Catalyst

GCSE Science Review

Volume 17
Number 3
February 2007

Deadly sparks

philip allan UPDATES
www.philipallan.co.uk

Catalyst

Volume 17 Number 3 February 2007

The front cover shows what can happen if there is a fault with a plug or socket (Alan Sirulnikoff/SPL).

Contents

How science works

Welcome to the February issue of Catalyst. In this issue, two articles look at aspects of the way in which science works. William Herschel and his sister Caroline made great contributions to astronomy, including the discovery of Uranus. William is also known for his discovery of infrared radiation (which later led to the discovery of the complete electromagnetic spectrum). We look at the thinking that went into his series of experiments, and have arranged for his papers describing them, published in 1800, to be available to you on the Royal Society's website.

We also look at different theories of evolution. Why do most scientists reject the idea of intelligent design as an alternative to Darwin's theory of evolution by natural selection? Darwin's ideas have been tested many times; they have been modified and extended, but, like Herschel's, they have withstood the test of time.

David Sang

Published by Philip Allan Updates, Market Place, Deddington, Oxfordshire OX15 0SE.
www.philipallan.co.uk

ISSN 0958-3629

Publishing Editor: Catherine Tate.
Design and artwork: Caleb Gould.
Reproduction by De Montfort Repro, Leicester.
Printed by Raithby, Lawrence and Company, Leicester.
Printed on paper sourced from managed, sustainable forests.

Eyes

Nigel Collins

Steve Allen/SPL

Capillaries show up clearly in this healthy retina, viewed through an ophthalmoscope

We depend on our eyes to provide us with information about our surroundings. This article looks at the basic functioning of the eye and at what can be done to maintain function when something goes wrong.

GCSE key words
Short sight
Long sight
Colour blindness
Parts of the eye

The structure of the eye is shown in Figure 1. Light is refracted as it enters and passes through the eye and what is being looked at should end up being focused on the light sensitive cells of the retina, which line the eye.

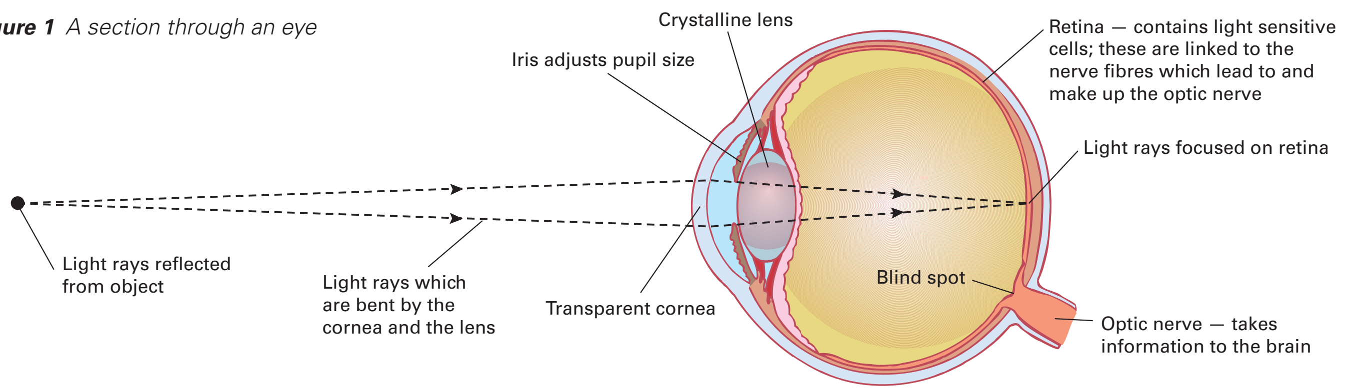
If you need an eye test the retina is one of the first places an optometrist will look. He or she will use an **ophthalmoscope** to look through the pupil of your eye to examine the retina at the back. The retina is the only place in the body where it is possible to see blood vessels and nervous tissue clearly, without surgery.

Eyes out of focus

The normal light path through the eye is shown in Figure 1. The cornea is responsible for much of the refraction, but only by a fixed amount; the lens refracts less but is adjustable, so contributes to fine focusing.

- **Make sure that you can identify all the parts of the eye shown in Figure 1.**

Figure 1 *A section through an eye*



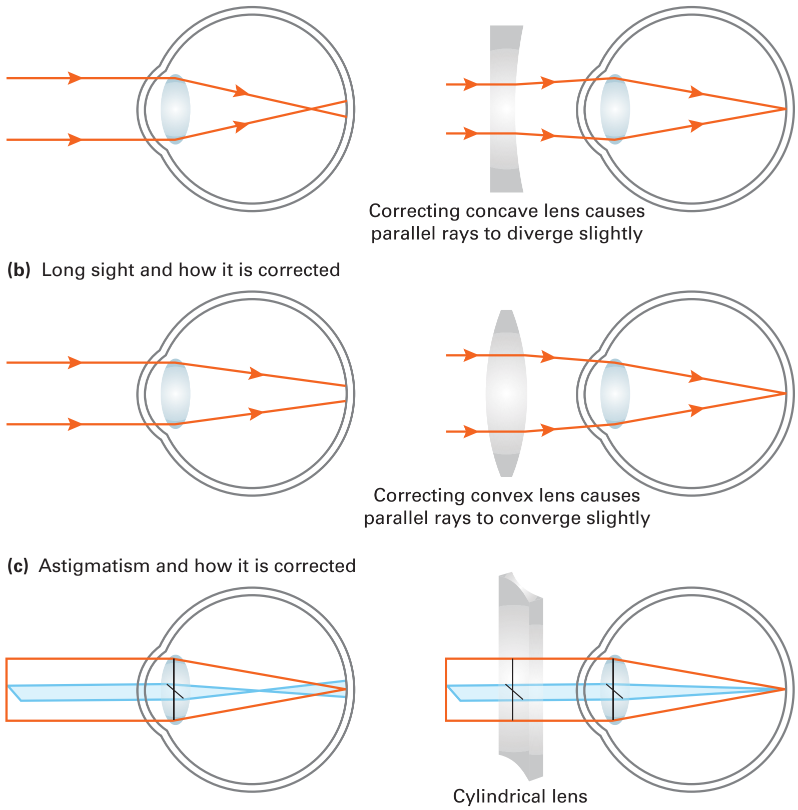


Figure 2 ***(a)*** *Short-sightedness,* ***(b)*** *long-sightedness,* ***(c)*** *astigmatism*

In this prescription the right eye is short sighted and needs a diverging lens of power –1.00 D.

It is also astigmatic and needs a cylindrical component of power –0.75 D with its axis positioned at 90° to the horizontal.

It also needs a prism so that both eyes see in the same direction.

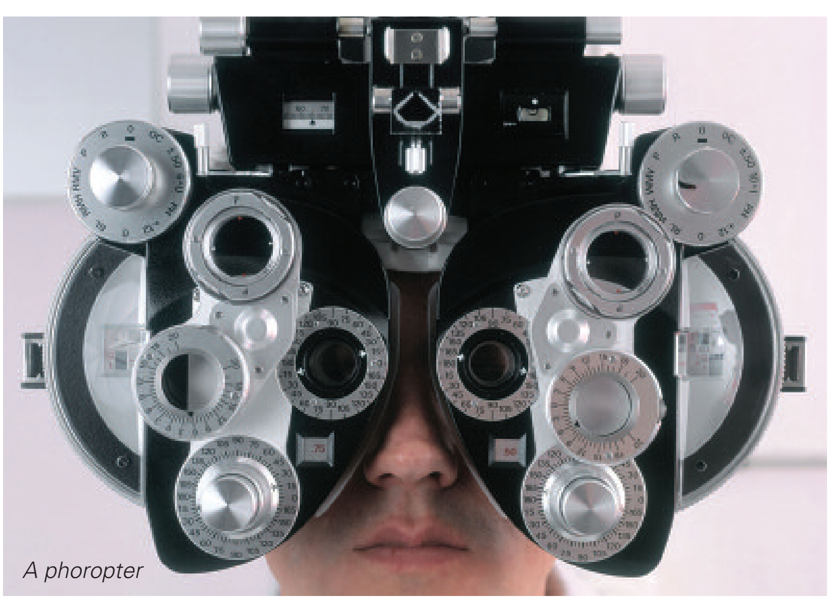
RIGHT	Sph	Cyl	Axis	Prism	Base		Sph	Cyl	Axis	Prism	Base	LEFT
	-1.00	*-0.75*	*90*			Distance	*-1.00*			*1Δ*	*IN*	
	+1.50	*-0.75*	*90*			Near	*+1.50*					

For near vision a converging lens of power +1.50 D with the same correction for astigmatism is needed.

The left eye needs the same spherical power without the astigmatic correction.

D = dioptres

Figure 3 *NHS prescription form*



A phoropter

Frank Chmura/Alamy

Problems with focusing

The following three conditions make it impossible to focus unaided: myopia, hypermetropia and astigmatism.

Myopia (short- or near-sightedness) is a defect of the eye in which the image is focused in front of the retina. People with myopia can normally see nearby objects clearly, but distant objects appear blurred. This is because the eye is too long or its focusing power is too great.

The opposite condition is **hypermetropia** (far- or long-sightedness). This occurs when the cornea is too flat or the eye is too short, causing the image to form behind the retina. A person suffering from this cannot focus on near objects; in extreme cases, a sufferer may be unable to focus on objects at any distance.

Both of these defects may be complicated by **astigmatism**. This occurs when the eye has uneven curvatures, so that, for example, horizontal lines may appear in sharper focus than vertical ones.

Figure 2 shows the ray patterns and the correcting lenses for each of these conditions.

Detecting problems with focusing

All three conditions can be detected using a **retinoscope**. The optometrist shines a light into your eye from the retinoscope and moves the beam from side to side, observing its reflection from the retina. This tells the optometrist whether you are short- or long-sighted or suffer from astigmatism.

The optometrist then uses another instrument, a **phoropter**, to measure how much your eyes refract light incorrectly. You look through it at an eye chart placed at optical infinity (6 metres). The optometrist then changes lenses and other settings, while asking you for feedback on which settings give the best vision.

Correcting problems with focusing

Optometrists grade lenses by their 'light bending' power, measured in dioptres. The power of a lens in dioptres = 1/focal length of the lens (metres). Converging lenses have positive powers, diverging concave lenses have negative powers. By inserting different lenses in the phoropter frame, the optometrist assesses the power of the lenses you need to correct the defects in your eyes. The optical power of these lenses increases in steps of 0.25 dioptres.

In general, diverging lenses are used to correct short-sightedness (Figure 2a) and converging lenses to correct long-sightedness (Figure 2b). Astigmatism can often be corrected by glasses with a more complicated lens, with different radii of curvature in different planes, a so-called **cylindrical lens** (Figure 2c).

Figure 3 is a prescription arising from an eye test, with comments explaining the values in the different boxes.

Colour blindness

The most common cause of colour blindness is an inherited disorder which affects some of the receptors in the retina. Other causes include damage to the retina, to the optic nerve or to visual centres in the brain. Few people are completely colour blind — seeing only in black and white and all the shades of grey in between. Most suffer from a condition in which they have trouble telling red from green.

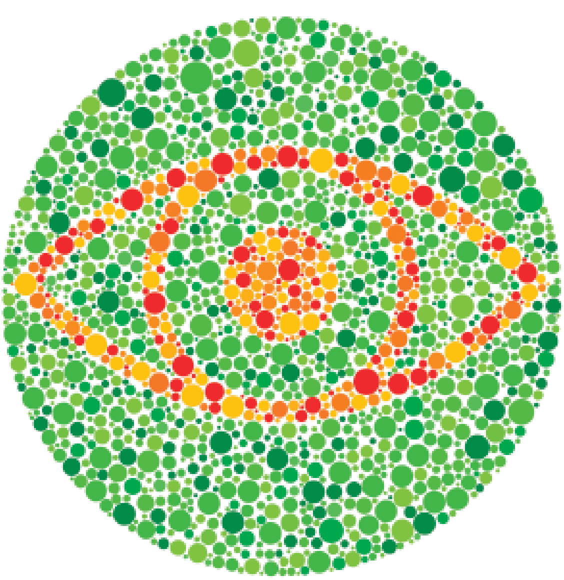
Diagnosis

Diagnosis of basic colour blindness is often done with Ishihara cards (Figure 4). Colour blindness (or deficiency) is caused by recessive alleles. It is much more common in men, as the recessive allele is carried on the X chromosome. A single copy of the recessive allele is expressed, as there is no dominant allele on the small Y chromosome to mask its presence.

Cone cells

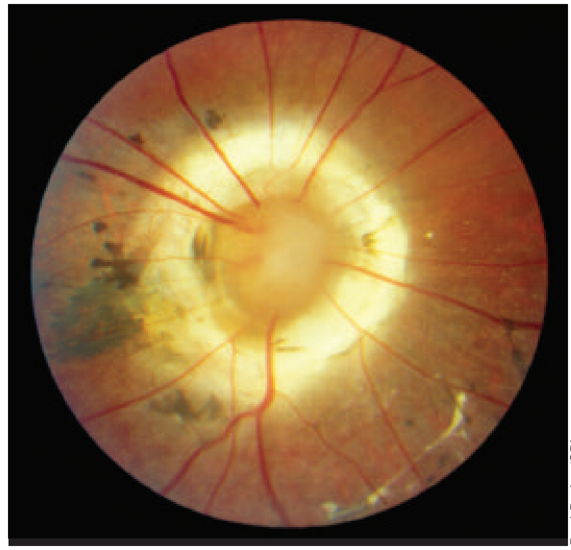
The retina includes two types of cell: **rod cells** (active in low light intensities) and **cone cells** (active in broad daylight). There are three types of cone cell and each type contains a pigment which absorbs light across a different and overlapping range of wavelengths. Between the three, with overlap, they cover the visible spectrum. Nevertheless, they are often referred to as 'blue', 'green' and 'red' receptors. Light across a limited range of wavelengths will stimulate some or all of them to a greater or lesser extent, so that the eye can discriminate between subtly different colour hues.

Colour blindness arises from partial or complete defects in particular types of cone. The commonest defect leads to difficulty in discriminating between reds, yellows and greens — so called red-green colour blindness.



David Nicholls/SPL

Figure 4 *Ishihara card. A person with normal vision will be able to see an image of an eye. A person who is colour blind will not see the eye*



Paul Parker/SPL

Left: *Damage caused inside the eye by glaucoma*

● **Find out more about the effects of glaucoma at www.VisionSimulations.com/Glaucoma.htm**

Glaucoma

The fluid inside the eye is slightly pressurised. Because the eye is a very tough structure it cannot expand if the pressure increases for any reason — as a result, increasing pressure is exerted on the lining of the eye. This condition is called **glaucoma**. The weakest point in the lining is where the optical nerve leaves the eye and as this becomes damaged peripheral vision is reduced. This causes the area of effective vision to shrink. If left untreated, glaucoma can cause blindness.

High blood pressure (see 'Blood pressure', CATALYST Vol. 17, No. 1) can cause glaucoma. Optometrists routinely check the pressure in the eyes of patients over the age of 40 using a **tonometer**. There are two main methods. One uses a sterile probe which is pressed against the surface of the cornea. The force needed to flatten a particular area of the cornea is measured and this correlates with the pressure inside the eye. Before the test, anaesthetic drops are placed in the eye, followed a short while later by a drop of yellow fluorescein dye, which, used with a blue filter makes it easier for the optometrist to check the flattened area. Another method places a nozzle close to the cornea and the deflection of the cornea surface is measured when a puff of air is blown at it. Although not as accurate as the first method it is useful for screening and with young children.

● **Find out more about colour blindness at www.VisionSimulations.com/Color.htm**

Some visual problems are caused by faults in brain processing, not in the eye.

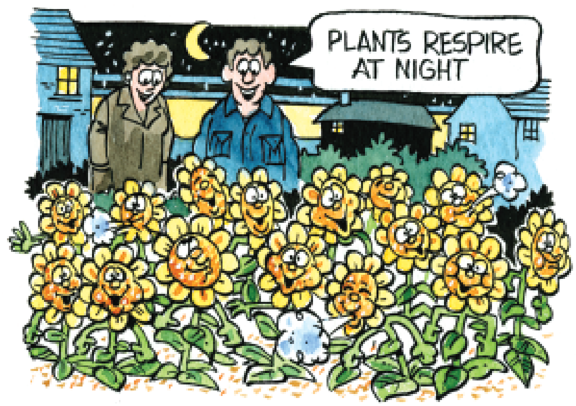
The rows of letters on an eye test chart are numbered. The row labelled '20' should be legible at a distance of 20 feet (6 metres) if your eyesight is good; hence '20/20 vision'.

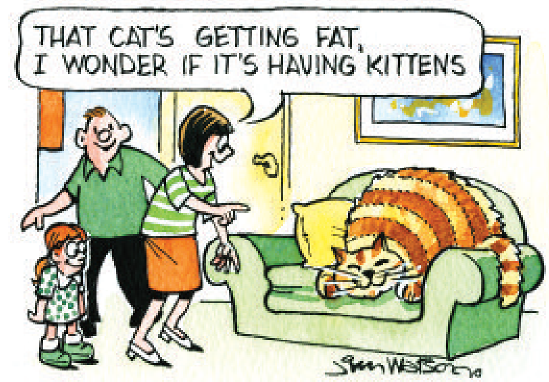
Cataracts

The lens in the eye is completely transparent. In older people it may become progressively more cloudy. Clouding causes vision to become more and more blurry and often more yellowish or brownish over time. This can have a huge impact on people's lives, preventing them from reading or driving. The clouding (cataract) cannot be reduced, but the lens can be removed and replaced with a plastic lens (or a transplanted one), which can improve vision greatly.

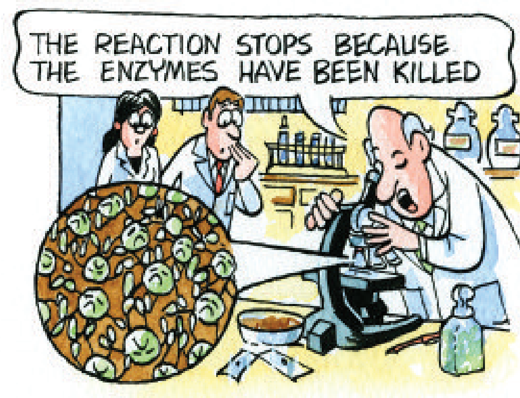
● **Find out more about cataracts at www.VisionSimulations.com/Cataract.htm**

Nigel Collins *is a myopic and an editor of* CATALYST.





Mind your language



Literacy — how well you understand what you read and how well you express yourself in writing — is as important as knowledge in doing well in exams. This is true in science subjects as much as in English.

If a question requires you to write a chemical formula or to calculate how fast a lawn mower is moving the answer is clear and unambiguous. Either you have got it right or you have made a mistake — there isn't much chance of writing something you didn't mean to. Chemistry and physics questions often require this kind of answer. However, in biology many questions ask you to describe or explain something in one or two sentences. If you're not careful, a casual use of words that also have a precise scientific meaning can trip you up.

Fat cats not lenses

Let's take the word 'fat' as an example. In everyday life we often use 'fat' to mean 'big' — for example, a fat pay packet, fat tyres on a customised car, or 'that cat's getting fat, I wonder if it's having kittens'. However, in biology and chemistry 'fat' has a precise meaning. It is a type of organic hydrocarbon molecule, comprising carbon, hydrogen and oxygen atoms; and there are often double bonds in the molecule. It is found in living tissue as a component of cell membranes and it forms an energy store. When you describe a cat as getting fatter, scientifically you are saying that it has laid down more fat deposits, not that it could be pregnant.

This can cause real problems in exam questions. Take the following question about the human eye, for example:

Describe how the lens changes shape when you stop looking at a distant object to focus on something nearby.

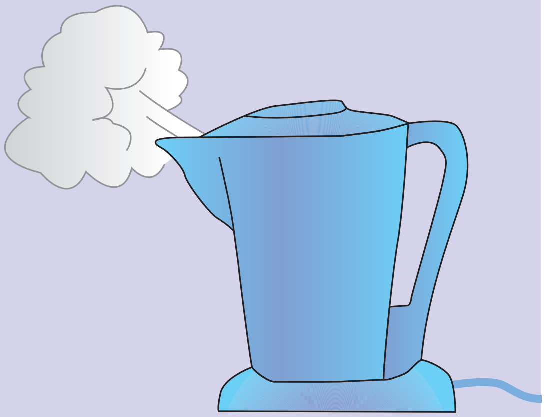
The correct answer is that the ciliary muscles contract, the suspensory ligaments slacken and the lens springs into a **more convex** shape (see Figure 1). However, many people would say that the lens has gone from being thin to being fatter. You would not earn any marks if you wrote this because the lens has not had fat laid down in it to change its shape.

Common mistakes

'Close the door, you'll let the cold in'

What's wrong with the above statement? Heated air molecules have more energy, move around more

Box 1 Evaporation



All too often students write 'a substance boils (or evaporates) because bonds in the molecule break'. This is wrong. It is bonds *between* molecules that break, not bonds within the molecule itself. Think about water. When water boils, steam (water vapour) is given off, not hydrogen and oxygen — if you got these, you would have solved the world's energy problems!

Box 2 'Electricity flows...'

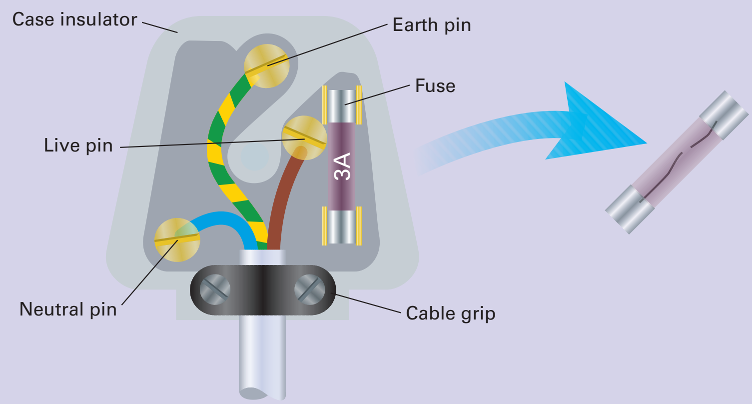


Figure 2 *The wire in the fuse has melted. A larger than normal flow of current causes it to melt*

Topics connected to electricity seem to be a minefield for the unwary. Most of the errors come from everyday language which is often used incorrectly even by those who work in the field. For example, electricians often talk about fuses blowing, but if you do that in an exam paper your mark could be at risk. Fuses break or melt — they never blow, trip or explode, although some textbooks do say fuses blow. Similarly electricity does not flow, only current flows.

rapidly and leave the room when a door is open. In science there is no such thing as 'cold'. We always talk about the movement of heat energy.

Another common statement is that 'heat rises above a fire'. This is not strictly true. **Heated air molecules** rise and move out and are replaced by cold air.

'Plants respire at night...'

Sometimes students are guilty of just forgetting to mention important points. When writing about photosynthesis, for example, many students say that plants take in carbon dioxide and release oxygen during the day, but respire at night when they use oxygen. Of course plants respire during the day too, but the carbon dioxide they release is recycled within the leaf for photosynthesis. What we measure in our experiments is merely the **net uptake** of carbon dioxide, not the total amount used, because we don't measure the amount recycled.

Concentrated or strong?

Concentrated refers to how much of a substance there is in a solution, but strong (and strength) refers more specifically to **acids** and how many hydrogen ions there are in solution. The more ions there are the stronger the acid. Hence you can have a dilute solution of a strong acid and vice versa.

'The reaction stops because the enzymes have been killed...'

Something has to be alive before it can be killed. Think back to MRS GREN — the characteristics of a living thing — and you will realise that enzymes are not alive, they are just molecules. They can be **denatured**, that is have their shape changed by heat or changes of pH, so that they no longer function, but they cannot be killed.

Conclusion

Your teacher will use the correct terms with you in class; make sure you learn them. One final word of advice — when calculating the speed of a vehicle in metres per second, don't be absent-minded and put mph — wrong units lose marks.

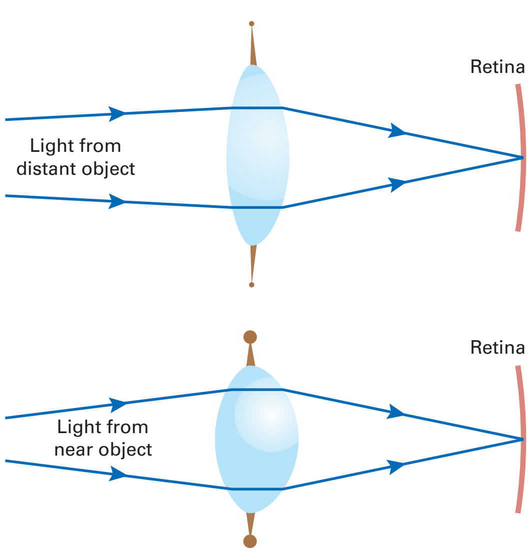
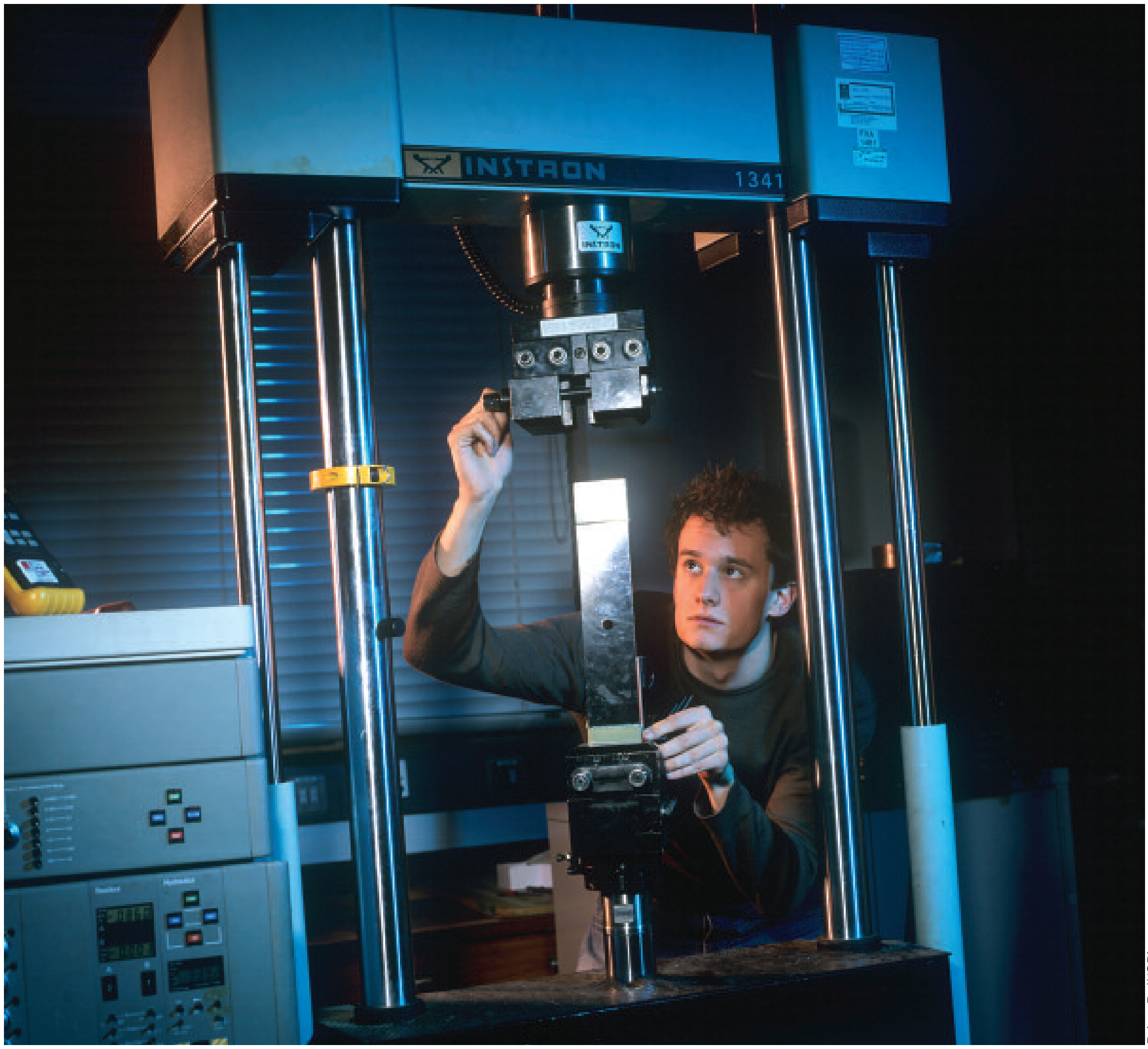


Figure 1 *Change in lens shape*

Jane Taylor *teaches biology and is an editor of* CATALYST.



Brian Bell/SPL

Right: *Researcher working with a composite material intended for use in the aerospace industry*

It's a material world

What do the latest iPod, a dual fuel car and an artificial hip have in common? The answer is easy – they are all made of something. Materials scientists decide which material is best for each application.

You're probably familiar with the periodic table. This is a wonderful tool that tells materials scientists about the elements that they have to choose from. Some of these elements can't be used because they are dangerous, or they have only existed for a few nanoseconds in a laboratory somewhere. However, many of them are not only useful, but vital to the society in which we live. In some cases we use elements, such as gold, silver and carbon, in their pure state, but most of the time we use compounds and mixtures of the elements.

Understanding materials

The structure of materials

As a materials scientist or engineer the first thing you need to understand is the **structure** of a material – how the atoms arrange themselves into crystals or molecules and how those crystals or molecules arrange themselves with regards to each other. This structure has an important influence on the properties of the material. It will affect how strong or tough it is, whether it conducts electricity or whether it is transparent. But it's no use having a fabulous material with great properties if it can't be made into the right shape.

Processing materials

A materials scientist also needs to understand how materials can be processed. **Processing** covers the whole life cycle of the material, from obtaining raw materials from the Earth's crust, to extracting the useful part and forming this into everyday objects,

- **Visit the *Challenge of Materials* gallery at the Science Museum in London to see some modern, exotic materials, their structures and uses.**

right through to investigating the best ways to reuse, recycle or dispose of the material.

Materials scientists need to know all this, for many different materials, so that they can make sure that the right ones are used.

Working as a materials expert

Materials science and engineering is a broad discipline. Materials experts have played a role in everything you see and use. Some work on the fundamental science behind the materials, investigating structures and properties in a laboratory at a university or company. Others work in design and manufacturing, turning ideas into reality.

For example, some are involved in transportation, developing cars, trains, aircraft and the associated infrastructure such as roads and rails. Others are concerned with the manufacture of sports equipment which will maximise the performance of athletes, whether they are amateurs or world-class professionals. Materials experts also work alongside surgeons and clinicians, developing a wide range of replacement body parts, including hip and knee joints, artificial arteries and even replacement lenses for our eyes.

A great deal of research is being done at the moment looking at the next generation of materials, such as those on the nanoscale, and semiconducting and superconducting materials, which could change our lives over the next few decades.

If you think this sounds interesting, you might consider becoming a materials expert yourself. Here's something that may surprise you — you are already on the way to being one! You have been studying materials in science and technology since you started school — remember sorting and grouping materials and looking at reversible and irreversible reactions at primary school? And you make choices about materials in your everyday life — for example, choosing to go out in a coat made from a waterproof material when it's raining.

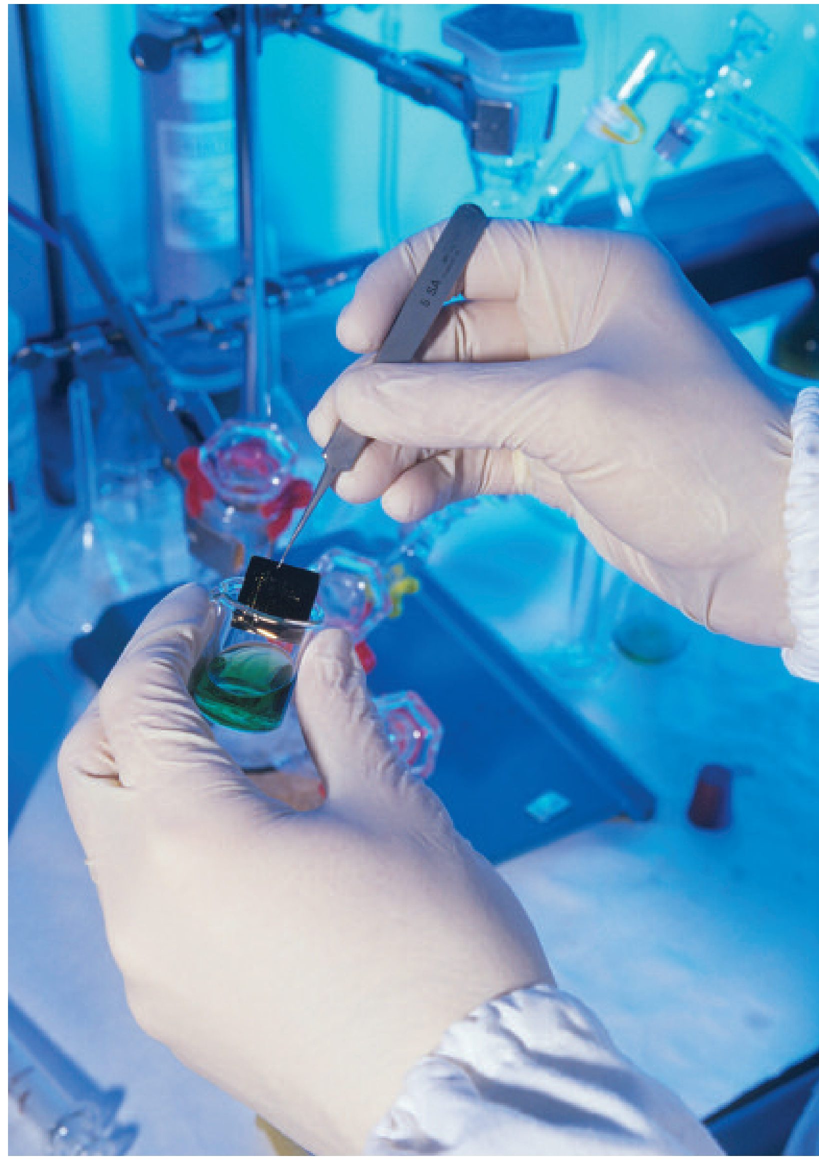
Box 1 Materials degree courses

Titles of university materials courses include:

- biomedical materials
- sports science and materials technology
- metallurgy and materials
- automotive engineering
- polymer technology
- aerospace engineering with materials
- dental materials

Most courses include a broad introduction to materials, with the opportunity to specialise later.

You need three A-levels (or two A-levels and an AS) for admission to an undergraduate course in materials. Choose at least two from maths, physics, chemistry, and design and technology.



Pasquale Sorrentino/SPL

Above: *Researcher using forceps to place a semiconductor sample in a chemical*

How to become a materials scientist or engineer

You can begin a career in materials at many levels. If you want to get a job when you've finished your GCSEs or A-levels, many companies employ technicians at 16 or 18 and will provide training on the job and through college courses. Alternatively, you might want to study materials at university, in which case there are many interesting courses to choose from (see Box 1).

Whether you decide to enter the materials world after GCSEs, A-levels or a degree, you can be sure that you will have an exciting, rewarding and challenging career and the chance to change and improve the world around you. If you would like more information on careers in materials, minerals and mining engineering go to **www.materials-careers.org.uk** or contact **education@iom3.org**.

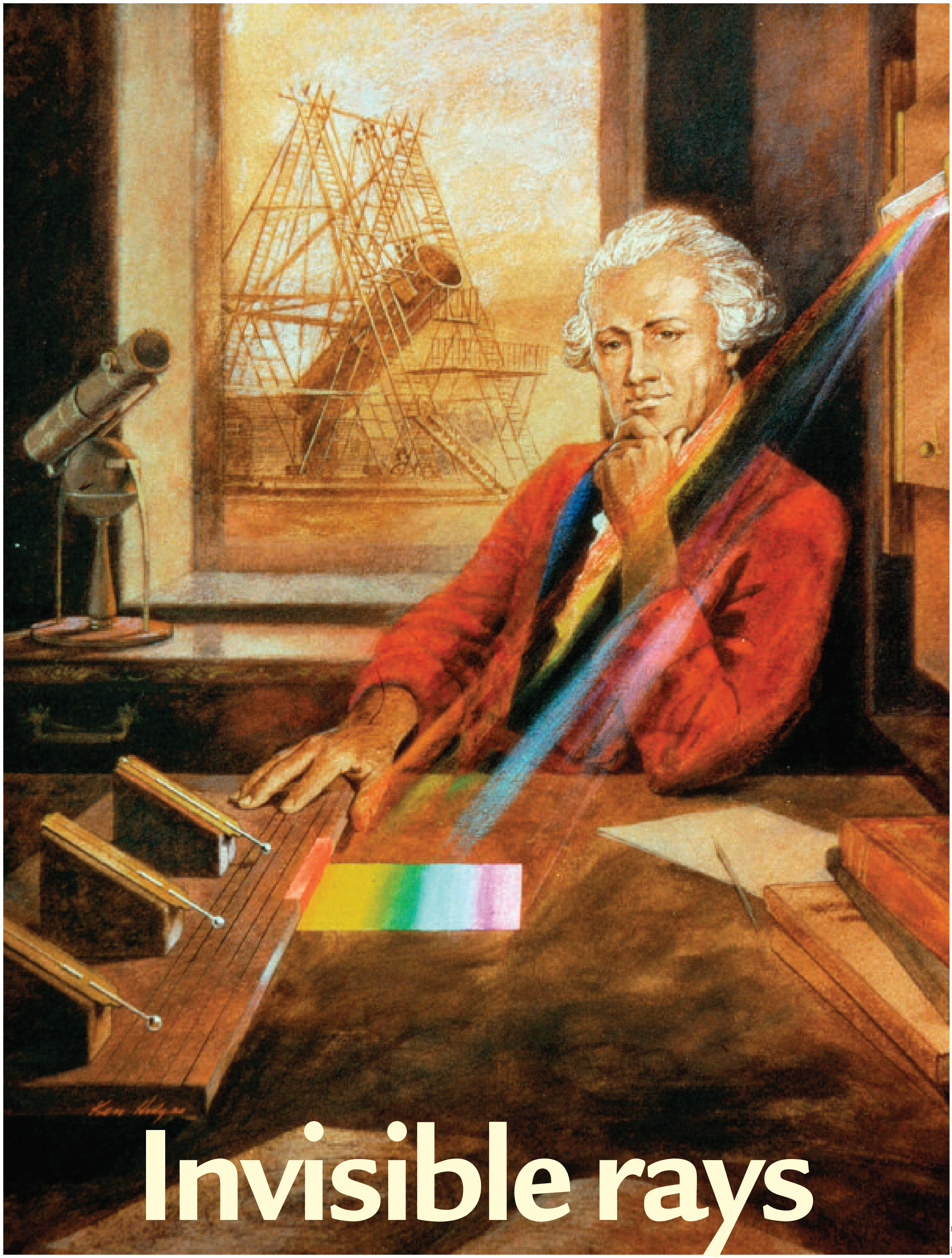
Dr Diane Aston *is Education Coordinator at the Institute of Materials, Minerals and Mining.*

- **Check out which universities offer materials courses on the UCAS website (www.ucas.ac.uk).**

Materials science is sometimes broken down into metallurgy, ceramics and polymer science.

David Sang

Invisible rays



TopFoto

Right: *William Herschel conducting his experiment*

GCSE key words
Infrared radiation
Electromagnetic spectrum
Experimental control
Scientific publication

William Herschel was an astronomer. When he discovered Uranus in 1781, he became the first person since ancient times to identify a new planet. However, he is also known as the 'accidental' discoverer of infrared radiation. Is this a fair description? Can such discoveries really happen by accident?

At the end of the eighteenth century, William Herschel was a well-established scientist. He was appointed court astronomer in 1782, which allowed him to establish an observatory in Slough, near Windsor Castle. He worked there with his sister Caroline; together they produced a vast catalogue of nebulae, distant clusters of stars which appear as cloudy patches in the night sky.

Box 1 William Herschel (1738–1822)

1738 Born in Hanover, Germany.
1752 Joined army band as oboist.
1757 Emigrated to England.
1766 Became church organist in Bath; developed interest in astronomy.
1773 Started making telescopes.
1781 Discovered Uranus.
1782 Appointed court astronomer.
1800 Discovered infrared radiation from Sun.
1822 Died in Slough.

Box 2 Caroline Herschel

William Herschel's sister Caroline was a greatly respected astronomer in her own right. She discovered 14 nebulae and 8 comets. She and her brother jointly constructed the telescope with which they discovered Uranus. She died aged 98 in 1848.


David Parker/SPL

The William Herschel telescope in its opened protective dome at dusk on La Palma

The William Herschel telescope on the island of La Palma in the Canaries is a reflector telescope — its mirror is the third largest in the world.

Through a glass darkly

During the day, William used his telescope to make observations of the Sun. The intensity of the Sun's rays makes this dangerous, so he used coloured glass filters to reduce the brightness to a safe level. Something concerned him: some of the filters seemed to transmit more of the light, while others let through more of the heat. As he wrote:

> I used various combinations of differently-coloured darkening glasses. What appeared remarkable was that when I used some of them, I felt a sensation of heat, though I had but little light; while others gave me much light with scarce any sensation of heat.

Any good scientist would recognise that this was important. Could the filters be affecting his observations of the Sun? William set about finding out.

Comparing colours

When light falls on a dark surface, it is absorbed and the surface gets hot. Energy from the light has become heat energy in the absorbing surface. William wondered if different colours of light might have different heating effects. Might a green filter, for example, let through little heat because green light has a weak heating effect? He set up an experiment to find out.

In a darkened room, he arranged a piece of cardboard with a slit in it so that a narrow beam of light came through the window. The beam struck a glass prism, forming a spectrum on his workbench. Now he could measure the heating effect of each colour in the spectrum.

He set up three thermometers side by side on a sloping stand, so that he could move the central thermometer into different regions of the spectrum. The thermometers to the right and left were outside the spectrum; they acted as experimental controls, to check that any rise in temperature recorded by the central thermometer was due solely to the absorption of light.

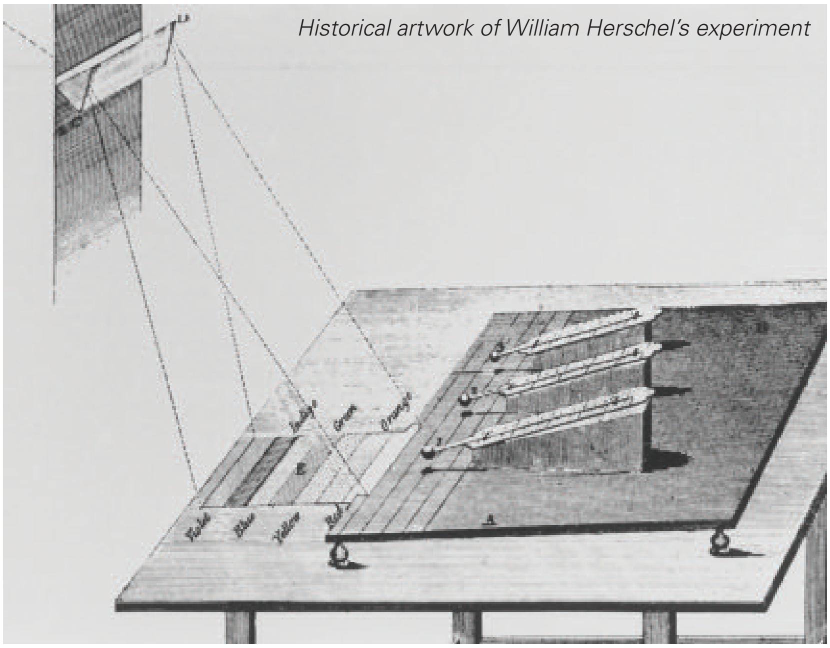
Table 1 *Average rise of temperature after 10 minutes in Herschel's experiment*

Type of light	Average temperature rise
Violet	2.0°F
Green	3.2°F
Red	6.9°F

Table 1 lists the temperature rises he noted after 10 minutes in each case. (Notice that English scientists at the time used the Fahrenheit scale of temperature.)

To convert Herschel's temperature rises to °C, multiply by 5/9.

Herschel was able to conclude that red light has the greatest heating effect of all colours in the spectrum of visible light. He wrote: 'The heating



Historical artwork of William Herschel's experiment

SPL

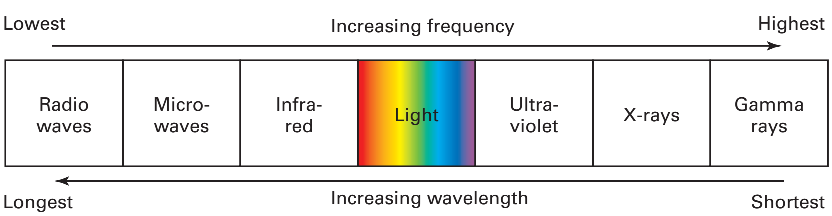


Figure 1 *The electromagnetic spectrum*

Box 3 Useful websites

- You can download Herschel's original papers, which appeared in the *Philosophical Transactions* of the Royal Society for 1800, from:
http://tinyurl.com/v45fh
http://tinyurl.com/yxb3m3
http://tinyurl.com/y82dsk
Select *Open Full Text* to read them.
- Follow this link to see how to repeat Herschel's experiment:
http://coolcosmos.ipac.caltech.edu//cosmic_classroom/classroom_activities/herschel_experiment.html
- Watch two short videos of the Herschel Space Telescope at:
www.esa.int/esa-mmg/mmg.pl?type=V&mission=Herschel

Unexpected and unplanned findings are called serendipitous discoveries.

The European Space Agency is to launch an infrared space telescope – the Herschel Space Telescope, named after William and Caroline. It will look at distant objects in space which are so cool that they do not emit visible light.

power of the prismatic colours is very far from being equally divided, and the red rays are chiefly eminent in that respect.' This was a new observation, of importance in itself. But there was more to come.

Beyond the red

Herschel noticed that the heating effect of light was greatest at the red end of the spectrum. He wondered if it might extend beyond there, to a region where the Sun's rays were invisible. He set up his thermometers accordingly and discovered that, as he had suspected, the central thermometer's temperature rose. In fact, the greatest temperature rise was at a point a little beyond the red end of the visible spectrum.

What conclusion could Herschel draw? He realised that the Sun's rays consist of both visible light rays and invisible heat rays. Today, we call these invisible rays **infrared radiation**. Herschel was working in the winter of 1799–1800, and sunny days were few and short. Before darkness fell, he quickly checked to see if he could find a heating effect beyond the violet end of the spectrum, but without luck.

Herschel's explanation

Were these two types of different rays? Herschel thought not; the simplest explanation was that both light and heat were forms of the same radiation: '...we are not allowed, by the rules of philosophising, to admit two different causes to explain certain effects, if they may be accounted for by one.'

This is an example of a principle known as **Occam's Razor**; complex explanations should be rejected if a simpler one can be found. Today, we would say that both light and infrared are forms of **electromagnetic radiation**, and that they lie on a much-extended spectrum, stretching from gamma rays and X-rays at one end to radio waves at the other (Figure 1).

Herschel presented his findings to a meeting of the Royal Society, and published them as three papers in the Society's *Philosophical Transactions*. These papers are easy to read; you can find them on the internet (see Box 3).

A happy accident?

Some accounts of Herschel's experiment suggest that he left the room for a while. The Sun moved across the sky, and the spectrum moved across the workbench. When he returned, his test thermometer was no longer in the spectrum, and yet he noticed that it still showed a high reading. He then made careful measurements to find out what was going on.

Many important findings are described in this way. Something unexpected and unplanned happens, it catches the eye of a keen scientist, and a great discovery is made. We can't say if this is what happened to Herschel. His papers present a logical development of ideas, with each observation suggesting further measurements, leading to the discovery. But that is how scientists present their findings – it's how you are expected to write up your investigations.

Conclusion

Herschel noticed a trend in the heating effects of different colours of light, from violet through green to red, and then had the sense to see if the trend continued further. This seems a more likely description of his work than the 'happy accident' version.

David Sang *writes textbooks and is an editor of* CATALYST.

Down House

Visit Down House in Kent, the home of Charles Darwin, to find out more about his life and work.

When he was a young man Charles Darwin voyaged for 5 years around the world on the *Beagle* as ship's naturalist. He studied the plants, animals and geology as he travelled. However, after his return to England he never left these shores again. He married Emma Wedgwood, and purchased Down House, a few miles east of London in the Kent countryside.

The ground floor rooms have been restored to look as they would have done when it was Darwin's family home. The first floor houses an exhibition about Darwin's life and works, and his formulation of the theory of evolution by natural selection, an idea that still creates controversy today.

Darwin's study

At the heart of the house is Darwin's study. To step inside is to be transported into a bygone age where the focus of biology was on classification and description, and naturalists studied whole organisms. All the important original items of furniture remain.

If you half-close your eyes you can imagine Darwin sitting on his large black leather chair. This was specially modified by the addition of wheels to enable him to propel himself from one side of the room to the other, perhaps from the large table that occupies the centre of the room to his microscope in the window and back again.

Darwin's work

After publication of *On the Origin of Species* in 1859 Darwin continued to write and to experiment. He was a meticulous observer, recording everything in a series of notebooks.

Outside the house you can amble through Darwin's garden and around the Sandwalk, his 'thinking path' which he would walk several times a day, no matter what the weather. You can also visit his greenhouse where he cultivated the orchids and carnivorous plants that formed an important part of his later investigations. Not only was Down House his home for 40 years, it was Darwin's experimental station.

He published many other books, including *The Movements of Plants* in 1880 and *Vegetable Mould and Earthworms* in 1881, the year before his death. Much of the content of these books was based on observations he made in the grounds around Down House.

Volker Steger/SPL

Darwin's home and workplace at Down House and the surrounding area in Downe, has been nominated as a World Heritage site. This will be considered by UNESCO in July 2007.

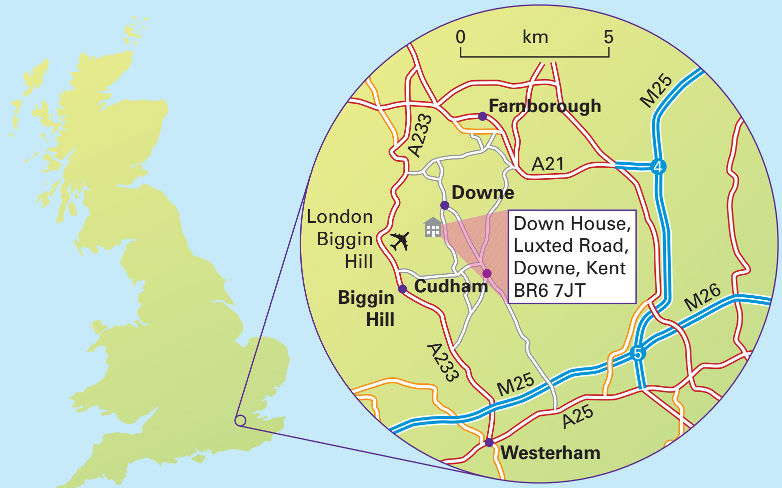
There will be many events in 2009 to celebrate the bicentenary of Darwin's birth.

● Read 'Evolution in the news' on pages 18–19 to find out more about Darwin's theory of evolution.

Box 1 Visiting information

Opening times

April to September: Wednesday to Sunday, 10.00–18.00
October: Wednesday to Sunday, 10.00–17.00
November to March: Wednesday to Sunday, 10.00–16.00
Find out more at: www.darwinatdowne.co.uk
or at: www.english-heritage.org.uk/server/show/ConProperty.102



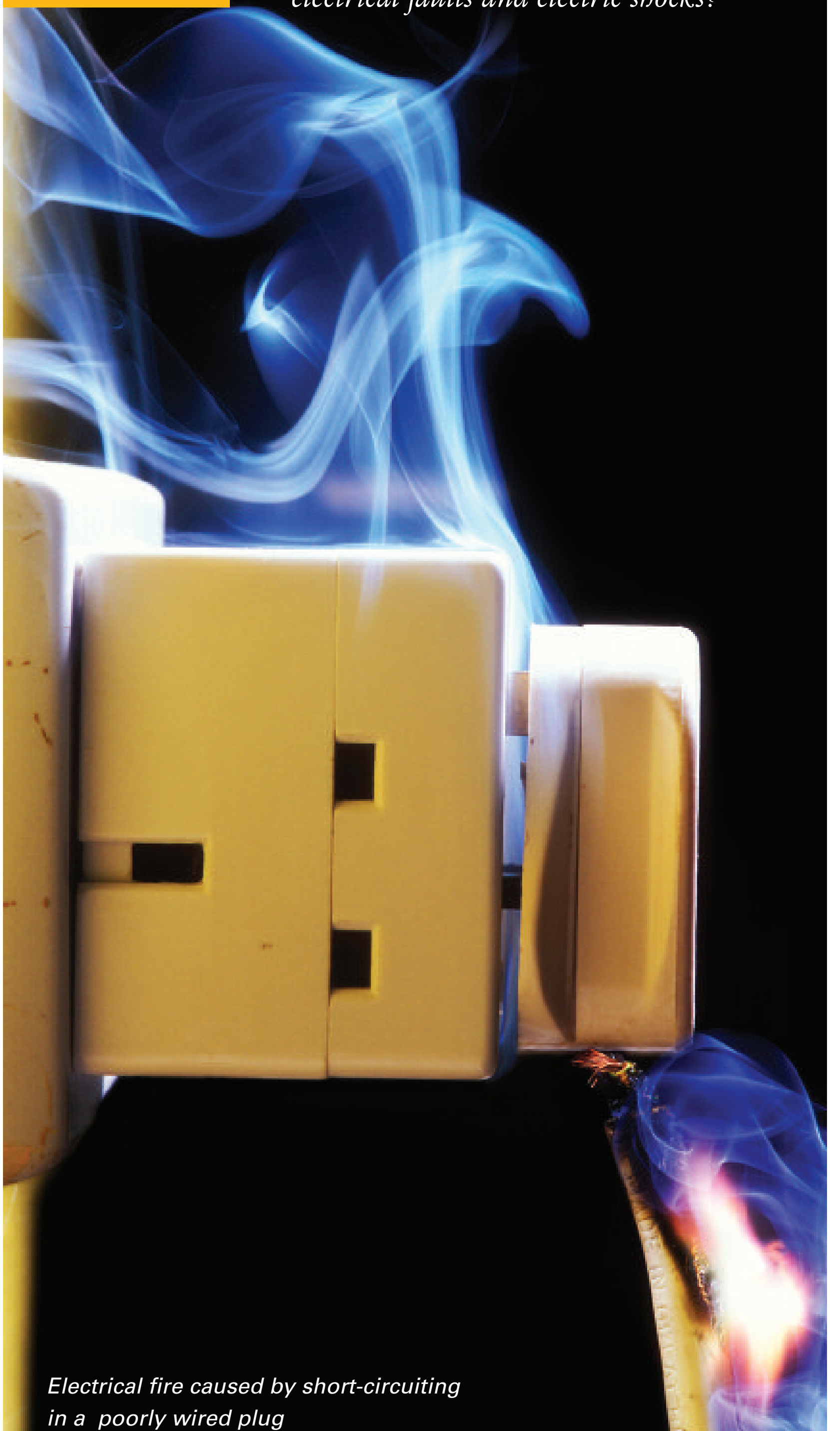
***Philip Seaton** taught biology for more than 30 years. He now works full time in orchid conservation and visited Down House recently.*

Howard Goodenough

Electrical safety

GCSE key words
Circuit breaker
Fuse
Residual current device

What causes faults in electrical appliances and the wiring installations in homes, and why do people receive electric shocks? How can regulations reduce the risk of electrical faults and electric shocks?



Dr John Brackenbury/SPL

Electrical fire caused by short-circuiting in a poorly wired plug

Electrical appliances are items such as electric cookers, washing machines, toasters, televisions, computers and battery chargers which draw current from the mains supply. The **electrical installation** in a house has three parts: the consumer unit (containing the main switch and either circuit-breakers or fuses), the fixed wiring to power and lighting points, and the associated switches, socket-outlets and light fittings, all on the consumer's or load side of the electricity meter.

Electricity is generally safe to use, but there are some potential hazards (see Box 1).

Faults and fires

Two types of fault can occur in an electrical circuit:

- An **earth fault** occurs when a live part comes into contact with earthed metalwork. This can happen, for example, if the insulation of the windings of a washing machine motor fail.
- A **short-circuit** occurs when a live part, such as the live conductor in a cable, comes into contact with a neutral conductor.

Each type of fault may cause currents of 1000 amps or more to flow. If such a current is not detected and interrupted straightaway, it will cause rapid heating, damaging the electrical installation; this could in turn set fire to the surroundings (see Box 2).

Box 1 Electrical hazards

Some of the ways in which hazards can arise in using electricity include:

- overloading circuits
- damaged adaptors and extension leads
- not following equipment manufacturer's instructions
- drilling into a cable buried in a wall or partition
- touching electrical equipment with wet hands
- using electrical equipment outside when it is raining
- trailing cables under carpets or across walkways
- not repairing damaged equipment
- cleaning or repairing equipment that is plugged in
- cutting through cables with lawn mowers or hedge trimmers
- leaving electrical equipment unattended
- drying wet clothes above an electric heater
- installing equipment incorrectly
- accidental damage to equipment

Box 2 Fire and electric shock statistics

The government collects statistics relating to electrical hazards. These indicate that 20% of all fires in homes in England and Wales are caused by electrical faults. These result in about 24 deaths and 590 non-fatal injuries each year. A further 12 deaths and 750 non-fatal injuries are caused by electric shock. Visit www.communities.gov.uk and search for 'electrical safety' to find the sources of the figures quoted here.

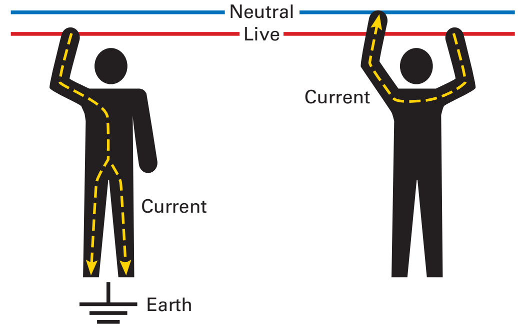


Figure 1 *Flow of current in the event of direct contact*

Electricians refer to the 'live' wire as the 'line' or 'phase' conductor.

Electric shocks

The effects on the human body of a shock from mains electricity are complex. They depend on both the size of the current and the time for which it flows:

- A current through the body of as little as 0.5 mA (0.0005 A) may be felt, but generally will not startle the person affected.
- Currents between 0.5 mA and 10 mA are likely to be painful and will cause involuntary muscular contractions, but will not usually have any harmful effects.
- A current of 10 mA (0.01 A) is called the 'threshold of let-go'. With currents greater than this, it may not be possible to release your grip on a pipe or equipment that has become electrically live. Currents of between about 10 mA and 50 mA, which last for a long time, can cause strong involuntary muscle contractions, difficulty in breathing and disturb heart function, but probably no lasting organic damage.
- Sustained currents of over 50 mA (0.05 A) can cause serious effects, such as cardiac arrest, breathing arrest, burns and other tissue damage.

The main reason why people die from electric shock is ventricular fibrillation, when the heart loses its regular waves of contraction. The risk of this happening increases with the magnitude and duration of the current. Alternating current (a.c.) is more dangerous than direct current (d.c.) because it is more likely to affect the natural rhythm of the heart.

Why do people receive electric shocks?

There are two ways in which people can suffer electric shock: direct and indirect contact.

Direct contact

Direct contact occurs when someone touches an exposed live part, such as a bare wire. Such contact should not be possible, unless a cable's insulation is damaged, or a plug top or socket-outlet is missing or broken. Other common causes of direct contact are included in Box 1. Figure 1 shows how the current flows when direct contact happens.

Indirect contact

Indirect contact occurs when someone touches a part which is not normally live. It becomes live due to a fault in the electrical installation or appliance. For example, failure of the electrical insulation between a live part and the metal casing of an appliance would cause the casing to become live. You can identify other examples of indirect contact in Box 1.

The nominal supply voltage and frequency for domestic electrical installations in the UK are 230 volts and 50 Hz (cycles per second).

Protection against shocks

People are usually protected from direct contact with electricity by the insulation and enclosure of live parts. For example, there is insulation around the conductors in a flexible cable (which in turn is mechanically protected by the outer sheath), and the live parts of a light switch are enclosed by the switch plate and back box.

It is important to recognise that even the smallest fuse or circuit breaker will not protect against electrocution by direct contact. For example, the smallest fuse in a normal electric plug is 3 A. It takes less than a twentieth of that current to kill an adult in less than one tenth of a second.

RCDs

A **residual current device (RCD)** can provide additional protection against direct contact. RCDs compare the sizes of the currents flowing in the live and neutral conductors of a circuit. In a healthy circuit, the currents will be equal. But if some of the current leaks to earth, for example through a person's body, the device will sense the imbalance and, if it reaches a predetermined threshold size, will rapidly disconnect the circuit.

RCDs are sometimes known as RCCBs (residual current circuit breakers). Don't confuse these with ordinary circuit breakers, which act as resettable fuses.

RCDs have a rated tripping current of 30 mA or less, and they are designed to operate within 40 ms (0.04 seconds). Anyone making direct contact with an RCD-protected circuit will still receive a painful electric shock, but it is unlikely to be lethal.

Anyone working with mains powered equipment outdoors should always use an RCD. This is particularly true for lawn mowers and hedge trimmers. People often cut through the supply cable accidentally, exposing themselves and others to the risk of electric shock.

A significant proportion of electrocutions occur in the garden. This is because the effects of electric shock are generally more severe outdoors, where people are in contact with the ground. Damp ground provides a relatively low resistance path for shock currents to

Answers to Box 4 on page 14, 'CE mark': appliance meets minimum safety requirements of the Low Voltage Electrical Equipment (Safety) Regulations 1989. 'Double square': appliance is double-insulated, so no earth connection is needed.

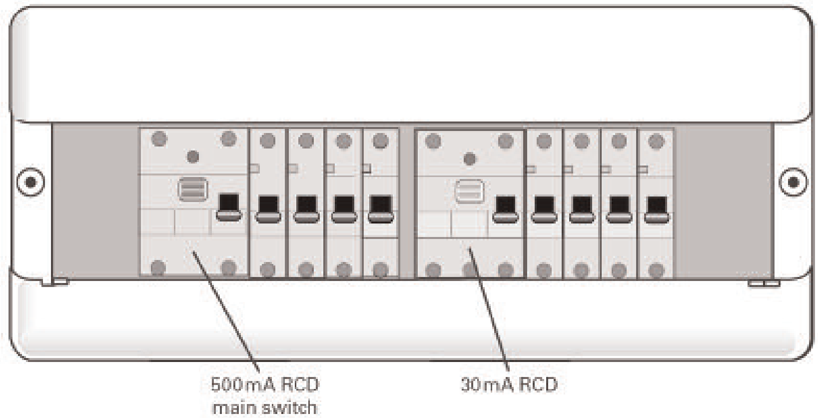


Figure 2 *Front view of a consumer unit containing a 500 mA RCD (used as main switch), circuit-breakers and a 30 mA RCD (used to protect circuits where portable equipment may be used outdoors)*

Some house fires are caused when mice, rats or squirrels gnaw through the insulation on cables in roof spaces.

flow through the body. Ideally, RCD protection should be built into the consumer unit (fuse box) to ensure it is always present (Figure 2). Alternatively, plug-in RCDs are available which, for less than £10, can literally be life-savers.

Fuses

Contrary to popular belief, the fuse in the plug of an appliance is not there to protect the appliance from overload, but to protect the flexible cord supplying it from overheating in the event of a fault (i.e. short circuit or earth fault).

If an appliance needs to be protected against overload, the means of protection must be built in to the appliance (see Box 3).

Safer appliances and regulations

All electrical appliances in schools are checked annually for safety. You will see 'passed' stickers on them, showing the date of the check.

Most mains powered portable appliances on sale these days have double or reinforced insulation. This includes electric kettles and irons which have metallic casings. These appliances do not have a protective (earth) conductor, and are less dependent for their safety on the condition of the electrical installation to which they are connected.

All electrical equipment put on to the UK market must comply with the Low Voltage Electrical Equipment (Safety) Regulations 1989. These regulations require electrical equipment to be safe and to be constructed in accordance with good engineering practice. Manufacturers must confirm that their equipment meets the minimum safety requirements by affixing the 'CE' mark (see Box 4).

Always treat electricity with care and respect.

The safety of electrical installations in all workplaces in the UK, including schools, is subject to the Electricity at Work Regulations 1989. These require all electrical installations to be constructed and maintained so as to prevent danger, as far as is reasonably practicable. Failure to comply with these regulations may result in criminal prosecution, especially if someone is injured or killed. The regulations do not generally apply to domestic electrical installations.

ELECTRICAL SAFETY COUNCIL

Sheila Terry/SPL

Anyone working with mains powered equipment outdoors should use an RCD

Box 3 Fuse wires

You should be clear about what a wire fuse does and does not do. If an appliance develops a fault:

- too large a current causes the fuse to melt
- preventing the flow of current
- preventing the flex overheating and causing a fire
- preventing further damage to the appliance

The appliance itself could be protected by a built-in electromagnetic trip switch.

Box 4 Electrical appliances

Electrical appliances may carry these two marks (among others). What do they mean?

Answers on page 13.

In January 2005, most electrical installation work in homes in England and Wales became subject to the Building Regulations. Similar requirements are in force in Scotland. The intention of the regulations is to improve the general safety standard of domestic electrical installation work.

To reduce the risk of danger, it is important that any electrical work is carried out by a competent person — someone who has sufficient technical knowledge and experience to carry out the work successfully and safely.

This article has been written by ***Howard Goodenough*** *of the Electrical Safety Council. Check its website for further information on electrical safety (***www.electricalsafetycouncil.org.uk***).*

Salt

David Moore

GCSE key words
Ions
Uses of sodium chloride
Electrolysis


Charles D. Winter/SPL
Salt crystals

The lowest freezing temperature of water which can be obtained by dissolving salt in water is called the eutectic point and is −21 °C. (This is the basis of zero on the Fahrenheit temperature scale.)

We need salt (sodium chloride) in our diets to survive, but too much can be toxic. Where does it come from, and what is it used for?

Deep under the Cheshire countryside there are vast deposits of solid sodium chloride (salt). These were laid down on the beds of ancient shallow seas which used to cover this area of Britain 225 million years ago. The salt deposits stretch for many kilometres and are at least 24 metres thick and up to 150 metres underground.

Mining in Cheshire

Shafts are sunk into these salt beds from the surface so that the salt can be mined. The salt is a dense solid which is slightly orange-coloured (due to traces of iron oxides). The salt is structurally very strong so it can be dug out without the need for too many supports to keep the roof up.

The salt is mined by blasting areas of it with explosive and then cutting out the remaining pieces with huge cutting machines (which resemble large hedge trimmers). The large lumps are crushed underground before being raised to the surface using lifts.

The impure salt mined in this way is spread on roads in cold weather to prevent any water from freezing. Remember that impurities, such as salt, dissolved in water reduce its freezing point, hopefully below the temperature of the surrounding air and road surface, and so the water on the road will not freeze.


Cutting rock salt at a mine in Cheshire
TopFoto

Right: *Mine buildings at Boulby in North Yorkshire*

James King-Holmes/SPL

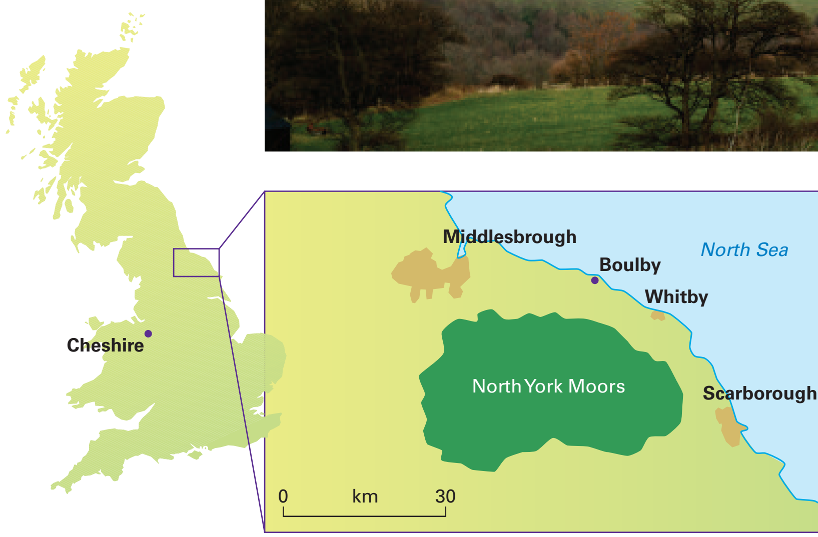


Figure 1 *Map showing the locations of Cheshire and Boulby*

Over the years many areas of Cheshire have been subject to subsidence. Ancient underground salt workings have collapsed resulting in the land above them slumping into the hole that is formed. Newer methods of mining are designed to prevent this from happening.

Mining at Boulby

The preserved bodies of prehistoric salt miners who met with accidents have been found in Austria. Salt prevents bacterial decay so the bodies still have flesh, hair and clothes.

Salt is also mined at Boulby, near Whitby, in North Yorkshire. Boulby is the site of one of the deepest mineshafts in Europe. Sodium and potassium chloride are brought up from beds 1100 metres below the surface. Mining is continuous and about 60 000 tonnes of potassium chloride and 12 000 tonnes of sodium chloride are dug out each week.

Potassium chloride is mostly used in the manufacture of fertilisers, although a small amount is used for making television and computer screens.

Box 1 Dark matter

Scientists are using Boulby mine to look for 'dark matter'. This matter, which is thought to make up nearly 90% of the total mass of a galaxy, has no detectable radiation or absorption. A 200 tonne tank of water at the bottom of the mine is being used to try to detect this matter as a new type of heavy neutral particle.

Look for salt content guidance information on packet food from major supermarkets.

Solution mining

The technique of **solution mining** is used to obtain pure salt for industrial use. Three concentric tubes (one inside the other) are sunk through the ground into the salt beds. Hot water and high pressure air are passed down two of the tubes and a concentrated solution of salt emerges from the third. Many impurities are left deep underground.

The concentrated solution of salt is pumped to storage ponds before being piped into factories where it is turned into useful chemicals. This method creates large pear-shaped cavities in the salt beds. These are left full of solution in order to stabilise the cavities and prevent them from collapsing.

The salt produced by this technique can be used for cooking and flavouring purposes, but it has to be made especially pure before it can be consumed by humans. To do this the salt is purified by dissolving it and then recrystallising it in specially designed tanks. Different shaped crystals can be obtained by varying the conditions of temperature, pressure and the amount of stirring of the crystallising mixture. The slower the crystals are allowed to grow, the larger the crystals become. Box 2 describes the role of salt in the body.

Box 2 Salt in the body

Salt helps to maintain the correct water balance in the blood. When dissolved, the sodium and chloride ions also play a major part in initiating and transmitting impulses along nerves and in muscle action.

Excess salt in the diet can cause fluid retention (oedema) and may contribute to high blood pressure. Loss of salt from excess sweating due to exercise or hot weather can cause heat exhaustion. The World Health Organization recommends we consume a maximum of 5 g of salt a day, but in the Western world our intake is often up to 15 g a day.

Box 3 Useful websites

- Read about mining salt in Cheshire by logging on to Northwich Salt Museum's website: www.saltmuseum.org.uk
- Boulby mine is described at: www.mining-technology.com/projects/boulby
- The search for dark matter at Boulby mine is illustrated at: http://hepwww.rl.ac.uk/ukdmc/pix/boulby.html and described at: http://news.bbc.co.uk/1/hi/sci/tech/2981837.stm
- You can find out about how salt used to be purified at: www.lionsaltworkstrust.co.uk

Box 4 Modelling the structure of salt

Obtain equal numbers of red and green cocktail cherries. Lay them out in a 3 by 3 grid on a table so that they are alternately red (corresponding to sodium ions) and green (chloride ions). If they are touching, the natural stickiness should keep them together. Enlarge your model by putting a layer of cherries on top of the first layer – still ensuring that opposite colours are on top of each other. A third layer can be added to make a regular cube.

Salt crystals also form in a cube shape – this is because the sodium and chloride ions are approximately the same size and so stack on each other easily. If you look at crystals from a salt pot (or crystals of sea salt) you will see the cubic shape.

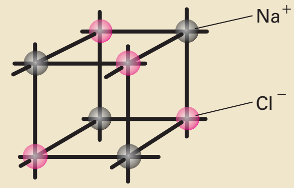


Figure 2 *Structure of salt*

Industrial uses

Salt solution is very important industrially as it can be used to produce a wide variety of chemicals. Electrolysis of the solution allows it to be split into chlorine, sodium hydroxide and hydrogen. These chemicals can then be reacted further to produce other useful chemicals, such as calcium and sodium hypochlorite, sodium chlorate, sodium sulphate and hydrochloric acid.

Molten sodium chloride can be electrolysed to make sodium and chlorine. This is called the **Downs process**. Sodium chloride is also used in metallurgical processes (e.g. for heat treatment baths), as a preservative (e.g. for cheese making and curing food) and in other industrial processes (e.g. for regenerating ion exchange columns, as a dehydrating agent and for glazing tiles).

A salt is a compound formed by the reaction of an acid with a base. Sodium chloride is often just called 'salt', although it is really a specific example of a salt.

David Moore *teaches chemistry and is an editor of* CATALYST.

Chemicals made from salt

Puzzle

Match the pictures with the chemicals. Use the internet to find the connections.

Chemicals

1 Hydrogen
2 Sodium
3 Sodium hypochlorite
4 Chlorine
5 Sodium hydroxide

Answers on page 21.

Nigel Collins

Evolution in the news

GCSE key words

Fossils
Evolution
Natural selection
Theory

In his marvellous travel book, *The Voyage of the Beagle* (1839), Darwin gives you a vivid picture of his experiences and you can follow him as he accumulates observations that later contributed to his theory of how evolution occurs.

Charles Darwin as a young man

TopFoto

This article looks at the evidence for evolution and considers the ongoing conflict between scientists and creationists.

Charles Darwin returned from his travels around the world on *HMS Beagle* in 1836. Over 20 years later, in 1859, he published *On the Origin of Species by means of natural selection*. The book was much in demand and the first print run was soon sold out.

Darwin was one of many people involved in the accumulation of compelling evidence that the world was a much older place than had been assumed on the basis of biblical accounts of 'creation'. However, he went further than the other gatherers of evidence for evolution and proposed a theory that described how the process of evolution might work — hence, *On the Origin of Species* ***by means of natural selection***. Darwin's theory of evolution is as much about mechanism — how it happens — as about cataloguing evidence that it has occurred (see Box 1).

Box 1 Darwin's theory of natural selection

Darwin proposed that natural selection is the mechanism whereby new species evolve from earlier species across millions of years. His observations and deductions can be summarised as follows:

- Observation 1: Individual organisms within a population have great reproductive potential.
- Observation 2: The number of individuals in a population usually remains approximately constant.
- Deduction 1: Many individuals fail to survive or reproduce. There is a 'struggle for existence' within a population.
- Observation 3: Variation exists within populations.
- Observation 4: Although the organism's environment can affect the extent of variation shown, variation can be inherited.
- Deduction 2: In the 'struggle for existence' those individuals showing variations that are advantageous are more likely to survive, reproduce and have more offspring, who may inherit this advantageous variation.

- **Read 'Places to Visit' on page 11 to find out more about Charles Darwin.**

- **Follow the movement of humans as they colonised the planet at www.bradshawfoundation.com/journey**

When Darwin published his theory, many people in England regarded the biblical creation story as literal truth and believed that the world was about 4000 years old.

Facts and theories in science

Since Darwin's time many other scientists, both professional and enthusiastic amateurs, have added more and more evidence to support the idea of evolution as a fact. Yet some people still say 'it's just a theory'.

A theory in science is a general idea or explanation which has a lot of evidence to support it. The evidence for evolution is very wide-ranging. It includes that from the fossil record, coupled with the dating of rocks in which the fossils are found, through to evidence from comparative anatomy and adaptive radiation. There is also evidence in our proteins and in our genetic material (DNA) that reveals how humans evolved, and our relatedness to our ancestors and to other organisms. You can follow the spread of humans and their relatedness in the website listed in the margin.

We can also observe evolution taking place in the short term, in moths and antibiotic resistant bacteria, for example. The theory of evolution has been tested endlessly and it continues to stand up. That is why most scientists now accept it as a fact.

The evidence of fossils

Fossils of organisms never seen before are being discovered all the time. The initially incomplete picture of earlier life forms is being filled in steadily. Last year a new fossil showing the divergence of bees from ancestral wasps was found. Such finds make

Pasieka/SPL

Left: *Comparisons of DNA and fossil records suggest that humans and modern African apes evolved from a common ape-like ancestor*

Box 2 'Truth in Science'

In September 2006 an organisation called 'Truth in Science', which believes in intelligent design and irreducible complexity, sent DVDs to all secondary schools in the UK. The origins of this organisation can be traced back to a group of the same name in the USA, where the DVDs first appeared in 2002. It is quite easy to follow the affiliation of this group on the internet back to its creationist origins.

In America, court cases have led to 'intelligent design' being banned from science lessons. In England, the creationist position and its offshoots, based in belief rather than science, are also not regarded by the Department of Education as part of science lessons.

evolutionary lineages clearer. New fossils fitting into the story of the evolution of birds have also been found recently. *Archaeopteryx* no longer sits alone between birds and reptiles.

It has also become possible to look at the available evidence and make predictions. For example, palaeontologists knew that some rocks of a particular age contained fossil organisms that they thought were descended from different fossil organisms present in older rocks. They predicted that rocks known to be of an intermediate age would contain intermediate forms. Rocks of this age occurred in the Arctic — and scientists found intermediate fossil fishes there in 2006.

Creation myths and creationists

Despite the fossil evidence, and all the other evidence in support of evolution, some people still believe in creation myths as the literal truth. They are known as 'creationists'. They refuse to accept the scientific evidence for evolution and instead say that their creationist myth offers a proper explanation of how the world and the organisms in it came into existence.

Some creationists have put forward other ideas about 'intelligent design' or 'irreducible complexity', but these do not stand up when examined in detail against scientific evidence for evolution (see Box 2) or when the logic of the particular examples given is tested.

Today, creationists make up a small proportion of the world's Christians. Some people of other religious faiths have equivalent fundamentalist views on creation. However, most Christians now recognise that our collective knowledge and understanding has moved on since the days when the creation myth in the opening chapter of the Bible was first recorded and accept the fact of evolution. They do not regard this as incompatible with their beliefs and wider faith.

Nigel Collins *teaches biology and is an editor of* CATALYST.

Box 3 Scientists urge evolution lessons

The world's top scientists have joined forces to call for 'evidence-based' teaching of evolution in schools.

A statement signed by 67 national science academies says evidence on the origins of life is being 'concealed, denied, or confused' in some classes. It lists key facts on evolution that 'scientific evidence has never contradicted'.

Read more, including the full statement, at: http://news.bbc.co.uk/1/hi/sci/tech/5098608.stm

- **Listen to a talk by Steve Jones on 'Why creationism is wrong and evolution is right' and see some of his illustrations at www.royalsoc.ac.uk/page.asp?id=4400&tip=1**

Most peoples of the world have developed stories that count as creation myths, imaginative notions about how living things were 'created'.

Damian Murphy
Music technologist

Left: *Damian setting up microphones for measuring the acoustics of a decommissioned nuclear reactor hall deep beneath the city of Stockholm*

Above: *Damian listening back to these virtual environments in the recording studio at York University*

Dr Damian Murphy is a Lecturer in Music Technology in the Department of Electronics, University of York. His work involves the physical modelling and acoustics of buildings and environments, both real and virtual.

I focused on sciences for my A-levels at school — maths, physics and chemistry — and went on to study maths at university. Here I became aware of a subject that captured my interest like no other: music technology. This is the science and technology associated with music, acoustics, audio and sound. When I thought back to the day my guitar teacher brought an electric guitar and portable recording studio into school I realised this career was meant for me. At 16, I built my own electric guitar for my GCSE craft, design and technology course. It won me a prize, but I admit it was nowhere near as good as the home-made guitar belonging to that well known ex-physicist turned musician, Brian May of Queen.

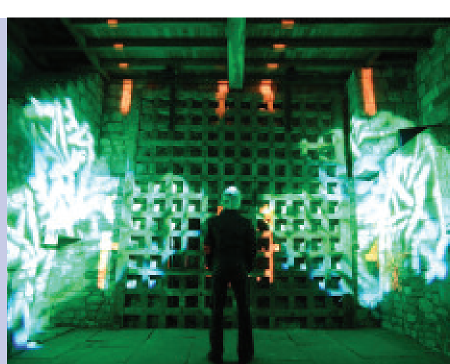
Studying sound

During my final year at university I applied for the MA/MSc Music Technology course at York University — the first such course in the UK and still one of the few available. I started the following year. The course gave me a thorough grounding in electronics, signal processing, acoustics and computer science, all as applied to music, composition and recording. My final project involved using maths and physics to synthesise the sound of strings and membranes, in what is known in the field as **physical modelling**. Compared with the synthesisers of the time, this new method created sounds with a previously unheard realism and naturalness.

I went on to do a PhD, looking at how these fundamental ideas could be applied to modelling the acoustics of a room. I am still exploring how to physically model sound-wave propagation within a space (Figure 1). Most other models approximate the complex behaviour by copying the way in which a ray

Box 1 *A Sense of Place*

One of the most important things about my work for me is that the results obtained from the maths and science used day to day to solve problems in acoustics and audio are used to create music. *A Sense of Place* was a sound and light art installation on which I collaborated with other artists. It recreated the measured acoustics of York Minster in a much smaller and more enclosed environment.



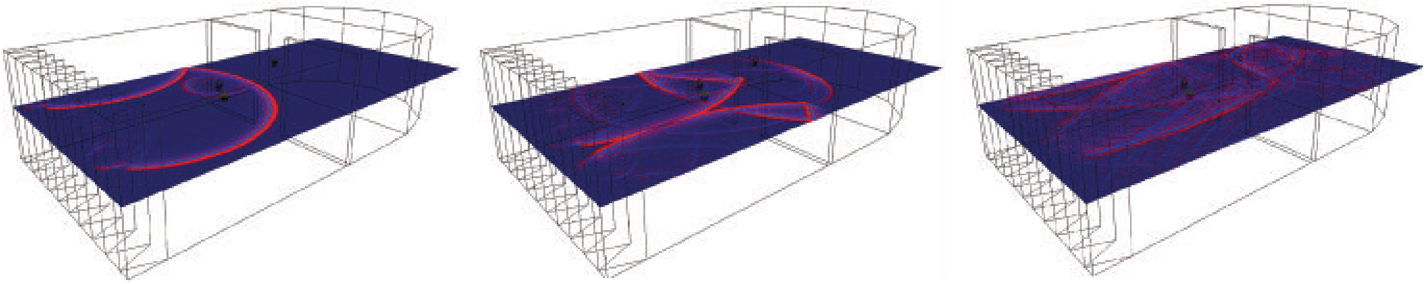


Figure 1 *An example of sound-wave propagation through a computer based virtual model of two (linked) spaces. Notice the reflection, diffraction and interference patterns that arise as a consequence of the underlying wave-based modelling technique*

of light might travel around a room, bouncing off mirrored surfaces. Although this is a good approximation, it is very poor at low frequencies, where isolated resonant frequencies and wave effects such as diffraction are evident. The models I am working on with my team are based on actual wave motion, and so give a truer representation of the acoustic properties of a simulated space.

Virtual spaces

In applied music technology, it is important to listen to the sound heard in various different acoustic environments. This fundamental process is used in nearly all modern music production. Physical models allow sound engineers, composers and computer musicians to use simulation to listen to the way in which a particular environment will shape and influence sounds and music. A simulated space can be tweaked and altered so that the music sounds just right. This opens up a whole new acoustic canvas, allowing access to 'spaces' that no longer exist or are simply impractical to record in. We can construct spaces that are limited only by our imaginations.

Outside of the music industry, this research is proving useful to architects who can listen to how their buildings will sound long before the foundations are laid. This can help them to avoid costly errors. We have presented this work at meetings and conferences around the world in cities including New York, San Diego, Montreal, Stockholm, Madrid and Verona. The team has also been exploring how its work might be applied to a very different acoustic space — the human vocal tract — with a view to synthesising realistic and natural human speech. How close have we got to this? See the links in Box 2.

Acoustic archaeology

My multidisciplinary approach to teaching and research, combining aspects of music and creativity, physics and maths, led to me being appointed as an arts/science research fellow by the Arts and Humanities Research Council and the Arts Council England. Rather than simulating the sound of virtual spaces, this project involved the acoustic measurement of some important architectural and archaeological buildings across the UK.

Once captured, this acoustic information can again be used as part of the music production process — playing back audio tracks in unusual, interesting and beautiful sounding environments without the musicians ever having to be there. The data can also yield information about the buildings themselves, their construction and even how they might have been used by the original owners.

This work has involved me crawling down Neolithic burial chambers in the middle of a winter night in Orkney, climbing up ladders to place microphones in the rafters of churches, and spending the night in Europe's finest Gothic cathedral. I have even worked in a subterranean nuclear reactor hall (happily long-since decommissioned) beneath Stockholm, and will soon experience the lingering smell of over 100 years of chocolate production at Rowntree, in one of York's oldest and most iconic buildings.

Box 2 Useful websites

- Find out more about *A Sense of Place* at: www.boothambar.org.uk and www.renaissanceyork.org.uk
- You can find out more about the acoustic measurement work and the spaces measured so far, as well as listen to their 'sound' at: www.space-net.org.uk/IRs.html
- Listen to what a physically modelled human voice or vocal tract might sound like at: www-users.york.ac.uk/~dtm3/vocaltract/
- More general information about Damian's work is available at: www-users.york.ac.uk/~dtm3/

Brian May of Queen is at present completing the PhD he gave up many years ago to be a rock musician. He has just published a book written with Patrick Moore and Chris Lintott: *BANG! The Complete History of the Universe*.

Answers to Chemicals made from salt, page 17

1A Hydrogen is used to hydrogenate vegetable oils to turn them into margarine.

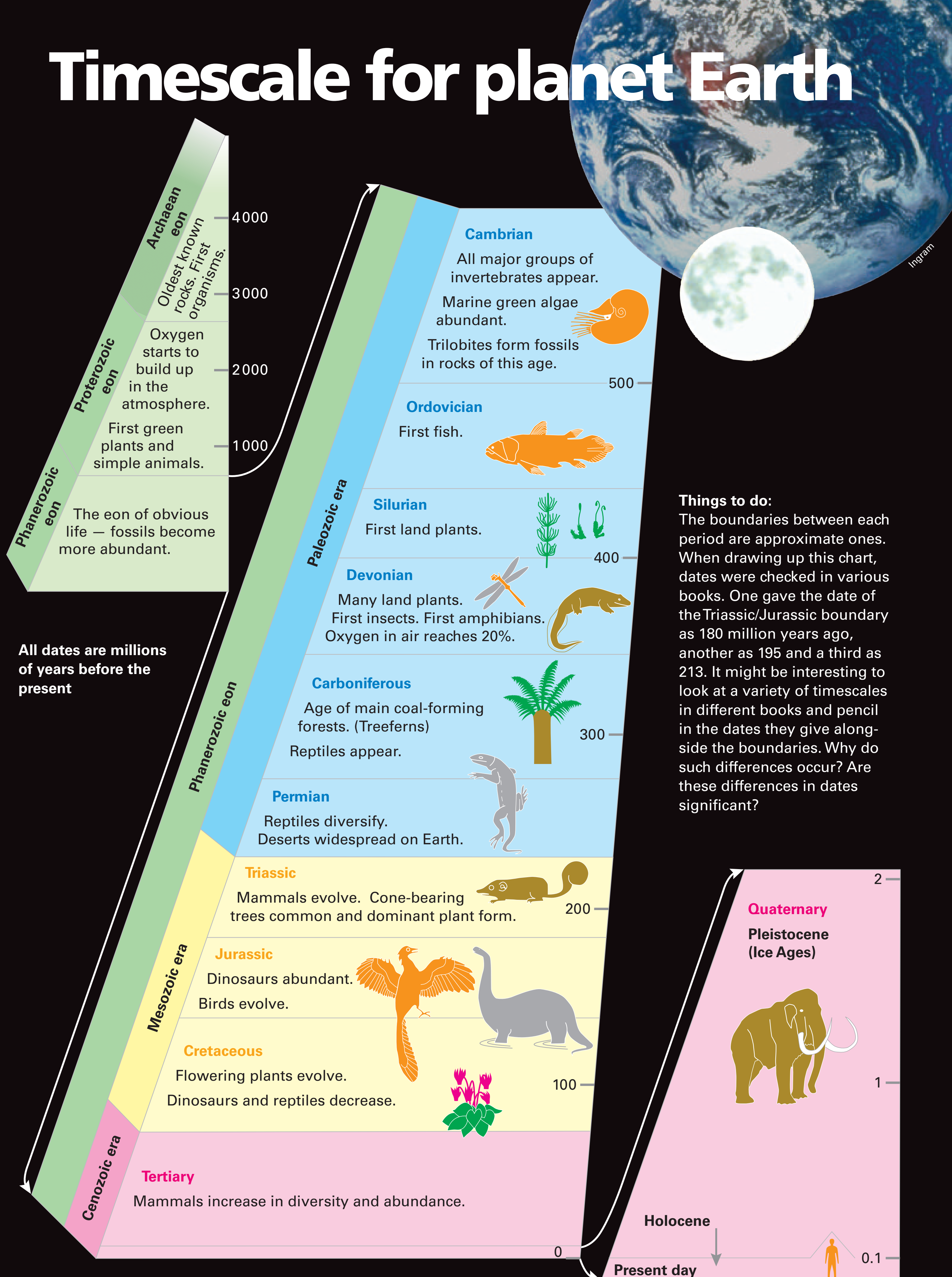
2B Sodium is used in the manufacture of indigo which is used to dye blue jeans.

3E Sodium hypochlorite solution is known as domestic bleach.

4D TCP is a solution of chlorinated phenol.

5C Sodium hydroxide is used in the manufacture of ceramics.

Timescale for planet Earth



Things to do:
The boundaries between each period are approximate ones. When drawing up this chart, dates were checked in various books. One gave the date of the Triassic/Jurassic boundary as 180 million years ago, another as 195 and a third as 213. It might be interesting to look at a variety of timescales in different books and pencil in the dates they give alongside the boundaries. Why do such differences occur? Are these differences in dates significant?