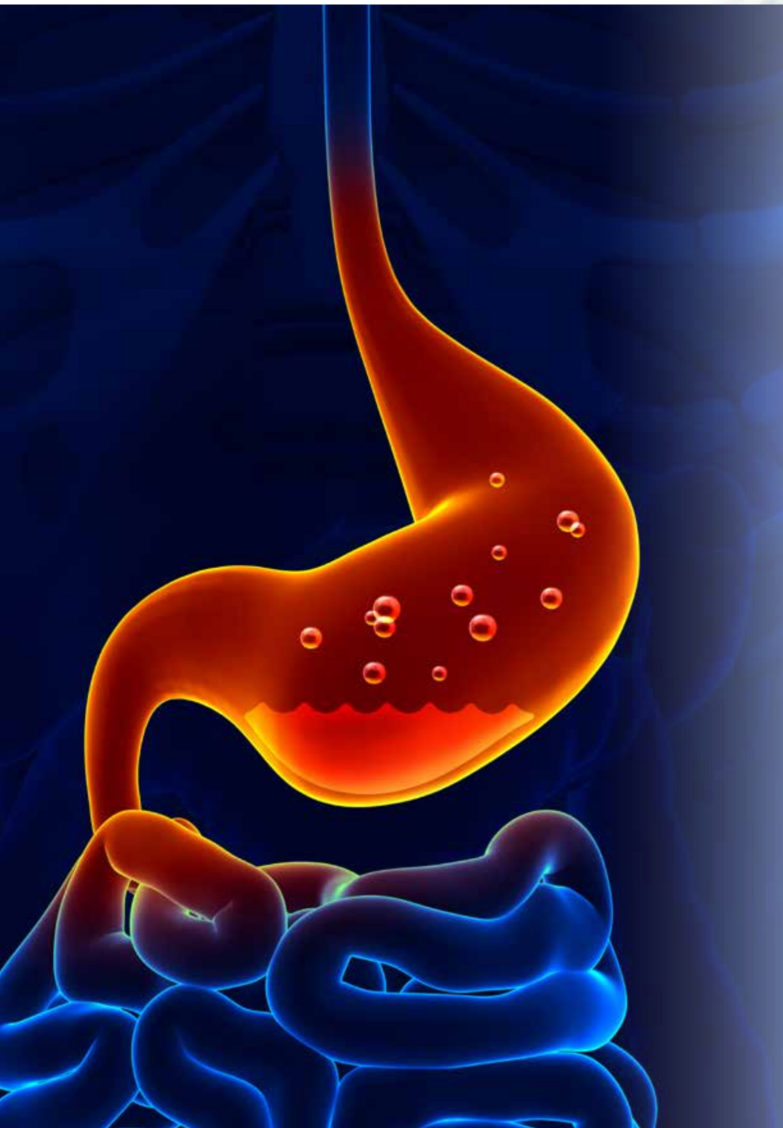
What do you think will happen if you add an acidic solution to an alkaline solution?

Ocean Acidification

Over the past 300 million years, ocean pH has been slightly alkaline, averaging about 8.2. Today, it is around 8.1, a drop of 0.1 pH units, which actually represents a 25 percent increase in acidity over the past two centuries.

Scientists attribute this change to increasing amounts of carbon dioxide in the atmosphere. When carbon dioxide dissolves in the ocean, carbonic acid is formed. This leads to higher acidity, mainly near the surface and has been proven to inhibit shell growth in marine animals and may also cause reproductive disorders in some fish. Consequently ocean acidification could have an impact on the fishing and aquaculture sub group within Scotland's Food and Drink Industry which relies on healthy populations of shell fish and marine animals. Scientists continue to carefully monitor Scotland's coastal waters.





Neutralisation Reactions

Acids and Alkalis are chemical opposites and when mixed together will react to form new products in a neutralisation reaction. If an alkali is added to an acidic solution, the pH would be altered to move up towards pH 7. Similarly, if an acid is added to an alkali, the pH moves down towards pH7. Neutralisation reactions can very useful.

The stomach contains acid to help break down and digest food. Indigestion is caused by a build up of acid in the stomach, often by eating too quickly. Indigestion tablets contain alkalis like calcium carbonate that act to neutralize the acid build up and reduce the indigestion.

Other neutralization reactions include the use of lime (calcium oxide) by farmers to neutralize acidic soils and the use of the alkali baking powder to neutralize an acidic bee sting.

Micro-Organisms in Food and Drink

Micro-organisms have been used in food and drink processing for centuries. Both brewing and baking rely on a process called fermentation which uses yeasts or bacteria to turn sugar into carbon dioxide, alcohol and heat. In baking, the carbon dioxide becomes a rising agent while the alcohol evaporates off. In brewing, the alcohol is distilled and used in a variety of ways to make wine, beer and spirits.

Bacteria also play a crucial role in the production of cheese and yoghurt from milk. The presence of bacteria enables the sugar lactose to turn into lactic acid which in turn allows the milk to thicken and start the production of cheese or yoghurt.

Micro-Organisms and Food Spoilage

While some micro-organisms are essential for food and drink processing, the growth of others can cause food to spoil. As food ages, micro-organisms within the air or within the food itself are able to multiply and produce mould or toxins that can spoil the food product. Various processes have been developed to slow down this process, including refrigeration, drying and preservatives.

Low temperatures can greatly reduce some micro-organisms ability to multiply while preservatives are chemicals which are added to foods to make them last longer and prevent the growth of mould. The chemicals can be natural or synthetic.

Common natural preservatives include salt, sugar and vitamin C. Sugar is used partly for this purpose in the making of jams and jellies. Artificial preservatives include sulfites that stop the growth of micro-organisms by interrupting the function of their cells and are often used in the preservation of fruits and vegetables. Nitrates are artificial preservatives which are commonly used to preserve meat.

Removing all the water from micro-organisms leads to them drying out. This process also stops the micro-organisms from growing and multiplying and can be used to keep pasta and fruit for longer periods of time.

Freezing also stops micro-organisms from reproducing and can preserve food for longer periods of time.

Pasteurisation

The great 19th Century French scientist, Louis Pasteur spent his career studying micro-organisms and diseases.

He used his knowledge to investigate how liquids like wine and milk were spoiled by micro-organisms such as bacteria and moulds. He found that heating up the liquids would kill most of the micro-organisms and allow the drinks to last longer and be safer to drink. This process became known as pasteurization and is still done on many foods such as milk, vinegar, wines, cheese, and juices. Today, pasteurised milk is heated to 72C for 15 seconds while UHT (Ultra High Temperature pasteurisation) milk is heated to 140C for 3 seconds and then cooled rapidly. This allows the milk to be stored in an airtight container for several months.

Food and Micro-Organisms

Activity

Ideal conditions for mould experiment

As food ages, micro-organisms within the air or within the food itself are able to multiply and produce mould. Scientists say warm, dark and moist conditions accelerate the growth of micro-organisms, like bacteria, in food.

Design your own experiment to investigate whether warm, dark and moist conditions accelerate the growth of bacteria on food.

Keep a written record of your observations and write a short report, including:

- Details of your experiment.
- A summary of your results.
- A conclusion to support or disagree with the scientific view that mould grows faster in warm, dark and moist conditions.

?

Hints

- Bread is a good food for testing. To ensure a fair test, one slice can be cut into several small pieces of equal size.
- To prevent contact and 'breathing in' of mould, place each piece in a sealed see-through bag. Do not open bags. Dispose of unopened bag at the end of the experiment.
- Consider several locations and add water to some of your samples to create 'moist' conditions.
- Test period should be at least 8 – 10 days. Keep written observations and/or daily photos.

Researching micro-organisms

Research one of the following topics and write a paragraph or give a short talk about the role micro-organisms play within the process.

Food Poisoning **Preservatives** **Fermentation**

Micro-organisms play an important role in our Food and Drink industry and scientific research into the benefits and the control of micro-organisms continues to help us lead healthy lives with high quality food standards and testing.

Food and Nutrition

We all consume foods and drinks in order to obtain energy which then allows us to live our daily lives. A healthy diet should provide us with the right amount of energy (measured in calories or kilojoules) from foods and drinks to maintain an energy balance.

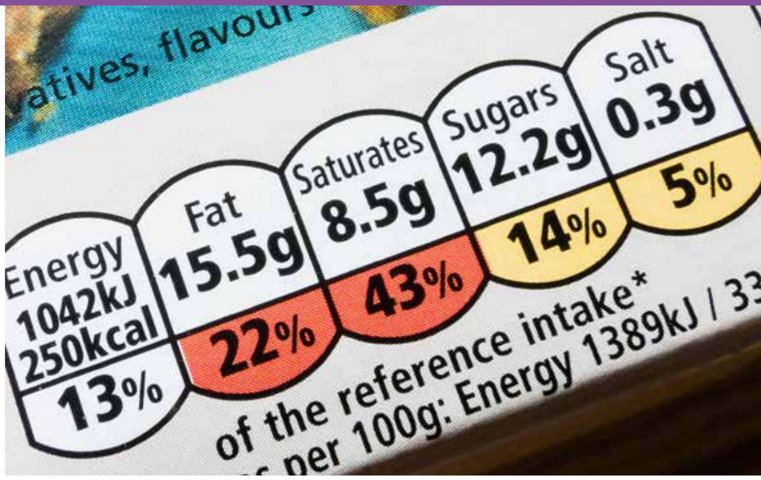
Energy balance is achieved when the calories we consume are equal to the calories our bodies need to use in order to function. This includes physically moving around, and also processes like breathing, digestion and pumping blood around our bodies. If, over time, we consume more calories than our body needs it will cause weight gain. This is because the extra calories are stored as fat. Latest research indicates that over half of adults in the UK are overweight or obese. This can also increase the risk of type 2 diabetes, heart disease and some cancers. Consequently maintaining a healthy weight is very important for our health and well-being.

Calorie Intake

The amount of energy you need from foods and drinks depends on a variety of factors, including age, genes and how active you are, but on average:

Women should have 2000 calories (8400 kilojoules) per day

Men should have 2500 calories (10,500 kilojoules) per day



Eating as many calories as we need, will help us maintain a healthy weight. However, a balanced diet with foods and drinks from the five main food groups will also help provide the different essential nutrients to help our bodies function properly and stay healthy.

The 5 main food groups are:

- Fruit and vegetables
- Starchy carbohydrates like potatoes, bread and rice
- Proteins like beans, pulses, fish, eggs and meat
- Dairy and alternatives
- Oils and spreads

Most of our food should come from the starchy carbohydrates and fruit/vegetables groups with moderate amounts of food from the protein and dairy groups. Finally, the oils and spreads group demonstrates that we need some fat for a healthy diet, but this should be unsaturated and in small amounts.

Each food group provides different essential nutrients which are needed to ensure our body functions properly and remains healthy.

The main nutrients are carbohydrates, proteins, fats, vitamins and minerals. Each nutrient plays a different role and has a different purpose within our bodies.

Carbohydrates

Carbohydrates provide our bodies with energy. There are two types of carbohydrates – starch and sugar. Starch can be found in cereals, pasta, potatoes and bread while sugar is found in fruit, honey, cakes, pastries and biscuits.

Proteins

Proteins are needed to help our bodies grow and repair. They are found in animal products like meat, fish, cheese, milk and eggs. Vegetable proteins include soya, nuts and pulses.

Vitamins

Vitamins are needed to help the body grow and maintain health. The main vitamins are:

- Vitamin A for good vision and healthy skin and found in green and yellow vegetables and dairy products.
- The B complex of Vitamins which release energy from food and keep skin and hair healthy. Commonly found in bread, milk, eggs, meat and fish.
- Vitamin C for healthy skin and cell protection and found in fruit and vegetables.
- Vitamin D for calcium absorption and healthy teeth and bones, found in margarine and oily fish.

Fats

Fats also help to provide energy and can insulate the body in cold weather. There are two types of fat – saturated and unsaturated. Saturated fats are normally obtained from animals like butter and lard. Unsaturated fats are normally from vegetable sources like sunflower or olive oil.

Minerals

Minerals are needed to help body cells function properly. Calcium and iron are two of the most important minerals. Sources of calcium include milk, cheese, eggs and wholegrain cereals. Iron is essential for the formation of red blood cells and sources include red meat and green vegetables. Other minerals that the body requires include zinc, sodium, magnesium and potassium.

A healthy and balanced diet is the basis for a well-functioning body. Poor diet has been directly linked with diseases, poor quality of life and a variety of mental health issues.

In Scotland we have access to a rich abundance of natural and home-grown produce, from quality beef and fresh fish to local fruit and vegetables. Our thriving Food and Drink Industry relies on these products, as well as continued world-class research in food, plant and animal science and technologies.

Activity

Essential nutrients

1. **Research the different nutrients in the table below. List at least 2 different foods that will provide each of the nutrients.**

Nutrient		Food Example
Carbohydrates:	Starch	
	Sugar	
Proteins		
Fats:	Unsaturated	
	Saturated	
Vitamins:	A	
	B	
	C	
	D	
Minerals:	Calcium	
	Iron	

2. **Research reasons why too much saturated fat is bad for our health.**

List at least 2 reasons.

Counting kJ's

1. **Below is a label from a tin of baked beans.**

NUTRITIONAL INFORMATION	
Typical Values	**Per 100G of product**
Energy	329kJ
Fat	0.2g
Carbohydrate	12.5g
Fibre	3.7g
Protein	4.7g
Salt	0.6g

One tin of beans contains 400g.
How much energy does it contain?
__________kJ's

If you ate ½ a tin of beans and a slice of toast (500kJ) for lunch – how much energy have you consumed?
_____________kJ's

2. **Find 6 food items from your kitchen cupboards or fridge and work out the amount of energy a single portion will contain. (e.g. ½ tin of soup, 250ml glass of milk, 2 eggs scrambled, packet of crisps.)**

Food	Energy

Eat local investigations

Scotland is home to a wide selection of different foods which can provide all our essential nutrients.

1. Design a 3 course menu with a starter, main course and dessert where the majority of the ingredients come from within Scotland. Write an accompanying paragraph to highlight which of your ingredients are Scottish produced and at what time of year the produce is normally available. E.g. Aberdeen Angus beef would be available all the year round but Scottish strawberries would only be available during certain months.
2. Write a list of your favourite fruit and vegetables. Try to include at least 8 items. Visit your local supermarket and investigate where your choices have originated from. How many have travelled from outside of Europe? The distance that food has travelled to be in our shops is often referred to as food miles. Research the advantages and disadvantages of buying food that has been imported to Scotland from distant countries. Discuss your findings with other learners.

Advantages of food imports	Disadvantages of food imports

Useful Information and Acknowledgements

In this section:

Case studies	p100
Glossary	p111
Helpful websites	p114
Curriculum mapping	p116
Activity answers	p120
Acknowledgements	p125

Case studies

Careers that use science

There are four case studies in this section, each featuring someone with a job that uses science. They are:

102

Craig: Scottish Power

104

Meghan: Roadbridge Construction

106

Shaun: Riverside Music Complex

108

Gill: Loch Lomond & The Trossachs National Park

Choose two of the four case studies. Read them and think about the ways that the people use science in their work. Write down your ideas:

Do you know anyone who works in any of these types of workplaces?

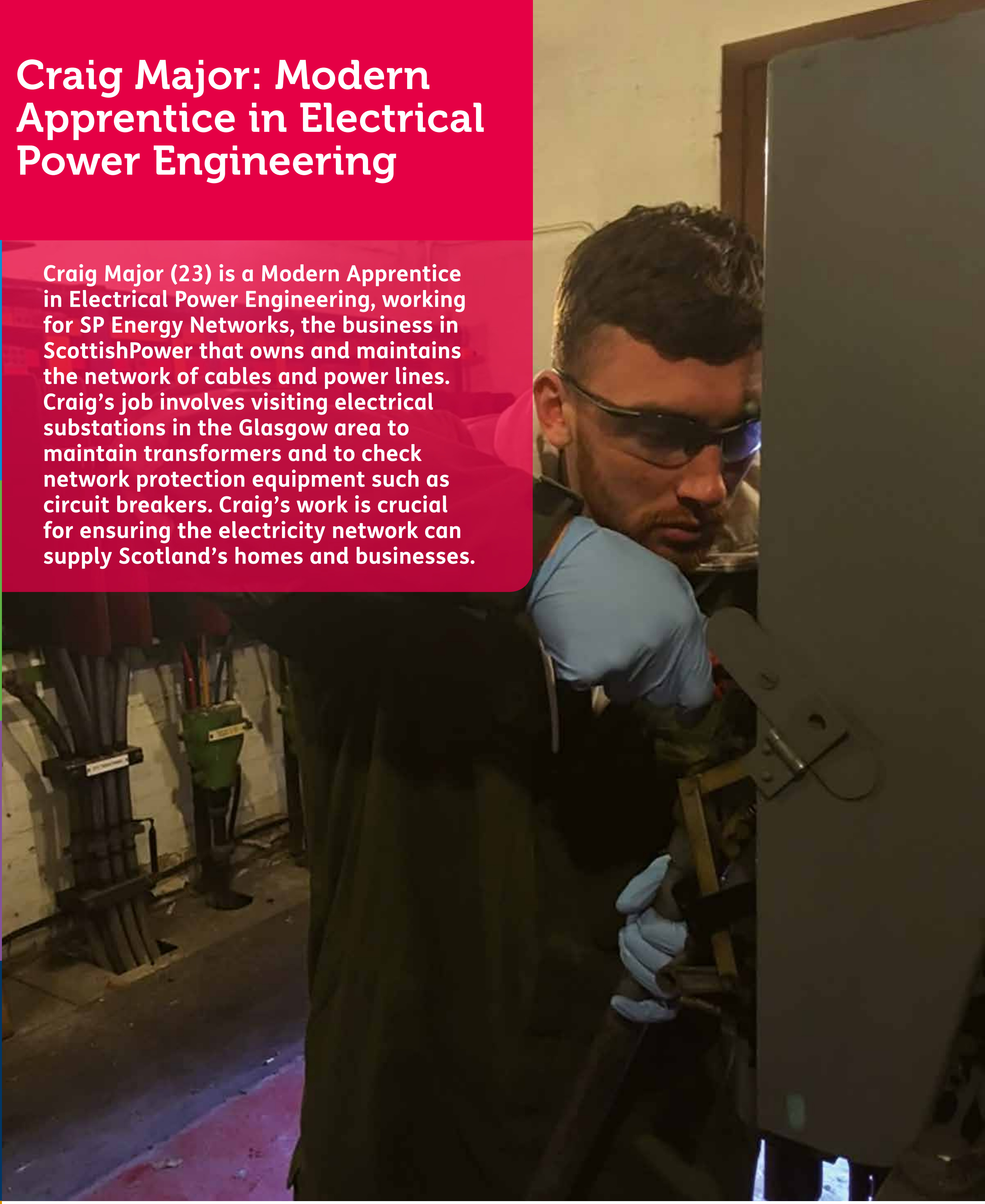
Can you name any local companies or organisations where science would be used in the workplace?

Is there a science-related career you would be interested in finding out more about?

How could you find out more about it?

Craig Major: Modern Apprentice in Electrical Power Engineering

Craig Major (23) is a Modern Apprentice in Electrical Power Engineering, working for SP Energy Networks, the business in ScottishPower that owns and maintains the network of cables and power lines. Craig's job involves visiting electrical substations in the Glasgow area to maintain transformers and to check network protection equipment such as circuit breakers. Craig's work is crucial for ensuring the electricity network can supply Scotland's homes and businesses.



SP ENERGY NETWORKS

Craig's learning pathway

Craig left school with grades that weren't quite good enough for him to get onto a Modern Apprenticeship straight away, so he applied for ScottishPower's Engineering Foundation Programme, a "pre-apprenticeship" course at Glasgow Clyde College (formerly Cardonald College), which provides the skills and entry level qualifications necessary to move into a Modern Apprenticeship. Craig's place was sponsored by ScottishPower. He attended college three days a week and received a monthly allowance towards travel and course expenses. Following completion of the course, which led to a National Certificate in Electrical Engineering, SP Energy Networks recruited Craig, and four of his course mates, onto a three-year Modern Apprenticeship in Electrical Power Engineering at Scottish Credit and Qualifications Framework level 5.

The first year involved six months of study at Forth Valley College, followed by another six months at ScottishPower's purpose built training centre in Cumbernauld. Craig says this is where he started to really "learn the basics of the trade".

Years two and three of Craig's Modern Apprenticeship have involved hands-on work every day, and shadowing more experienced colleagues. Craig records his learning in an online log-book which is signed off by an in-house assessor each month. He has meetings every three months with a manager and with his assessor from Forth Valley College.

Craig is now approaching his final "authorisation" which means he will have succeeded in completing his Modern Apprenticeship and gain a permanent job with SP Energy Networks.

How Craig uses science at work

Craig uses science along with maths in almost every task he does. He gives examples of using Ohm's law to calculate electrical resistance and the formula for working out the power (or wattage) of an electrical appliance. He says:

"We have to work out what size of cable to install depending on the load it can take. We also have to work out the size of transformers and what fuses we need."

Craig and his colleagues use science not least to keep themselves safe. He says:

"We work a lot in electrical substations, where high voltage electricity gets transformed into the right levels for homes and businesses. We have to handle cables that were live maybe only ten minutes ago! It sounds scary, but if you go through the correct procedure then it's completely safe."

Craig's advice for people thinking about following in his footsteps

Craig is keen to stress how useful understanding the physics of energy is for any electrical career. He is also keen to encourage young people to consider taking a Modern Apprenticeship. He says:

"You're getting paid every day and you're learning all the time. Instead of sitting in a classroom, you're out and about and hands-on."

Meghan Nicholson-Brown: Environmental Adviser, Roadbridge Construction

Meghan Nicholson-Brown works as an Environmental Adviser for Roadbridge, an Irish company with offices across the world. The Scotland office is located in Bellshill, Glasgow. This is Meghan's first job since finishing university in summer 2016.

Roadbridge

Meghan is currently working in Cockermouth in Cumbria, where her company is installing a 56 kilometer-long water pipeline to supply fresh drinking water for the people of the region. This is because the population of Manchester is growing, and the reservoirs that Manchester and Cumbria currently share are at risk of running low. Meghan's work will help Cumbria get its water from a new reservoir of its own.

Meghan's role includes overseeing the installation of culverts. These are plastic, concrete or steel pipes that contain the stream water, and protect the quality of the water during heavy construction work. Meghan has an important role during this process to protect sensitive environments. If need be, she has the power to stop construction work so that measures can be put in place to keep the environment safe.

Meghan's learning pathway

Meghan left school without the qualifications she needed to get into university. She decided to apply to Glasgow Clyde College (then Cardonald College) to study for a Higher National Certificate (HNC) in Applied Sciences. This course included a full range of science or science-related topics, including: chemistry, physics, biology, as well as maths and environmental science.

The HNC meant Meghan could apply to the University of Stirling to study for a Bachelor of Science degree (BSc) in Environmental Science and Outdoor Education. Meghan describes the degree as:

"Quite practical: it was outdoor-based a lot of time, and you learned lots about how to work in the field. For example, that you need to take two hats with you: a fluffy one to keep your head warm and a hard one to keep you safe!"

How Meghan uses science at work

Meghan uses a range of science in her day-to-day work. For example, she uses chemistry for monitoring and measuring the quality of water and how much silt it contains. She explains:

"I have to test the water in the rivers and streams continually for turbidity [cloudiness] and silt. I need to know how much silt has been mobilised. This is because silt gets picked up and then lands when the water slows down. When it lands it can damage fish eggs and young fish. With good working practices and constant monitoring we can ensure that we're not harming the environment."

Meghan uses her biology knowledge to identify invasive species in plants and trees. She also uses physics when she is calculating the amount of water in a river, to see how many pumps to use when her colleagues are building a temporary dam. Meghan uses maths in all of her decision making.

Meghan's advice for people thinking about following in her footsteps

Meghan believes that knowledge of science is crucial in her job. She says:

"Environmental protection is about knowing how the environment works and how to monitor it. Jobs like this are here now, and will be here in the future. The world is finally seeing that we need to protect the planet. Ultimately this is about bio-security, and protecting our supplies of food and water."

Shaun Neethling: Lecturer, Riverside Music Complex

Shaun is in the fourth year of a degree in Music Technology at the University of the West of Scotland. He also teaches part-time at the Riverside Music Complex in Glasgow, on modules in Sound Reinforcement, Multitrack Recording and Advanced Studio Techniques. These modules are part of the Higher National Certificate (HNC) and Higher National Diploma (HND) in Sound Production.

Shaun's background is in music performance in South Africa. He toured, playing drums, for a number of years, and later worked in studio production, producing other people's music, and composing and producing his own work. He had a mixing suite at home, and taught himself post-production techniques.

RIVERSIDE
MUSIC COMPLEX

Shaun's learning pathway

When Shaun moved to Scotland from South Africa, he had the chance to go back to college and learn the theory and technical craft behind his music.

He studied for an HNC and then an HND in Sound Production at the Riverside Music Complex – the two qualifications that he now teaches part-time. Afterwards, Shaun applied to the University of the West of Scotland to study for a degree in Music Technology.

Shaun says that he has enjoyed learning much more about the theory and technical craft of music production. Shaun claims that learning how music works made him "more geeky about the maths and the science". He also says that learning has given him confidence and even that it has changed his identity as a professional. He says:

"I used to be a music performer who could handle the technical side. Now I'm a technician who can apply myself in any music genre."

Next, Shaun would like to study for a Masters, then go into professional post-production work, possibly producing his own compositions. He would also be interested in a career as a "Foley artist", creating sound effects for radio, television and film.

How Shaun uses science at work

Shaun sees everything he does in music production as science-based. He says:

"Although you study the theory in the classroom, when it comes to production and performance you're not conscious that you're applying scientific principles, because it's so "hands on"."

Shaun gives a few examples of ways in which he uses science in his work and his studies:

"When we record sound we're recording small electrical signals generated from transducers in the microphones, which are basically magnets. These signals travel through copper wiring into the mixing desk where we can see a visual presentation of the sound. We use that to help us optimise the sound to the level we want it.

"We use the computer to shorten or lengthen the frequency of the sound waves, if we want to raise or lower the pitch. We measure frequency in Hertz.

"We can also measure the amplitude of the sound wave: the higher it is, the louder the volume, and we measure volume in decibels."

Shaun says that much of this scientific and mathematic theory is learned in the classroom, but that it is all applied when you are making creative decisions. He gives the example of setting up a venue for a gig, and the importance of arranging the room and equipment so that the acoustics work for the crowd and for the musicians.

Shaun's advice for people thinking about following in his footsteps

Shaun says to people thinking about a job in sound production:

"Your own musicality isn't enough. You need the technical side and the theory behind it too. All of the science you learn is contextualised and applied, but you need to understand it and be ready to apply it."

Gill Walker: Seasonal Ranger with Loch Lomond & the Trossachs National Park

Gill Walker is currently a seasonal ranger with Loch Lomond & the Trossachs National Park. Her job runs from March to October and focuses on visitor management and environmental conservation within the National Park.

Gill found her way into this role through a number of volunteering and training opportunities that allowed her to expand her knowledge and skills within the environmental conservation sector.

Gill's learning pathway

Gill grew up in the countryside and was always very interested in wildlife. At school she was particularly interested in environmental science. After school, Gill spent six months living in Australia, volunteering for a conservation organisation. On her return to Scotland, she started a degree in Conservation Biology at the University of Aberdeen that involved studying a number of areas including: zoology, forestry, geography, plant diversity and conservation.

Gill completed two years of her degree but felt that university life and academia weren't for her. Instead she worked full time in a number of different supervisory jobs within the hospitality sector and set up her own painting and decorating company, which she ran for five years. During this time she continued to study in her own time, completing modules in environmental science through the Open University.

Gill volunteers as a ranger with Woodland Trust Scotland in a visitor engagement role, drawing on the people skills she has learned in her work in the retail and hospitality industry.

Gill also volunteers with Loch Lomond and the Trossachs National Park, carrying out practical conservation roles across the park, working with the rangers and a number of partner organisations, such as Scottish Natural Heritage and the Royal Society for the Protection of Birds. These roles involve carrying out surveys of wildlife, clearing invasive species, maintaining pathways and a variety of other conservation tasks.

In 2016 Gill had the opportunity to apply to become a paid trainee with a project called The Mountains and the People. She was successful, and began a six-month traineeship. The role focused on upland footpath building and path maintenance across the National Park and, after doing a number of SQA modules including Wildlife Surveying and Habitat Management, she achieved an SVQ level 2 in Environmental Conservation.

Gill now has a seasonal job working as a ranger for the National Park where she gets to put her learning to good use.

How Gill uses science at work

Environmental protection, and the science behind it, is a major part of Gill's everyday work. Visitor engagement and education are at the forefront of her role as a ranger, but she also gets involved with wildlife surveys, which require a number of observation skills, including the ability to survey using a "transect" model. A "transect" is a path through an area. The observer moves along this transect recording data about species.

Water voles were reintroduced to the park by Forestry Commission Scotland in 2008. Water voles are difficult to spot, and Gill's volunteer role with the park sees her work with partner organisations and other rangers to survey water courses such as streams and rivers, checking for signs of water voles. These signs can include: prints, signs of vegetation being eaten, burrows and latrines. Ideal habitat is extremely dependent on how wide the water course is, and how fast the water is flowing.

Carbon in the atmosphere is a huge contributor to climate change. Gill's role with the Mountains and the People allowed her to work with the National Trust for Scotland, aiding in a peat bog restoration project. This activity aims to capture carbon in the landscape. One way of doing this is to create dams to reverse the function of drainage ditches that were dug into the hillsides after World War II. As the peatbogs become saturated, they are able to capture carbon from the atmosphere once again.

Lastly, whilst Gill was carrying out her mountain path building, she had to be aware of rock types she was working with. As well as making sure it was going to have longevity as a path feature, a particular type of rock could change the acidity or alkalinity of the soil as it erodes, which could affect what plant life can grow.

Gill's advice for people thinking about following in her footsteps

Gill stresses that a good foundation in science can open a number of doors for a future career. She says:

"It's really easy to assume that a science is one dimensional, but what I've learned is that there are so many paths of science that you can go down. You never really know where you will end up. Having a passion for being outdoors, and for animals or geology is a brilliant start, and by volunteering or getting involved with a local community project you can begin to explore a variety of fields within the science industry."

Glossary

Most scientific vocabulary used within this resource is clearly defined at point of use. This glossary aims to explain additional terms and more advanced concepts within the units.

Energy

Closed system – a system that doesn't exchange any matter (anything that has mass and takes up space) with its surroundings, and isn't subject to any external forces.

Combustion – the process of burning something. A chemical reaction that involves the rapid combination of a fuel with oxygen.

Electrical generator – a device that converts kinetic and potential energy to electrical energy for use in an external circuit.

Enzymes – biological catalysts that can increase the rate of chemical reactions without being used up. Amylase is a type of enzyme found in saliva which helps with the breakdown of food.

Glucose – a simple sugar which is an important energy source for plants and animals.

Gravitational attraction – the force that exists between any two objects within the Universe. The size of the attraction depends on how massive the object is.

Greenhouse gas – a gas that contributes to the warming of our atmosphere by absorbing infrared radiation. Carbon dioxide is an example of a greenhouse gas.

Minerals – naturally occurring inorganic (do not contain carbon) solids, with a definite chemical composition. Gold, salt and iron are all examples of minerals.

Organism – An individual form of life, such as a plant, an animal, bacteria or a fungus.

Photosynthesis – a process used by plants to convert light energy, normally from the Sun, into chemical energy that can be used to help the plant grow and survive.

Preservative – a substance or a chemical that is added to products such as food or drink to prevent it decomposing due to bacterial growth or some other undesirable chemical changes.

Respiration – the process of releasing energy from the breakdown of glucose.

Unsustainable – causing damage to the environment by using more of something than can be replaced naturally.

Tourism and Environmental Science

Temperate climate – usually describes countries mid-way between the Poles and the Equator where temperatures are 'moderate' and neither extremely hot or cold.

North Atlantic Drift – the continuation of the Gulf Stream – a warm flowing current of water – across the Atlantic towards the NW of Europe.

Matrix – fine, grained material in which larger grains or crystal can be embedded.

Corries – a steep bowl-shaped hollow found on a mountain and may contain snow all the year round, depending on shelter effects.

Plateau – an area of high land which is usually fairly flat but significantly raised above the surrounding area. Normally also has steep sides.

Hadrian's Wall – built in Roman times during the reign of the emperor Hadrian. It ran from the Solway Firth to the North Sea and marks the northern limit of the Roman invasion of Great Britain.

Latitude – a geographic coordinate that specifies how far North or South a location lies from the Equator.

Atmosphere – a layer of gases surrounding a planet.

Air mass – a volume of air that can be described by its temperature and water content.

Topography – the shape and features of the surface of the Earth.

Socio-economic – how economic activity influences, and can be influenced by, society.

Mitigation – taking action to reduce the severity of something.

Food security – ensuring there is an adequate supply of food and individuals have adequate access.

Ocean current – A permanent and continuous movement of water in a specific direction as a result of the Earth's rotation, the wind, temperature and saltiness.

pH scale – used in chemistry to specify whether a solution is acidic or alkaline. This can be linked to the activity of hydrogen ions and it is thought that pH stands for the 'power of hydrogen'.

Creative Industries

Magnetic field – the magnetic effect of magnetic materials and electric currents. A region of space where magnetic forces can affect objects.

Diaphragm – in acoustics, a thin, semi-rigid membrane that vibrates to produce or transmit sound waves.

Photosynthesis – a process used by plants to convert light energy, normally from the Sun, into chemical energy that can be used to help the plant grow and survive.

Interdisciplinary – the combining of two or more academic disciplines into one activity or field of study.

Prism – In optics, a transparent 3D shape with flat, polished surfaces that refract light.

Biodegradable – capable of being decomposed by bacteria or other living organisms and thereby avoiding pollution.

Synthetic fibres – manmade fibres, usually from chemical sources.

Life Sciences

Pharmaceutical – relating to medicines or medicinal drugs and their manufacture or sale.

Micro-organism – a living thing that is microscopic and cannot be seen with the naked eye. Can be single cell, or made from many cells.

Penicillin – a type of antibiotic. Antibiotics are used to treat or prevent some types of bacterial infection. They work by killing bacteria or preventing them from spreading.

Amphibian – cold-blooded animals that normally start life living in the water and then adapt to live on the land.

Nutrients – found in food to help organisms survive and grow.

Ethical – dealing with morals, or moral principles.

Cross-pollination – when one plant pollinates another plant of a different variety or type.

Food and Drink

Body cells – cells are the basic building blocks of all living things. The human body is composed of trillions of cells. They provide structure for the body, take in nutrients from food, convert those nutrients into energy, and carry out specialized functions.

Filtration system – an operation that allows the separation of solids from fluids by adding a medium, or ‘filter’, through which only the fluids can pass.

Inhibit – an action or process that restrains or prevents an action taking place.

Mould – a soft green or grey growth that can grow on old food or on objects that have been exposed to warm, damp conditions for a prolonged period of time.

Natural preservatives – a naturally occurring substance that can be added to a product to prevent decay by the growth of micro-organisms or by unwanted chemical changes.

Sustainable – able to be maintained at a certain level or rate.

Synthetic preservatives – a man-made substance that can be added to a product to prevent decay by the growth of micro-organisms or by unwanted chemical changes.

Toxins – any poisonous substance produced by living cells.

Helpful websites

- Counting on a Greener Scotland (COGS) is an adult learning resource which explores weather, climate and climate change and energy and renewables and links to everyday life.
  http://myclyde.ac.uk/course/view.php?id=82
- The BBC's free online study support resource for school-age students in the United Kingdom. It is designed to aid students in both schoolwork and, for older students, exams.
  www.bbc.co.uk/education
- The Scottish Wider Access Programme (SWAP) supports access to higher education for adult learners. SWAP access programmes run at colleges across Scotland and are a proven route into hundreds of degree courses at partner universities.
  www.scottishwideraccess.org
- Glasgow Science Centre creates interactive experiences that inspire, challenge and engage to increase awareness of science for all in Scotland.
  www.glasgowsciencecentre.org
- Dundee Science Centre is a charity and lifelong learning resource for the community.
  www.dundeesciencecentre.org.uk
- Dynamic Earth, in Edinburgh, tells the story of planet Earth and how our Earth works, how life has evolved on its differing environments and the future challenges faced by planet Earth.
  www.dynamicearth.co.uk
- Aberdeen Science Centre is a pioneer of interactive science discovery in Scotland. Today our dynamic team continues to develop interactive programmes transporting visitors, of all ages and backgrounds, to the heart of discovery.
  http://aberdeensciencecentre.org
- National Museums Scotland cares for collections of national and international importance.
  www.nms.ac.uk
- Glasgow Riverside Museum offers workshops and exhibits linked to transport and energy use.
  www.glasgowlife.org.uk/museums/riverside
- The Hunterian Museum is Scotland's oldest public museum and home to one of the largest collections outside the National Museums.
  www.gla.ac.uk/hunterian
- Whitelee windfarm visitors' centre offers hands-on interactive activities.
  www.whiteleewindfarm.com
- Hunterston Power Station invites people to explore nuclear power generation at Hunterston B Power Stations Visitor Centre with interactive exhibition which explains how electricity is generated in a nuclear power station.
  www.edfenergy.com/energy/power-stations/hunterston-b

- The James Hutton Institute is a well-respected and globally recognised research organisation delivering fundamental and applied science to drive the sustainable use of land and natural resources.
  www.hutton.ac.uk
- The Open Air Laboratories (OPAL) network is a UK-wide citizen science initiative that allows you to get hands-on with nature, whatever your age, background or level of ability.
  www.opalexplorenature.org
- The British Science Association (BSA) is a charity, founded in 1831. Its vision is of a world where science is at the heart of society and culture.
  www.britishscienceassociation.org/citizen-science
- Science Connects is responsible for the co-ordination and management of the STEM Ambassador Programme in the West of Scotland, inspiring young people in Science, Technology, Engineering and Mathematics.
  www.scienceconnects.org.uk
- STEM Ambassadors are able to enhance and enrich the teaching and learning of STEM subjects by sharing their own interest, skills and experience in STEM.
  www.stem.org.uk/stem-ambassadors/ambassadors
- Scottish Consortium for Rural Research (SCRR) is a consortium of Scottish organisations active in research relating to land, freshwater, coastal and marine resources.
  www.scrr.ac.uk/schools.php
- EDT – A nationwide education charity providing opportunities for young people in science, technology, engineering and mathematics.
  www.etrust.org.uk/contact-edt-scotland
- FDFS represents the interests of the food and drink manufacturing industry in Scotland.
  www.fds.org.uk
- Skills Development Scotland is the national skills body supporting the people and businesses of Scotland to develop and apply their skills.
  www.skillsdevelopmentscotland.co.uk
- SEA LIFE Trust – Inspires conservation campaigns and fund projects and education programmes that champion the need for plastic-free oceans, sustainable fishing, effective Marine Protected Areas and an end to over-exploitation of marine life.
  www.sealifetrust.org
- SNH's work is about caring for the natural heritage, enabling people to enjoy it, helping people to understand and appreciate it, and supporting those who manage it.
  www.snh.gov.uk
- The Mountains and the People project involves people in the enhancement and protection of the wild and special qualities of the mountains within Scotland's National Parks.
  themountainsandthepeople.org.uk
- The John Muir Trust's mission is to conserve and protect wild places with their indigenous animals, plants and soils for the benefit of present and future generations.
  www.johnmuirtrust.org

Curriculum mapping

Curriculum for Excellence Science Experiences and Outcomes

***Science for a Successful Scotland* has been developed as an adult learning resource but it also provides many learning and teaching opportunities for primary and secondary school practitioners. The five units within the resource can be used in a variety of ways to support learning, teaching and skills development within several curricular areas, including the Sciences, Technologies, Numeracy and Mathematics, Social Studies and Health and Well-being. The resource can also be used to support an interdisciplinary learning approach.**

Since our key project aims focus on increasing knowledge and skills in the sciences, a mapping of the content within each of the units to relevant Curriculum for Excellence experiences and outcomes in the Sciences at first, second and third level, has been provided as a guide for practitioners. Experiences and outcomes (often called Es+Os) are a set of clear and concise statements about children's learning and progression in each curriculum area. They are used to help plan learning and to assess progress.

https://education.gov.scot/scottish-education-system/policy-for-scottish-education/policy-drivers/cfe-%28building-from-the-statement-appendix-incl-btc1-5%29/Experiences%20and%20outcomes#sciences

The experiments and activities included in the resource will also contribute to a range of scientific skills development, namely - inquiry, investigation, analytical thinking and scientific literacy skills as highlighted within Education Scotland's Benchmarks for the Sciences, which aims to provide clarity on the national standards expected within the science curriculum at each level.

https://education.gov.scot/improvement/Pages/Curriculum-for-Excellence-Benchmarks-.aspx

Unit 1: Energy	Experiences and Outcomes
Energy Types and The Law of Conservation	SCN 1-04a, SCN 2-04a
Energy and Biology	SCN 1-02a, SCN 1-03a, SCN 2-02a, SNC 2-02b, SCN 3-02a
Energy and Chemistry	SCN 2-15a, SCN 3-15b, SCN 2-19a
Energy and Physics	SCN 2-04b, TCH 2-02b

Unit 2: Tourism and Environmental Science	Experiences and Outcomes
Geology	SCN 2-17a, SCN 3-17a
Weather and Climate Change	SCN 2-05a, SCN 3-05a, SCN 3-05b
Ocean Acidification	SCN 3-18a

Unit 3: Creative Industries	Experiences and Outcomes
Science of Sound	SCN 1-11a, SCN 2-11a
Science of Light	SCN 3-11a, SCN 3-11b, SCN 4-11b
The Science of Materials	SCN 4-16a

Unit 4: Life Sciences	Experiences and Outcomes
Living Things	SCN 2-01a, SCN2-02a
Human Body Systems	SCN 2-12a, SCN 3-12a
Health Technology	SCN 3-12b
Cells and Micro-Organisms	SCN 1-13a, SCN 2-13a, SCN 3-13b, SCN 4-13c

Unit 5: Food and Drink	Experiences and Outcomes
Mixtures and Solutions	SCN 2-16a, SCN 2-16b
Acids and Alkalis	SCN 3-18a, SCN 2-19a
Micro-organisms	SCN 2-13a, SCN 3-13b

The following Topical Science outcomes are also explored across the units -

SCN 2-20a, SCN 2-20b, SCN 3-20a, SCN 3-20b, SCN 4-20a

We hope that this innovative and flexible resource with its associated case studies will not only help to support practitioners in their delivery of science within Curriculum for Excellence, but also enable successful family learning. This will encourage both parents and pupils to recognise the benefits and potential career paths from choosing science subjects for the senior phase within Scottish education.

Activities mapped against SQA Core Skills

SQA's Core Skills[1] reflect fundamental skills that are deemed necessary to live and work in today's world. The Core Skills are: Communication; Numeracy; ICT; Problem Solving; and Working with Others. The Core Skills are available at SCQF levels 2 to 6.

We have undertaken a subjective exercise to identify how we believe the activities in Science for a Successful Scotland can produce evidence of capability for each of the Core Skills, and the level at which we believe they can best produce it. SQA have not been involved in this mapping document and it should be used purely as a guide.

Key: 4 = produces evidence mostly at SCQF level 4

(4) = could produce evidence mostly at SCQF level 4 with some adaptation: for example, an activity could produce evidence for Working with Others if it were undertaken in a group rather than by an individual working alone

Unit 1: Energy

Activity	Communication	Numeracy	ICT	Problem Solving	Working with Others
Energy transfers in everyday life	4	-	-	-	(4)
Planning a seed growing investigation	4	4	-	4	(4)
Food chains and food webs	4	-	(4)	4	(4)
Kitchen chemistry – a toasty experiment	4	4	-	4	(4)
Bicarbonate of soda volcano: a chemical reaction experiment	4	(4)	-	4	(4)
Calculating the running costs of electrical equipment	4	4	-	4	(4)
Nuclear energy discussion	4	-	-	-	4

[1] https://www.sqa.org.uk/sqa/37801.7292.html

Unit 2: Tourism and Environmental Science

Activity	Communication	Numeracy	ICT	Problem Solving	Working with Others
Earthquake House, Comrie	4	-	4	-	(4)
Scottish rocks in use	4	-	4	-	4
Water cycle in a bowl experiment	4	4	-	4	(4)
The particle model challenge	4	-	-	4	(4)
Local weather investigation	4	4	4	4	4
Climate change and Scottish impacts	4	(4)	(4)	-	4

Unit 3: Life Sciences

Activity	Communication	Numeracy	ICT	Problem Solving	Working with Others
Life processes and classification	4	-	-	-	(4)
Monitoring health	4	4	(4)	4	4
All about cells	4	-	-	-	-
DNA and its applications (plus GM crops)	4	-	-	-	4

Unit 4: Creative Industries

Activity	Communication	Numeracy	ICT	Problem Solving	Working with Others
Science and numeracy	4	4	-	-	(4)
Science of sound	4	4	4	4	(4)
Sound of light	4	4	4	4	(4)
Sound of materials	4	-	4	-	(4)

Unit 5: Food and Drink

Activity	Communication	Numeracy	ICT	Problem Solving	Working with Others
Mixtures and solutions	4	4	-	4	(4)
Acid or alkali experiment	4	4	-	4	4
Food and micro-organisms	4	4	4	4	(4)
Healthy eating	4	4	(4)	4	(4)

Activity answers

ENERGY

Activity: Energy Transfers in Everyday Life

1. a. Electrical transfers to heat, movement, sound
   b. Chemical transfers to electrical and a little heat
   c. Electrical transfers to heat, light
   d. Potential transfers to movement, sound
   e. Elastic potential transfers to motion, sound
   f. Chemical transfers to heat, light

2. Information for this found in Energy section pages 10 and 11

Activity: Energy Efficiency Calculations

1. Kettle efficiency = (350 ÷ 400) x 100 = 87.5%

2. Lawnmower efficiency = (300 ÷ 500) x 100 = 60%

3. Wind turbine efficiency = (8000 ÷ 10000) x 100 = 80%

4. Speakers efficiency = (200 ÷ 300) x 100 = 66.66%

Activity: Food Chains and Food Webs

1. a. Wildflowers Rabbit Hawk
   b. Grass Mouse Snake

2. Example answer for Marine: Producers: phytoplankton/seaweed; Primary consumers: small fish (juvenile stage of fish)/crustaceans (shrimps); Secondary consumers: larger fish (tuna)/sea mammals (dolphins).

Ocean acidification may impact crustacean populations which may seriously impact many species of fish.

3. Example answer: Pesticides can help to reduce plant diseases, reduce the number of pests eating crops and reduce the growth of weeds but they can also be hazardous to health. Consequently it is important that pesticides do not get into the human food chain and they must be used wisely. DDT, a powerful insecticide was found to remain in soil after killing insects – this is a good topic/case study for research.

Activity: Calculating the running costs of electrical appliances

Appliance	Power (kW)	Time used (hours)	Energy (kWh)	Cost per kWh (pence)	Cost of Energy used (pence)
Light Bulb	0.1	5	0.5	10	5
4 Slice Toaster	1.3	0.1	0.13	10	1.3
Kettle	3.0	0.5	1.5	10	15
Hairdryer	2.0	0.2	0.4	10	4
Microwave	0.8	0.3	0.24	10	2.4
Tumble Dryer	4.5	1	4.5	10	45

Activity: Nuclear Energy Discussion

Example answers:

NO	YES
List 3 arguments for why Scotland **should not use** nuclear energy	List 3 arguments for why Scotland **should use** nuclear energy
1. risk of contamination	1. clean
2. low probability of risk/hazard but this low probability would have a dangerously high impact	2. safe
3. terrorist threat	3. cheap

TOURISM AND ENVIRONMENTAL SCIENCE

Activity: Scottish Rocks in Use

1. Example answers:

a. Granite – a coarse-grained, pale-coloured, silica-rich igneous rock.
Example: Duke of Wellington plinth made from Aberdeen granite

b. Sandstone – a medium grained sedimentary rock
Example: Kelvingrove Art Gallery Glasgow

c. Slate – a fine grained metamorphic rock
Example: Scottish slate roof tiles

Activity: Water Cycle in a Bowl Experiment

What should have happened:

The heat from the sun evaporates the water, which rises and then condenses on the cool plastic and drops into the beaker/yogurt pot.

Use details from Tourism and Environmental science unit (The Science of Weather – The Water Cycle) to help label the process.

Activity: The Particle Model Challenge

ICE	LIQUID WATER	WATER VAPOUR
• Has a fixed shape and a fixed volume • the particles are packed close together • the particles can only vibrate	• can flow • can change its shape but has a fixed volume • the particles are close together but can move on top of each other	• has no fixed shape or volume • the particles are very far apart • can be compressed

LIFE SCIENCES

Activity: Life Processes and Classification

Life Process	Statement
Respiration	All living things use this process to release energy from food.
Excretion	The act of getting rid of waste in order to survive.
Movement	Animals do this in order to find food.
Reproduction	Birds lay eggs to carry out this life process.
Nutrition	All living things need food.
Sensitivity	Responding and reacting to environment changes e.g. light, heat.
Growth	Changing from a young state to adult size.

Activity: All About Cells

Words should appear in the following order: cell membrane, cytoplasm, nucleus, chromosomes, chloroplasts, vacuole, cell wall, cellulose.

Activity: DNA and its applications

Words should appear in the order as follows: molecule, double helix, instructions, function, deoxyribonucleic acid, nucleus, genes, chromosomes, humans

CREATIVE INDUSTRIES

Activity: Science and Numeracy

1. distance = speed x time = 7km/h x 4 hrs = 28 km

2. distance = speed x time = 0.5 hrs x 10 km = 5 km

3. speed = distance ÷ time = 250km ÷ 2hrs = 125km/hr

4. time = distance ÷ speed = 480 km ÷ 80 km/h = 6 hours

5. time = distance ÷ speed = 24m ÷ 32m/hr = 0.75 hr (45 mins)

6. distance = speed x time = 600km/hr x 6.5 hrs = 3,900 km

7. distance = speed x time = 343m/s x 60 secs = 20,580 m

Activity: Science of Sound

1. Words should appear in the following order: vibrations, vacuum, frequency, pitch, Hertz, loudness, loud, decibel scale, 120 decibels
2. Fan 1. Use equation time = distance ÷ speed (50m ÷ 343m/s) = 0.146 seconds
   Fan 2. Use equation time = distance ÷ speed (250m ÷ 343m/s) = 0.729 seconds
   Time difference between sound reaching the fan at the back is 0.729s – 0.146s = 0.583s

Loudspeaker diagram

Example answer: www.explainthatstuff.com/loudspeakers.html

Activity: Science of Light

2. Words should appear in the following order: waves, light, frequencies, wavelengths, second, Hertz, metres, radio waves, gamma rays, TV programmes, visible, colours

Activity: Science of Materials

2. Example answers:
   Electroluminescent materials give out light when an electric current is applied to them. Example uses include safety signs and clothing for use at night.
   Thermochromic materials change colour as the temperature changes. Example uses include contact thermometers and test strips on the side of batteries.

FOOD AND DRINK

Activity: Mixtures and Solutions – Scientific Terminology

Term	Definition
Solution	A liquid with a substance dissolved in it
Saturated Solution	A solution in which the maximum amount of solute has been dissolved in a solvent
Solute	A substance which creates a solution when dissolved in a solvent
Insoluble	A substance which does not dissolve in a liquid
Solvent	Normally a liquid in which another substance is dissolved
soluble	A substance which does dissolve in a liquid

Activity: Mixtures and Solutions – Experiments

Dissolving experiment

Saturation point

Factors affecting dissolving

1. Increases
2. Quicker
3. Slower, because the surface area which is presented to the solvent is reduced. This means the solvent will take longer to act on the solute.
4. Speeds up

Activity: Healthy Eating

Essential nutrients

1. Example answers:

Nutrient		Food Example
Carbohydrates:	Starch Sugar	Bread, potatoes, cake
Proteins		Eggs, fish, meat
Fats:	Unsaturated	Avocados
	Saturated	Butter
Vitamins:	A	Carrots
	B	Eggs, fish
	C	Citrus fruit, leafy greens
	D	Oily fish
Minerals:	Calcium	Milk, cheese
	Iron	Kale, red meat

2. Example answers:

It can increase cholesterol levels

Can increase risk of heart disease and stroke

Counting kJ's

1. a. 4 x 329 = 1316kJ's

b. (2 x 329) + 500 = 1158kJ's

Eat local investigations

2. Example answers:

Advantages of food imports	Disadvantages of food imports
• Access to products we can't grow easily here like pineapples. • Can get products all year round – e.g. strawberries can be bought in the winter months when they are not grown in Scotland. • Could be cheaper products. • Protects against over reliance on homegrown crops only.	• Climate impact of product transportation. • Added cost of travel on top of product cost. • Working conditions in developing countries not always fair trade. • If cheaper from abroad e.g. strawberries, fewer people buy local which has an impact on local growers livelihoods. • Some imports may come from countries with less stringent quality standards.

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