Catalyst

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Brain waves?

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Catalyst

The front cover illustrates the potential danger of mobile phones to our brains.

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Contents

Welcome to issue 1!

Each issue of CATALYST contains articles which increase your knowledge and understanding of your GCSE science courses. This will help you to get better grades in your exams.

In each issue there will be three longer articles that tie in with the biology, physics and chemistry components of your science course. Within each of these articles we will try to include a section on how your GCSE science relates to current scientific research. The fourth main article will vary — it may be about how scientific ideas have developed or tie in with some aspect of science applied in technology or engineering. In this issue we look at mobile phones.

The word *issue* also has another meaning — a matter subject to question or dispute. In this issue, For Debate discusses the questions raised by the use of mobile phones. In later issues, we will look at the issues surrounding food safety and research involving animals.

Nigel Collins

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Topfoto

Mike Follows

Do u wan2 tlk> ;-)

Mobile phones are everywhere; most people in the UK own one. But how do they work? This article looks at the science behind this popular piece of technology.

GCSE key words
Electromagnetic spectrum
Carrier wave
Audio wave
Modulation

Radio waves form part of the **electromagnetic spectrum** (Figure 1), so they carry energy at the speed of light. Guglielmo Marconi pioneered the transmission of radio waves at the end of the nineteenth century, but radio did not capture the public imagination until 1910 when the long arm of the law stretched all the way to Canada. Dr Crippen, who had murdered his wife, believed he had got away with his crime when he escaped Britain with his secretary on a ship bound for Canada. However, the British police were able to alert their Canadian counterparts by radio. On arrival he was arrested and returned to Britain to face trial and execution.

Since then, radio has revolutionised the way we live. Television broadcasts, mobile telephones and microwave ovens all make use of radio waves (see Table 1). Mobile phones mean that people can be contacted just about anywhere, and they have even saved the lives of people drifting out to sea or stranded on a mountainside.

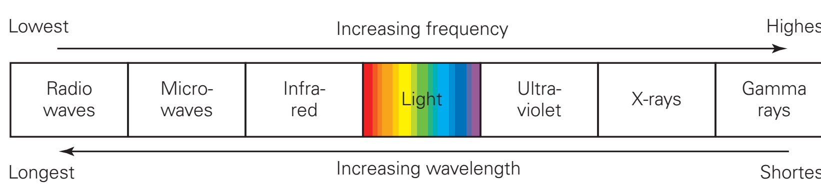


Figure 1 *The electromagnetic spectrum*

Table 1 *Typical wavelengths and frequencies in the radio spectrum*

Use	Wavelength (m)	Frequency
LW radio	1500	200 kHz
AM radio	300	1 MHz
Cordless phones	6	50 MHz
Radio-controlled cars and planes	4	75 MHz
FM radio	3	100 MHz
Television	1.5	200 MHz
Mobile phones	0.3, 0.16	900 MHz, 1800 MHz
Microwave ovens	0.12	2500 MHz

In the UK, there are more phones than people.

This base station carries aerials for several phone networks. You can also see two dish aerials which are used for microwave links between base stations

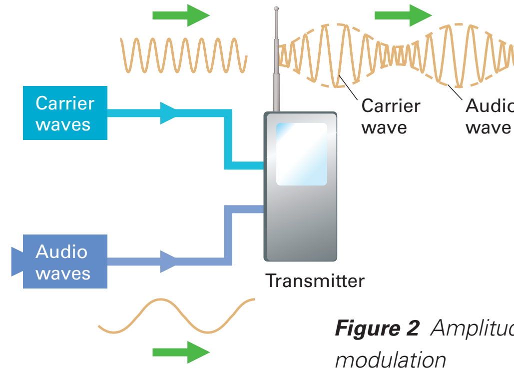


Figure 2 *Amplitude modulation*

The first mobile phones needed a battery the size of a car battery to work. They were usually used in cars — hence the term 'carphones'.

How does a mobile phone work?

A mobile phone transmits and receives radio waves, depending on whether a message is being sent or received. Inside, there is a circuit called an **oscillator** which causes a current to flow up and down the phone's aerial at a frequency of about 900 MHz (or 900 million times a second). This produces a radio wave that spreads out in all directions. Any nearby phone mast absorbs some energy from this radio wave, causing electrons (i.e. a current) to move up and down at the same frequency as the original signal. These radio waves do not themselves transmit a message, but they can be used as **carrier waves** to carry information.

- **It has been suggested that house sparrows are in decline because they are affected by the radiation from phone masts. How could you test this idea?**

Carrier waves

A message needs to be imprinted on the carrier waves. One way to do this might be to use Morse code. You could use a tapping key to switch the radio transmitter on and off repeatedly, so that shorter and longer bursts of carrier waves would travel to the receiver. The receiver would then translate the dots and dashes into a written message.

But it is much better if the receiver can hear the speaker's voice. A microphone picks up the voice and converts it into an electrical signal or **audio wave**. This is used to change or **modulate** the carrier wave.

- In **amplitude modulation**, the audio wave is used to change or modulate the **amplitude** of the carrier wave. This is shown in Figure 2.
- In **frequency modulation**, the audio wave is used to modulate the **frequency** of the carrier wave. This is shown in Figure 3a.

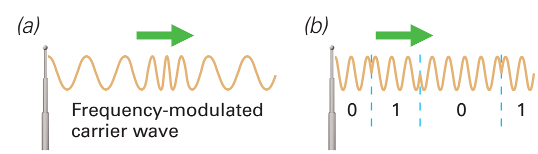


Figure 3 *(a) Frequency modulation and (b) phase modulation*

At the receiver, the electrical signal is demodulated. The carrier wave is removed, leaving just the audio wave that can be converted back into sound.

Digital signals

Mobile phones work in a slightly different way. First, the signal from the microphone is digitised; this means that the height of the original analogue signal is measured many times a second and converted into a series of ones and noughts. This is then used to modulate the carrier wave by **phase modulation** (Figure 3b).

Digital signals are good because, even if they become slightly degraded by noise, they can be recovered. They also enable several calls to be transmitted simultaneously; this is multiplexing.

What is a 'cell phone'?

Mobile phone companies divide up areas, such as cities, into **cells**. This is why mobile phones are also known as 'cell phones', particularly in the USA. A base station with transmitting and receiving aerials serves

Box 1 Why are the aerials for mobile phones so short?

In order to transmit or receive signals, a current of electrons must run up and down an aerial. If these aerials are not long enough, the electrons run out of aerial before the signal tells them to switch direction and the transmitted or received signal will be highly distorted.

Mobile phones operate at about 900 MHz or 900×10^6 cycles per second. The period of the wave is given by:

$$T = 1/f$$
$$= 1.11 \times 10^{-9} \text{ seconds}$$

During each cycle the electrons change direction so they are only moving in either direction for half of this time.

If the signal were to travel up the aerial at the speed of light it would travel:

$$\text{distance} = \text{speed} \times \text{time}$$
$$= 3 \times 10^8 \text{ m/s} \times 5.55 \times 10^{-10} \text{ s}$$
$$= 0.17 \text{ m}$$
$$= 17 \text{ cm}$$

However, within the aerial the signal travels more slowly than this so aerials can be even shorter. In fact, they are so small that they are usually hidden inside the handset itself (Figure 4).

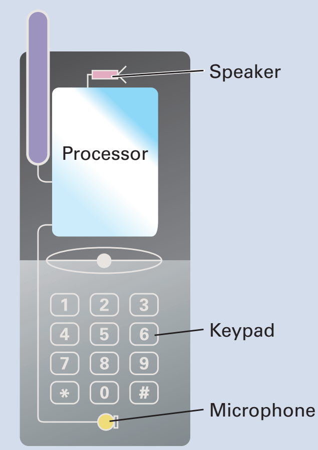


Figure 4 *Inside every mobile phone there is a processor, a microchip which carries out all the phone's functions*

Most mobile phones now include GPS satellite technology. Your phone provider can tell where you are to within a few metres. This could be useful in an emergency.

each cell, as shown in Figure 5. Cells can vary in size from **micro cells** with a radius as small as 50 m in densely populated areas to **hyper cells** with a 20 km radius. They can also vary in shape, but they are typically hexagonal.

Base stations operate at low power so that transmissions do not reach far into neighbouring cells. Because the nearest base station is never far away, mobile phones do not need powerful transmitters either. Once a phone has made contact with a base station, its power output is reduced to the level needed to maintain contact. The low power at which mobile phones operate means that they only need small batteries, so they are small enough to be carried around. Box 1 explains why the aerials of mobile phones are so small that they can be hidden inside the handsets themselves.

Left: *Early mobile phones were a lot bigger than those we use today*

Cells and base stations

The cellular approach requires a large number of base stations in a city but, because so many people use mobiles, the cost per user is low. To avoid interference, neighbouring cells must use different frequencies. However, people in the cells shaded green, for example, in Figure 5 can use the same frequencies to make their calls with no danger of interference between calls. The available radio spectrum can be divided up between a cluster of seven cells. The same frequencies can be reused in other clusters.

What happens if you move between cells during the same phone call? The signal received by the base station belonging to the cell you are leaving will get weaker while that received by the base station you are approaching will get stronger. At some point your phone receives a signal telling it to change frequencies and this **hand off** switches your phone to the new cell. By comparing the relative strengths of the signals received by the nearest base stations and working out how long it takes a signal from your phone to reach them, the phone companies can work out where you are to within a few metres. This information can be used to alert mobile phone users to things like the location of the nearest hotels and cash dispensers.

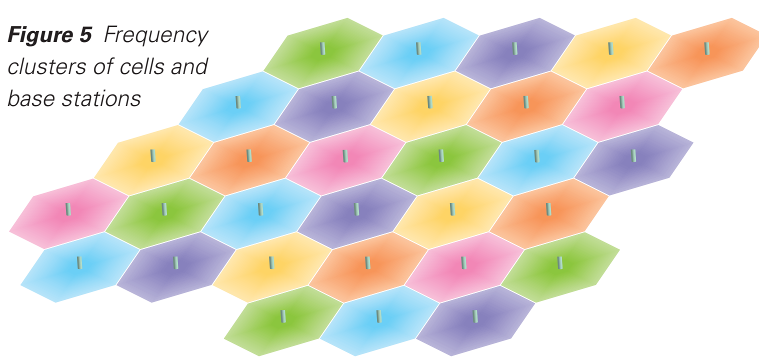


Figure 5 *Frequency clusters of cells and base stations*

• See 'For debate: Can your mobile phone damage your health?' on page 19 for a discussion of the hazards of mobile phones.

Mike Follows *has taught science at Sutton Coldfield Grammar School for Girls and is a part-time science writer.*

Improve your grade

Using datalogging for

When planning your practical investigations you may find that using a datalogger enables you to produce better data than more traditional methods. Datalogging software or a spreadsheet can also enable you to analyse your captured data more rapidly. But you must follow your exam board's guidelines because it must not appear that the computer has done all the work for you!

Sensors are available to measure many different quantities, including: time, temperature, pH, acceleration, light intensity, sound, voltage, current, radiation, oxygen concentration and movement.

Datalogging allows you to capture data that are hard to monitor or difficult to record. Examples of this sort of data include fast capture (e.g. sound waves), long-term recordings (e.g. temperatures in a pond over 24 hours or longer), and a range of timing experiments involving speed and acceleration.

Why is datalogging so useful?

Dataloggers can capture data in a much more stable and consistent way than you can by using your own eyes. They can capture more data points and can do so at more regular intervals. For example, think about the possible errors that might arise when measuring and recording a cooling curve using a substance such as wax:

- Did you read the thermometer accurately each time?
- Could you see the thermometer properly as the wax solidified?
- Did you lift the thermometer out from the boiling tube each time?
- Did you write each reading down correctly?
- Did you remember to record every 2 minutes without fail?

By using a datalogger you reduce the experimenter error because you can guarantee that the reading will be taken on time and more accurately.

Are dataloggers more accurate?

This does not mean that dataloggers are intrinsically more accurate. The example above refers to the datalogger recording samples regularly and consistently — dataloggers and computers are good at this. However, you must also take into account the accuracy of any sensor attached to the logger. Sensors

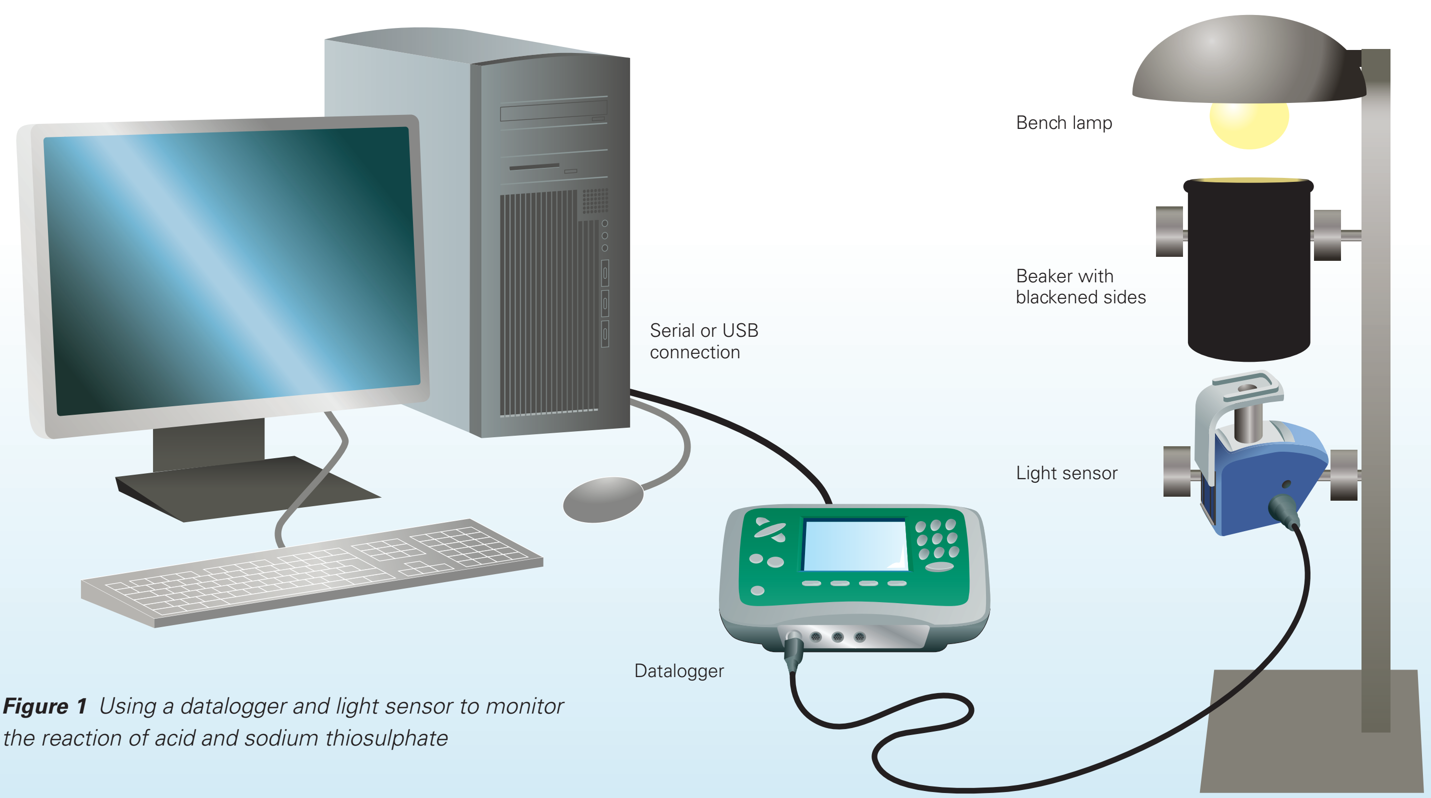


Figure 1 *Using a datalogger and light sensor to monitor the reaction of acid and sodium thiosulphate*

GCSE investigations

are not necessarily more accurate than normal laboratory equipment. For instance, in the cooling curve example above the actual temperature sensor may be no more accurate than a traditional thermometer, but the data collected are more consistent and accurate because there is no human error involved in the readings.

Take the errors out of guesswork!

At some point in your course you will probably investigate the reaction of acid and sodium thiosulphate, to find out how rates of reaction vary with either volume or concentration of acid.

Usually you stand the beaker on a sheet of paper with a cross. As the two solutions react, a precipitate of sulphur forms. This clouds the solution and the cross below the beaker slowly disappears from view. You need to try to monitor the time at which the cross disappears. How accurate is your decision as to when this happens? How many times might you and your friends disagree about the point at which it disappears?

If you use a light sensor (Figure 1) to record the clouding of the solution instead, you can agree a specific end point, for example when the light is reduced to 40%. When you change the volume or concentration of acid and repeat the experiment you can use the same 40% value as the agreed point rather than make inaccurate guesses. Look at Figure 2. It is easy to compare the 40% mark against the three different lines representing different volumes of acid added to the same volume of sodium thiosulphate.

Repeatability

Datalogging is a speedy process once set up, so you can easily repeat an experiment and compare results. You can compare the results in the thiosulphate experiment and analyse the data quickly — it would take you much longer to draw a graph for each set of results by hand. Another good example is when you are using light gates to measure speed — a simple click of the mouse allows you to record another run instantly and to produce a set of consistent results. Any errors are obvious straight away and you can discard any incorrect data.

Exam boards and datalogging

Exam boards are happy for candidates to use ICT in their work, but if you do use it you must meet the same criteria for assessment as you would if you were using traditional techniques. Therefore you must state why you decided to use a datalogger in your planning

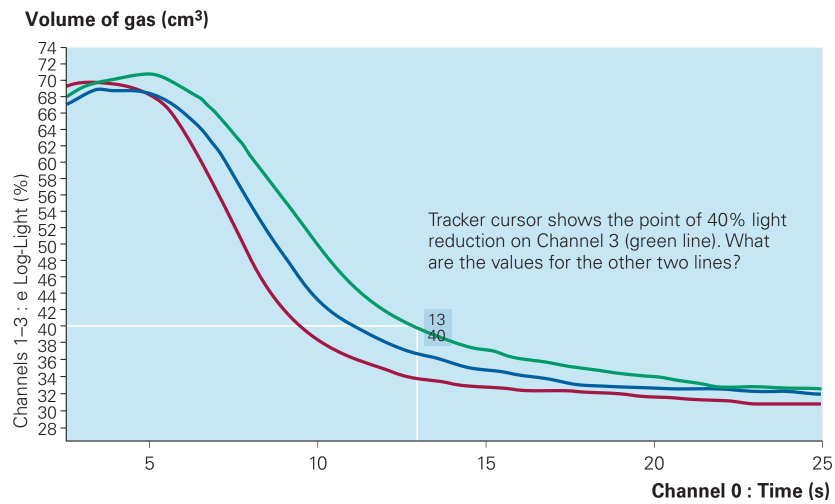


Figure 2 *Graphs generated by a datalogger to show the reaction of sodium thiosulphate with three different acid concentrations*

and explain how the software might help to improve your investigation. Obviously you must collect the necessary evidence/data and then display your findings in the form of appropriate charts and graphs.

You must take particular care about how you present and analyse your results. Computer-generated graphs are acceptable but you must be clear about why you set the graph axes as you did, particularly when datalogging software might do this automatically for you. You also need to explain your datalogging parameters, i.e. sample rate, duration of experiment and perhaps the range of the sensor used. You must ensure that the software plots sufficient points accurately for your examination board.

Once you have generated a graph you will need to identify patterns and trends in the data, carry out any calculation(s) and draw your conclusion(s). If a 'line of best fit' is appropriate then ensure you make a decision about the correct line, do not use a 'wizard' to do this for you. Remember that not all spreadsheets are scientifically based so their 'trend line' may not always be appropriate. If in doubt print out your graph with *points only* and then add your own 'line of best fit'.

Finally, when you evaluate your investigation you should comment on your use of datalogging, on quick repeatability, on faster graph production and on the options, if used, of data analysis provided by the software.

Phil Godding *helps develop new datalogging equipment and software.*

Dataloggers are useful in extreme environments or remote locations.

Seals in the Antarctic have been fitted with transmitting dataloggers which record heartbeat and the depth the seal is at. This information can be transmitted to scientists in the UK.

Submerged buoys are used in the world's oceans to log details about the surrounding sea. The data can be transmitted to scientists in the UK.

Your future

Forensic science

***Above:** Forensic scientists inspect the scene of a murder*

Television programmes often portray forensic scientists at the scene of a crime, aiding the police in tracking down a murderer. But their work is far more wide-ranging.

Forensic scientists aim to provide sufficient impartial evidence to make a clear case in court. They could be helping to convict a criminal, eliminate an innocent suspect, identify a forgery or establish a baby's paternity. First and foremost, they must be good scientists, and there are as many types of forensic scientist as types of crime.

***Below:** Staff at work in an evidence recovery unit*

The task of forensic scientists is to find links between the suspect and the crime. Materials such as fragments of glass or paint, fibres, DNA samples, firearms, items of clothing and documents arrive at the forensic laboratory in sealed and labelled bags. Usually more than one type of evidence will be required before the case is secure.

The work of the reporting officer (RO)

As the most senior type of forensic scientist, the RO has to decide what type of scientific analysis is required in each case, allocate resources and organise the work. Since an RO cannot be an expert in all fields, two reporting officers may work together on complex cases, while other assistants carry out analytical tasks. The RO reviews the work as it progresses and then writes it up clearly and accurately so that it can be read out by someone else in court and understood by non-scientists. ROs may sometimes be cross-examined in court themselves on their conclusions.

The analysis may require hours of painstaking work. In the Soham murder case, fibres from Ian Huntley's carpet were found on the girls' clothes and fibres from their sweatshirts were found on his carpet. Many thousands of fibres (mostly invisible to the naked eye) were collected by sellotaping over each small area of material and transferring the sellotape to plastic acetate sheets. Microscopes were used to look for a match. Matching fibres were then examined, using sophisticated scientific equipment, to determine the type of fibre, colour and dye composition. It took months. At the same time, other tests were also carried out: DNA analysis, examination of burnt items to find the cause of fire, and a study of pollen, leaves and insects (the girls' bodies were found in a wood).

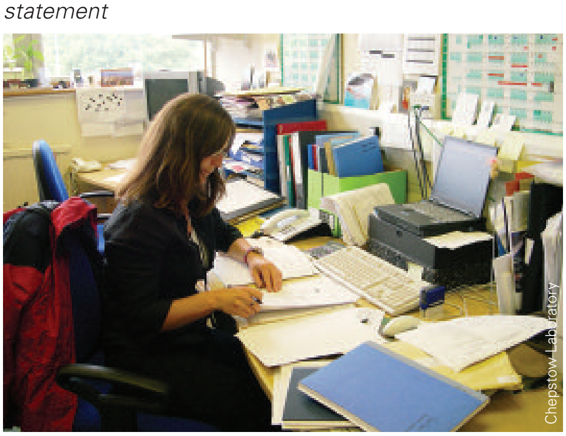
This was a huge operation, involving many forensic scientists, but even in simpler cases, several types of evidence are needed before they point inexorably towards one conclusion. Fingerprint evidence can be 100% conclusive, but nothing else is, not even DNA. Weighing up and combining evidence is a mark of the forensic scientist's skill.

Becoming a forensic scientist

If such a challenging job appeals, you can enter at various levels. A number of institutions employ forensic scientists, including the Forensic Science Service (UK). It has six laboratories, employing more than 600 scientists altogether, so competition is fierce. Entry after GCSE is possible for an assistant, but you will need very high grades and preferably an A-level in biology or chemistry. You may then work in an evidence recovery unit or specialise in certain analytical techniques. You will not be able to become a reporting officer without a very good degree.

Chemistry, biology or biochemistry are the preferred degree subjects. However, with the increase

Reporting officer checking through her completed statement



Box 1 Useful websites

To find out more log on to the following websites:
The Forensic Science Service (UK) at
www.forensic.gov.uk/forensic_t/inside/career/opp_1.htm
The American Academy of Forensic Science at
www.aafs.org

Left: *Recovery of glass and other debris*

in computer crime, electrical engineers and physicists are also required. Training will be given after starting work. Forensic science degrees give no advantage; if you are considering one, check that the course contains enough pure science to ensure that you become really competent.

Qualities needed by a forensic scientist

Some forensic scientists are employed by insurance companies to investigate fraudulent claims.

You will need the following qualities to be a forensic scientist:

- good qualifications
- good speaking skills
- meticulous care in your work
- good note-taking skills
- the ability to write accurately
- intellectual curiosity and a liking for puzzles
- personal honesty
- the ability to remain impartial — it is not your responsibility to put someone behind bars, only to deduce the truth as far as is possible using the evidence you have

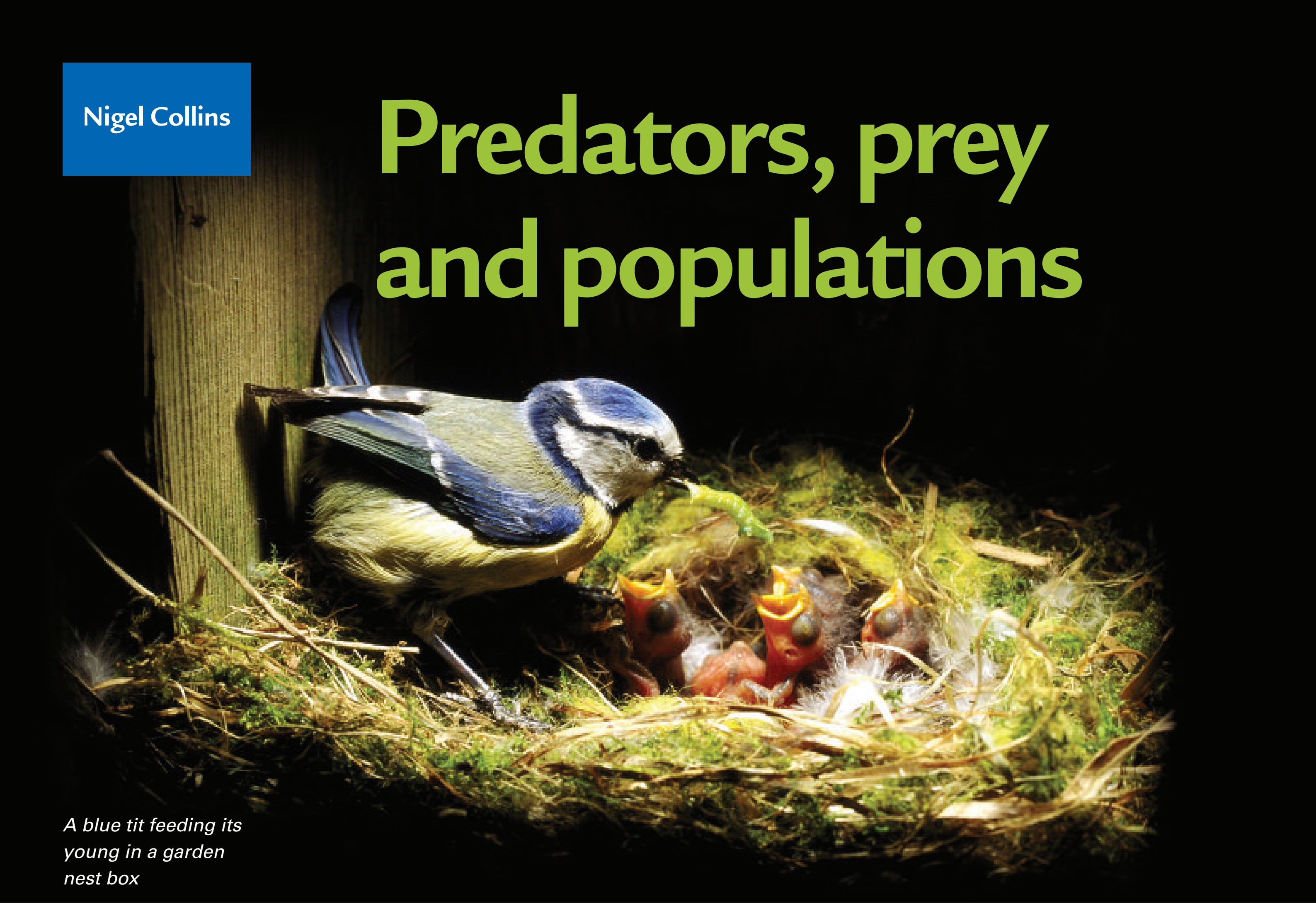
Still interested?

The internet has helpful information on opportunities and salaries. The websites of the Forensic Science Service (UK) and the American Academy of Forensic Science (AAFS) give a guide to the present scene (see Box 1). But with every advance in technology, the criminal world thinks of new possibilities and the work of forensic science changes. The future is anybody's guess. It could be yours.

Hazel Lucas *teaches physics and electronics at Haberdashers' Monmouth School for Girls and writes books on scientific issues for young people.*

Nigel Collins

Predators, prey and populations



A blue tit feeding its young in a garden nest box

GCSE key words
Predator
Prey
Population
Biocontrol

Animals that kill and eat other animals are called predators; the animals they eat are called prey. This article looks at some general principles that you need to understand about predator–prey relationships for GCSE. It also looks in some detail at the adaptations shown by a predatory insect being used in the control of an insect pest.

- **As you read this article, list factors that affect birth rate and death rate, which in turn help determine population size. (Answers on page 10.)**

Population size is also affected by immigration (movement in) and emigration (movement out).

Most organisms have the potential to increase their numbers dramatically through reproduction. A pair of blue tits in a garden nest box might have as many as 12 offspring hatching from a single clutch of eggs; in some years they might manage to fit in a second brood. Despite this, we are not overrun with blue tits — the population of blue tits visiting a garden stays much the same year on year. Why?

Changes in populations

Between one breeding season and the next one or both of the parents will probably die, as well as most of their offspring. All sorts of things may cause this. Birds of prey, such as sparrowhawks, might be responsible for some deaths. Domestic cats will take a heavy toll, especially those left out of doors overnight. There might be problems with food supply, linked with periods of bad weather, particularly in the winter following the hatching of the young. Competition between members of the brood might occur, resulting in some moving away to areas where blue tits are less common. Disease might also cause death.

In fact, extensive surveys of blue tit populations reveal that the population in England has shown a slight increase since 1966 (Figure 1). In recent years there have been fluctuations but no clear trend. One possible reason for the slight increase is that people

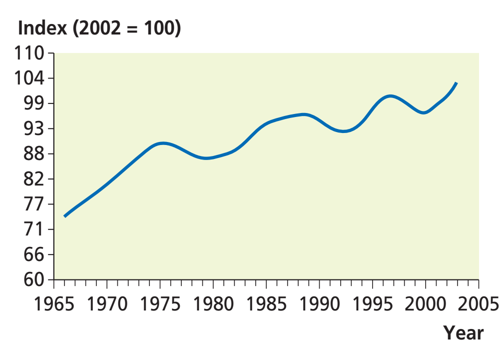


Figure 1 *Changes in blue tit population, 1966–2003. The population size in 2002 is given a value of 100. Other years are compared with this value*

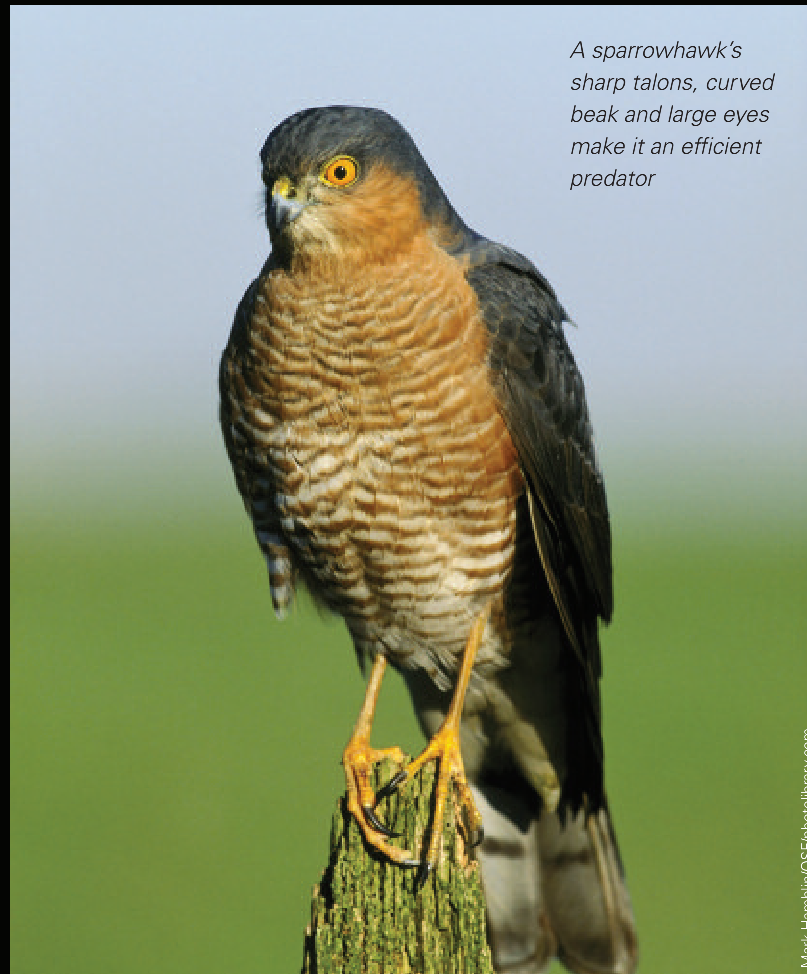
Box 1 Where have all the songbirds gone?

Although blue tit numbers have increased slightly, many other songbird populations have declined. Is there any link between this and the greater number of sparrowhawks around? Magpies, another possible predator, are also more common. Could this be linked as well?

The Royal Society for the Protection of Birds (RSPB) and the British Trust for Ornithology (BTO) have carried out intensive surveys of birds on farmland since the 1960s. Songbird numbers have not been linked to numbers of magpies or sparrowhawks. This suggests that magpies and sparrowhawks are not a serious cause of songbird decline. Studies, such as one at Wytham Wood in Oxfordshire, have shown that although predation of blue tits and great tits by sparrowhawks varied annually, the tit populations showed little change from one year to the next. You can find out more about this work at:
www.rspb.org.uk/birds/advice/predatorprey/facts_to_consider.asp

However, some people argue that predation by birds of prey such as sparrowhawks has been a significant factor in the decline in the number of songbirds. You can find out more about this argument at:
www.songbird-survival.org.uk/fact4.htm

Colin Milkins/OSF/photolibrary.com



A sparrowhawk's sharp talons, curved beak and large eyes make it an efficient predator

Mark Hamblin/OSF/photolibrary.com

provide food during winter and put up nest boxes, which protect eggs and nestlings from predators. In the wild predators may kill young birds on natural nests, which are more accessible than nest boxes. These predators include weasels, great spotted woodpeckers and magpies.

The population of sparrowhawks in the UK has increased markedly since 1974 (Figure 2). The population had dropped dramatically in the 1950s and 1960s as a result of organochlorine pesticides. These pesticides reduced the ability of the birds to breed successfully because their egg shells were so thin that they cracked in the nest. Improving breeding performance is likely to have contributed to the increase in population, and the birds are again producing thicker, tougher egg shells. The population seems to have stabilised since the mid-1990s.

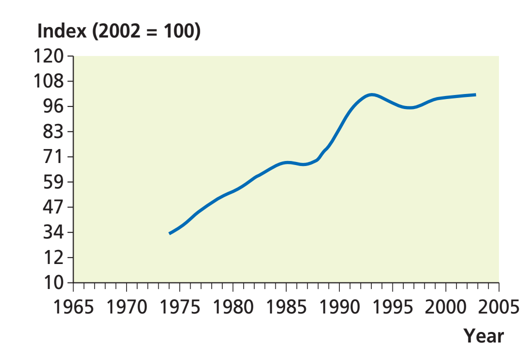


Figure 2 *Changes in sparrowhawk population, 1974–2003. The population size in 2002 is given a value of 100. Other years are compared with this value*

Adaptations shown by predators

A predator like the sparrowhawk displays obvious adaptations which make it an efficient predator:

- sharp, grasping claws or talons
- a curved, sharp beak for tearing its prey
- large forward facing eyes, giving it very good stereoscopic vision to mark out its prey

But what sort of adaptations are shown by other predators, such as insects?

- **Find out more about research on forest pests on Forest Research's website (www.forestresearch.gov.uk).**

Box 2 Useful websites

To find out about birds that are predators — often confusedly called birds of prey — and the small birds such as blue tits that may be their prey, log on to the RSPB's website (www.rspb.org.uk/birds). Then explore the A–Z index. As well as information about the birds, you will find video and sound clips.

You can see more graphs and maps of changes in blue tit populations at:
www.bto.org/birdtrends2004/wcrbluti.htm

You can see more detail on changes in sparrowhawk populations at:
www.rspb.org.uk/birds/advice/predatorprey/index.asp

Predators and biocontrol

Scientists at Forest Research have been examining the relationship between a predator and its prey in great detail because the prey insect, a beetle, is a serious pest. In western Britain, the spruce bark beetle, *Dendroctonus micans*, is a well-established pest that was accidentally introduced from continental Europe in imported timber. In Britain, the natural predators of *Dendroctonus micans* are absent and, freed from natural controls, it could quickly reach outbreak levels. When the beetle larvae hatch from eggs laid under the bark they tunnel to form galleries within the bark of living trees where they feed and develop, ultimately killing the trees.

Spruce is the UK's most important commercial tree species and managing this pest is a high priority. Forestry scientists have approached the problem in two ways:

- They have tried to restrict the spread of the pest by annual surveys around the edge of a quarantined area, followed by destruction of infested trees.
- They have bred and released a predatory beetle, *Rhizophagus grandis*. This beetle is found within the pest's natural range and preys only on the pest. This is an example of **biological control**.

This particular biological control programme has been highly successful because of the extraordinary ability of the predator to locate its prey even when there may be only a few infested trees in the forest.

- **Find out more about threats to UK forests from exotic pests and pathogens on the Forestry Commission's website (www.forestry.gov.uk/planthealth).**

- **Find out about what caused the death of most of the UK population of English elm trees. (Clue: the disease was confusingly called Dutch elm disease.)**

Right: Dendroctonus micans *adult and larvae*

Factors that affect birth rate and death rate and hence population size: food supply, weather, disease and predation.

Rhizophagus grandis

How does the predatory beetle find its prey?

The larvae of the bark beetle cluster together in a large gallery in spruce trees, eating the resinous bark and producing large amounts of faeces or 'frass'. In behavioural experiments with the predator, *Rhizophagus grandis*, using wind tunnels, scientists were able to show that the smell of this frass is highly attractive to the predator, much more so than the resin that flows from the gallery entrance formed by adult bark beetles or the bark itself.

The frass contains several resinous compounds called monoterpenes which are detected by sense organs located on the antennae. However, these same monoterpenes also occur in bark and in the 'resin tubes' at the entrance to the gallery, so why is frass in particular so attractive? From detailed chemical analysis in the laboratory, forestry scientists found that the secret lies in the blend — the distinctive 'scent' from the particular ratio of monoterpenes present in the frass.

Scientists reckon that the chain of events as the predator seeks its prey goes something like this:

- The predator initially responds to some of the individual monoterpenes that are highly attractive at low concentrations and therefore function as long-range attractants.
- Closer to spruce trees infected with the bark beetle, the distinctive 'scent' of the monoterpene mixture in frass attracts the predators to an infected tree.
- Once on the tree, predators walk to the source of frass odour and enter the bark beetle gallery.
- Within the gallery, final identification of the prey may occur through a response to specific chemicals associated with the bark beetle larvae, such as those that influence larval aggregation or perhaps the chemicals that stimulate egg-laying.

This small insect predator may show less obvious adaptive features than a sparrowhawk but it has nevertheless evolved a sophisticated set of adaptations. The same will be true of any predator.

Nigel Collins *is an editor of* CATALYST *and is grateful to Hugh Evans, Daniel Wainhouse and Nick Fielding of Forest Research for their assistance.*

Diamond's brilliant light

David Sang

In the heart of the Oxfordshire countryside, a brilliant new light source is under construction — the Diamond Light Source. How does this giant machine work and what will it be used for?

Diamond is a new science facility which will eventually host more than 30 cutting-edge research stations, conducting experiments in the life, physical and environmental sciences. It is housed in a striking doughnut-shaped building over half a kilometre in circumference and covering the area of five football pitches.

What is Diamond?

There are several ways to think of Diamond:

- It is a particle accelerator, in which a beam of electrons moves at speeds close to the speed of light.
- It is a source of brilliant light and other types of electromagnetic radiation, from X-rays to infrared radiation.
- It is a giant microscope, enabling scientists to study the internal structures of materials, right down to the level of atoms and molecules.

Synchroton light

Diamond will be a source of **synchrotron light**. Many of the everyday commodities we take for granted, from chocolate to cosmetics, from revolutionary drugs to surgical tools, have been developed or improved using synchrotron light. This uniquely bright and intense light can reveal, treat and transform a vast range of materials.

University researchers are the core users of synchrotron light, but household companies through to high-tech start-ups have already benefited from the sort of data that will be generated by a facility such as Diamond.

Accelerating electrons

A synchrotron is a type of **particle accelerator**. In this case, it is electrons which are being accelerated. The electron beam is initially produced by an **electron gun**, in much the same way as an electron beam is produced in a television tube (see Box 1). A high

GCSE key words
Electromagnetic radiation
Electrons
Acceleration

'Synchrotron light' is electromagnetic radiation. It is special because it comes as a narrow, intense beam and because its wavelength can be controlled, from X-rays through ultraviolet and visible light to infrared.

Box 1 Electron gun

An electron gun has a heated cathode, a cylindrical grid which is nearly closed surrounding the cathode and a series of anodes for focusing and accelerating the beam. If the beam wasn't focused, the negatively charged electrons would repel each other and spread out.

Above: *Dr Nick Terrill, Principal Beamline Scientist, overseeing the installation of the first girder, carrying vacuum equipment and magnets, into the storage ring*

Right: *Diamond storage ring being prepared for installation of girders*

voltage is used to accelerate the electrons; this happens in a linear accelerator (**linac**). They are then accelerated further along a circular path. Electric fields speed the electrons up and magnetic fields cause them to move around in a circle.

The aim is for the electrons in the Diamond beam to travel close to the speed of light. Once this has been achieved, they are deflected off to a doughnut-shaped vacuum chamber called the **storage ring** where they circle through specially designed magnets arrayed around the ring (see Box 2). Electrons can move at a steady speed in a straight line without losing energy; however, when the magnetic field causes them to move in a curved path, they lose energy, which emerges as beams of very bright, highly-focused light of different wavelengths. It is this light that scientists use to drive their experiments.

As the electrons curve around the storage ring, the light they emit travels off along a tangent to the ring (Figure 1). Scientific experiments will be set up in laboratories around the perimeter of the ring, at the points where these beams emerge (see Box 3). The laboratories are known as stations or 'hutches'.

The electrons in the storage ring beam have an energy of 3 giga-electronvolts (GeV); that is, the energy they would have if they were accelerated by a 3-billion volt battery.

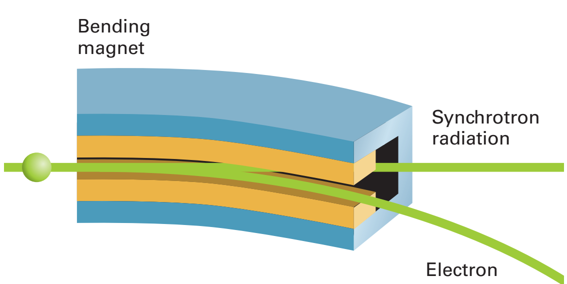


Figure 1 *Magnetic effect*

Box 2 Controlling the beam

The beam, as fine as a human hair, travels down the centre of an array of electromagnets. The powerful magnets are made from a super-conducting metal; it is cooled to a temperature close to absolute zero, where it loses all electrical resistance. Similar magnets are used in hospitals, in MRI (magnetic resonance imaging) body scanners.

Box 3 First experiments

When Diamond opens in 2007, seven experimental stations will come online, each with its own beamline coming off the storage beam:

- an extreme conditions beamline, for studying materials under intense temperatures and pressures
- a materials and magnetism beamline, set up to probe electronic and magnetic materials at the atomic level
- three macromolecular crystallography beamlines, for decoding the structure of complex biological samples, such as proteins
- a microfocus spectroscopy beamline, able to map the chemical make-up of complex materials, such as moon rocks and geological samples
- a nanoscience beamline, capable of imaging structures and devices at a few millionths of a millimetre

Plans and funding are in place for a further 15 beamlines to be added over the next few years, for all sorts of other experiments.

Because the electrons in the storage ring are losing energy, they slow down. Their speed is maintained by passing them through radio frequency cavities, which boost their energy each time they come around.

What benefits will Diamond bring?

Diamond will produce ultraviolet and X-ray beams of exceptional quality and brightness, a thousand billion times brighter than those from a hospital X-ray tube. These beams will enable scientists and engineers to delve deep into the basic structure of matter and materials, leading to scientific breakthroughs in the fields of biotechnology, medicine, environmental and materials science.

Biology and medicine

The fight against illnesses such as Parkinson's, Alzheimer's, osteoporosis and many cancers will benefit from the new research techniques available at Diamond. Investigating the structures of the proteins involved in such diseases will help scientists to understand them better, opening new avenues for treatment. For example, the 'anti-flu' drug Relenza,

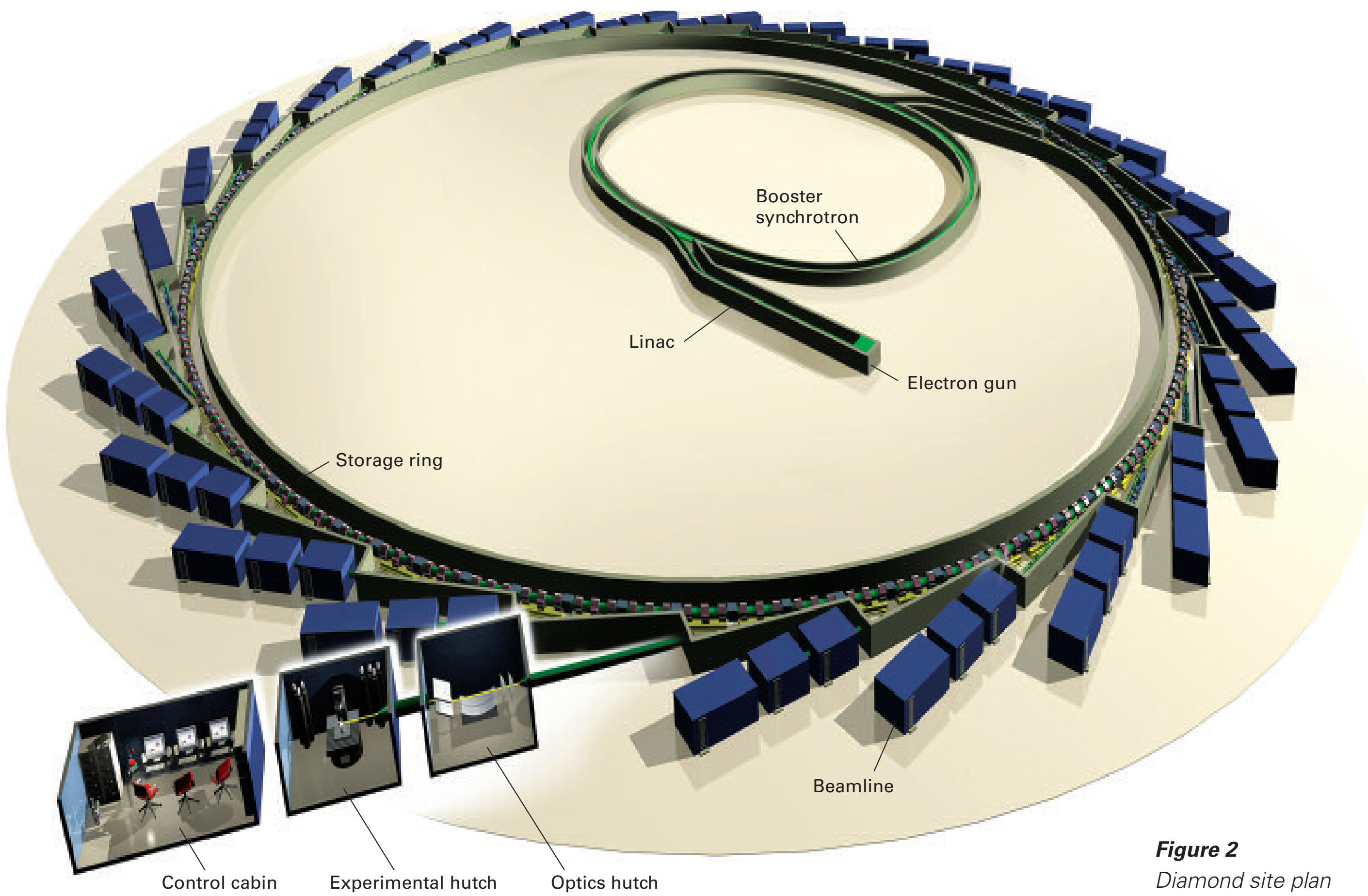


Figure 2
Diamond site plan

which was developed using structural information provided by synchrotron light, was a huge milestone in biomedical science.

Physical and chemical sciences

Without innovative, pioneering materials to choose from, UK industry would struggle to compete in the fast-moving world of product design. Often, understanding the structure of a new material is the key to perfecting the performance of the final product.

For electronic devices such as transistors, purity is crucial. The tiniest defect can ruin the quality of the entire component, leading to expensive waste during manufacture. A transistor is built up from layers of semi-conductor materials only a few atoms thick, so it is very difficult to see its structure. Using a synchrotron source, engineers can image structures down to an atomic scale, helping them to understand the way impurities and defects behave and how they can be controlled.

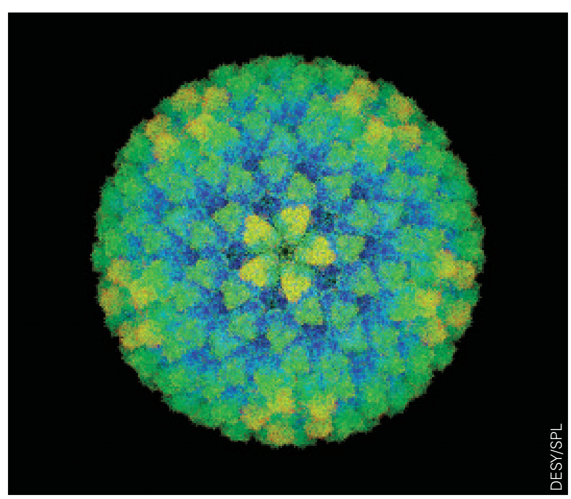
Environment and earth sciences

Pollution is one of the major problems facing us today. Understanding how contaminants make their way into the environment and how to counteract them can be a real challenge.

Some plants and microorganisms have a natural ability to absorb toxic metals from contaminated land and then deactivate them. Diamond will help researchers to understand how this happens and to identify organisms that target specific types of contaminant, opening up cheap and effective ways of cleaning up polluted land.

Synchrotron light has already helped scientists to understand the mechanisms and chemistry behind high levels of arsenic in Asian wetlands and pollutants in Pacific Ocean corals.

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



Synchroton radiation was used to determine the structure of this virus particle — a pathogen which causes bluetongue, a serious disease in cattle and sheep

The electron beam travels in an evacuated tunnel; the electrons would be stopped by collisions with air molecules if any were present.

- **Find out more about the Diamond Project and watch its progress on a webcam on its website (www.diamond.ac.uk).**

Nigel Collins

Coming to a beach near you!

GCSE key words

Carbon and nitrogen cycles

Factors affecting growth

What does a gully full of wobbling foam have to do with GCSE science? Read on to find out

Above: *A view from a high headland reveals the extent of the phenomenon*

During a recent short break on the south Wales coast, I headed for the beach down a familiar gully, but found my way blocked. The gully was full of undulating, wobbling foam, to a depth of at least 2 m. The foam, forming as waves broke on the sandy beach in the bay, was being blown into deep drifts across the beach and piling up in the gully.

In the odd corner the foam was starting to dry out, collapsing to leave a thin smear of dark green powder on the sand and rocks. Beneath the powder the sand grains had been cemented together to form a firm crust up to 5 mm thick. Some of the foam was being blown up the cliffs and inland onto fields.

A foam-flecked surfer provided an explanation. There had been an algal bloom – very rapid growth – in the Bristol Channel and the algae produce lots of sticky mucilage. Hence the foam produced by the breaking waves.

• When you are out and about let your mind play on all that you see around you and look for explanations from what you learn in GCSE science.

Links with GCSE science

How does this tie in with GCSE science? *Human impact on the environment* is involved – extra mineral nutrient input into the Bristol Channel may encourage the sudden growth of algae producing the bloom. It also ties in with other *factors affecting growth* – in this instance a few days of bright sunshine had warmed the surface waters of the Bristol Channel. And the sudden arrival of dead algae is organic input into the **carbon and nitrogen cycles** along the coast.

Mucilage holds the individual algal cells together. It is made of complex polysaccharides – chains of unusual sugar molecules.

Nigel Collins

Foam lying on the beach

The internet

A quick search on the internet led me to the marvellous Environment Agency website, a useful source of information when considering *human impact on the environment*. The specific address within this site that provides details about algal blooms is:

www.environment-agency.gov.uk/yourenv/eff/water/210440/212208/

It included a photograph identifying the probable culprit, *Phaeocystis*.

Further searching led me to the website of a district council on the Devon coast of the Bristol Channel which had a press release about foam the summer before:

www.torridge.gov.uk/index.cfm?articleid=4700

Click on the download on this site to find a poster that asks the question: *algae or sewage*?

Metals wordsearch

Puzzle

M	U	I	N	I	M	U	L	A	M
U	A	M	E	R	I	C	I	U	M
I	N	G	U	F	E	A	V	D	U
D	A	I	N	I	C	K	E	L	I
N	B	A	H	E	D	C	U	O	R
A	N	O	R	I	S	O	T	G	A
C	O	P	P	E	R	I	H	G	B
S	A	G	M	E	R	C	U	R	Y
P	O	T	A	S	S	I	U	M	L
S	C	L	A	M	U	I	D	O	S

There are 13 metals and their symbols in the grid – can you find them all? Words can run in any direction. Write the metals and symbols that you find on the lines below.

Answers on page 21.

Eggstra special fun!

Try this

Trick 1

Show your audience two eggs. One is raw, the other is hard-boiled. Can they tell which is which?

The secret

Set both eggs spinning. Touch one egg on the top, briefly, so that it comes to a halt. Repeat with the other. The egg which starts spinning again when you let go is the raw egg.

How it works

The liquid inside the raw egg keeps spinning even when you touch it. When you let go, the moving liquid exerts a drag force on the rest of the egg, pulling it round.

Trick 2

Show your audience a raw egg. Challenge them to break it just by squeezing it. (You can offer them a plastic bag or glove.)

The secret

Show that, no matter how hard you squeeze, you can't break the egg.

How it works

The shape of an egg is one of the strongest possible designs. It's like an arch. Squeeze it and the force is spread over the whole structure. To break an egg, you need to apply a sharp force at just one point – so don't wear a ring when you try this trick!

Box 1 More physics tricks

These tricks are from a collection of scientific tricks put together as part of the celebrations for Einstein Year. You can download more by logging on to:
www.einsteinyear.org/get_involved/physicstogo/document_view
and clicking on 'Physics Tricks'.

How can you tell if an egg is fresh or old? Place the egg in a jug of water. Newly laid eggs sink. The older the egg, the higher it floats. (As an egg gets older, air enters the air space at the end and water evaporates and diffuses out of the shell.)

Andrew Sharp

Aluminium

Aluminium is a shiny silvery metal, which is extracted from its ore by electrolysis. Further addition of other metallic elements results in an alloy, which can be cast into various shapes using moulds.

GCSE key words
Aluminium manufacture and uses
Electrolysis
Metals and structure

Aluminium ore (bauxite) is dug up in many parts of the world. Britain gets a lot of its supply from Jamaica. This ore is impure. The impurities are mainly from oxides of iron. The ore is carried by ship to treatment works, such as Auchinish in Ireland, where the impurities are removed. The pure oxide (alumina) is then shipped to aluminium smelting works (e.g. Anglesey Aluminium) where the process of electrolysis is used in order to separate the aluminium and the oxygen from the alumina.

Anglesey Aluminium extracts 142 000 tonnes of aluminium a year.

Extraction

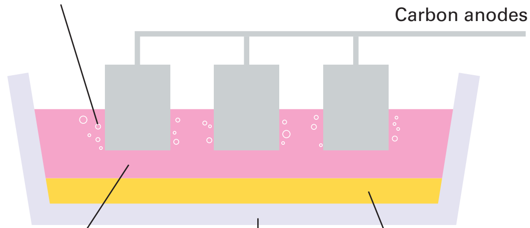
Aluminium oxide melts at 2015°C. It takes a lot of energy to get it to this temperature, so the oxide is dissolved in cryolite to reduce the melting point. Carbon electrodes are dipped into a bath of molten alumina and cryolite. A high current and low voltage are used to electrolyse the mixture (Figure 1). Aluminium is formed at the cathode and oxygen at the anode (Box 1).

Steel melts at 1535°C — without cryolite the steel container would melt!

Cryolite is sodium aluminium fluoride, Na_3AlF_6.

Electrolysis uses a current of about 125 000 amps and 4 volts.

Figure 1 *Extraction of aluminium from alumina*



The oxygen corrodes the carbon anodes and they break down forming carbon dioxide, so the anodes have to be replaced fairly often. The carbon dioxide produced is passed through a filter to remove any oxide dust particles and then released to the atmosphere. The high current which is used during the electrolysis process causes an increase in temperature and the mixture bubbles at about 1000°C.

One electrolysis cell makes about 5 tonnes of aluminium a day. At Anglesey Aluminium there are 135 cells in each of four different cell rooms. The aluminium produced is then cast into ingots or rods and sold to manufacturers who turn it into all sorts of different items made from aluminium and its alloys.

Aluminium is a relatively expensive metal since electricity is used in its manufacture, and electricity is costly, but aluminium has many useful properties (see Table 1).

Box 1 Electrode reactions in the manufacture of aluminium

At the cathode (negative electrode):

$$Al^{3+} + 3e^- \longrightarrow Al$$

At the anode (positive electrode):

$$2O^{2-} \longrightarrow O_2 + 4e^-$$

Aluminium ingots ready to be melted and cast

Objects made by casting

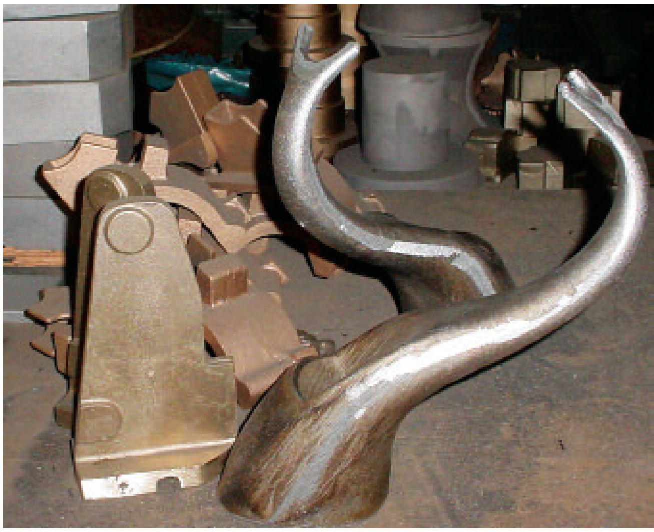


Table 1 *Properties and uses of aluminium*

Property	Example of use
Lightweight	Aeroplanes, boats and bicycles
Conducts electricity well	High-voltage power cables
Malleable	Boats, cooking foil
Doesn't corrode easily	Window frames

Casting

Aluminium can be used with other metals to form a range of alloys. These alloys are cast into a variety of useful and decorative objects which might be difficult to make by other means.

The White Eagle Foundry at Hurstpierpoint in Sussex casts aluminium into a range of products. In this foundry, ingots of aluminium (often containing other metals such as magnesium, iron, manganese, nickel, titanium and chromium) are melted using natural gas in refractory-lined ovens. Strontium, a group 2 metal, is often added in small amounts in order to cause small crystal grains to form when the metal solidifies. These small grains make the final product stronger.

Some hydrogen is absorbed into the molten metal as bubbles. This is because the molten aluminium reacts with moisture in the air. If the bubbles were left, they would cause a weakness in the final product. They are removed by blowing nitrogen gas through the mixture. Nitrogen absorbs the hydrogen and both gases are removed from the furnace. Aluminium oxide is also formed and floats to the surface. It is scraped off along with other impurities. If the impurities were left they would form impure lumps within the body of the cast object.

Preparing to blow nitrogen through the molten aluminium to remove traces of hydrogen dissolved in the metal

Stirring the furnace to ensure that the mixture is the same all the way through

Patterns and moulds

To make a casting mould a 'pattern' has to be made. This is an exact three-dimensional model of the object to be cast. It is made from wood, rubber or resin. The pattern is placed into a mould and sand is packed around it.

Several different types of sand are used. One commonly-used sand is Mansfield sand (also known as Greensand). This occurs naturally and was first discovered by the Romans. It is silica sand with 12–14% clay mixed in, which is bonded by water. It can be recycled by replacing the water lost as steam when the molten metal is poured into the mould. Other sands may have various resins and a catalyst added to them. The catalyst causes the resins in the sand to harden and so adopt the shape of the pattern.

An alloy is a substance made by mixing a metal with one or more other metals or non-metals. Alloys generally have different properties from their constituent elements.

- **Can you write the equation for the reaction of aluminium with water to produce hydrogen? (Answer on page 18.)**

Checking the mixture after the nitrogen blow

Right: Pouring molten aluminium into a mould

The finished object — ready to have excess metal trimmed off and then cleaned up

Right: Shrinkage occurs as the aluminium cools in the mould

Silica gel is a covalently bound network structure containing silicon and oxygen atoms.

The mould is made in two halves so that it can be separated and the pattern removed. This leaves a mould with the imprint of the object to be cast in it.

Channels are cut so that molten aluminium can be poured into the mould and to allow trapped air to escape. A reservoir is added so that when the molten metal contracts as it cools the mould can be topped up with molten metal (Box 2).

Aluminium shrinks by 6–7 % as it turns from liquid into a solid and then by a further 1.3% as the solid metal cools to room temperature. Patterns are therefore made larger by 1.3% to take into account any shrinkage. Often a ceramic filter is used in the mould to trap any remaining impurities and to stop them becoming part of the object being cast. Impurities weaken the structure.

- **Find out more about the White Eagle Foundry on its website (www.wef.co.uk).**

Box 2 Runners and risers

Channels which are added to allow metals to enter the mould are called **runners**. Extra shapes which may be added to feed the molten metal as it contracts are called **risers**.

Equation for reaction of aluminium with water:
$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$

Finishing the casting

Sometimes hollow objects may have to be cast, or shapes that cannot be cast from a single mould. If this is the case cores are used. These are special patterns which are made from a mixture of sand and silica gel. In order to get the silica gel to harden, carbon dioxide gas is blown over the pattern as it reacts with the silica gel.

Once the mould has been filled with molten aluminium alloy, it is allowed to cool. The sand is then knocked away from the cast object – this is usually with a sledge hammer! Any extraneous pieces of aluminium are sawn off – this is known as fettling – and the object is polished or treated prior to its use. Waste aluminium which has been cut off is returned to the melting furnace ready to be reused. The sand is crushed and screened to ensure that all the particles are of the correct size before being reused – this can be repeated many times before the sand finally becomes unworkable.

Finally

The casting process is labour intensive and so the objects produced are relatively expensive. This method is usually used when just a small number of items are made, or when items have a particularly complex shape. Countries such as China, where labour is cheaper, are now starting to compete for trade, with the inevitable closure of a number of foundries in the UK.

Andrew Sharp *is managing director of White Eagle Foundry, Hurstpierpoint, Sussex. He started life as an accountant and then trained himself in metallurgy and chemistry.*

Can your mobile phone damage your health?

Locals protest against a newly erected TETRA mast in their village

Topfoto

We are all bathed in the radio waves which spread out from mobile phones and masts. How would you set about finding out if this radiation is harming us?

Box 1 TETRA

The emergency services are making increased use of the Terrestrial Trunked Radio (TETRA) system. This is a mobile phone system with a difference — the strength of the signal varies with a frequency of about 17 Hz. There have been campaigns across the country against this, following reports of adverse health effects.

Box 2 Useful website

The Health Protection Agency Radiation Protection Board reports to the government on mobile phone safety. For the latest report, see its website: www.hpa.org.uk/radiation

YES

Concerned parent

'There's a proposal to put a phone mast on the roof of my daughter's school. She'll be exposed to radiation all day long.'

The radiation from a mast is very weak, provided your daughter is at least 2 m away from it. If she is using a phone of her own, the radiation entering her head will be much more intense.

Protester

'There's a case of a woman who has had dizzy spells ever since a TETRA mast was sited near her house. She can see it from her bedroom window.'

Do we know if her health problems started after the mast was switched on? There are many causes of such symptoms.

Official report

'Children may be more vulnerable because of their developing nervous system. In line with our precautionary approach, we believe that the widespread use of mobile phones by children for non-essential calls should be discouraged.'

Most calls made by children are non-essential.

NO

Complacent citizen

'With so many phones in use, we would surely have noticed by now if they caused cancer.'

There are many possible causes of cancer. It would take a proper scientific survey to determine whether cancer rates were being increased by mobile phone use.

Scientist

'We don't know of any mechanism by which the radio waves used by phones could cause cancer.'

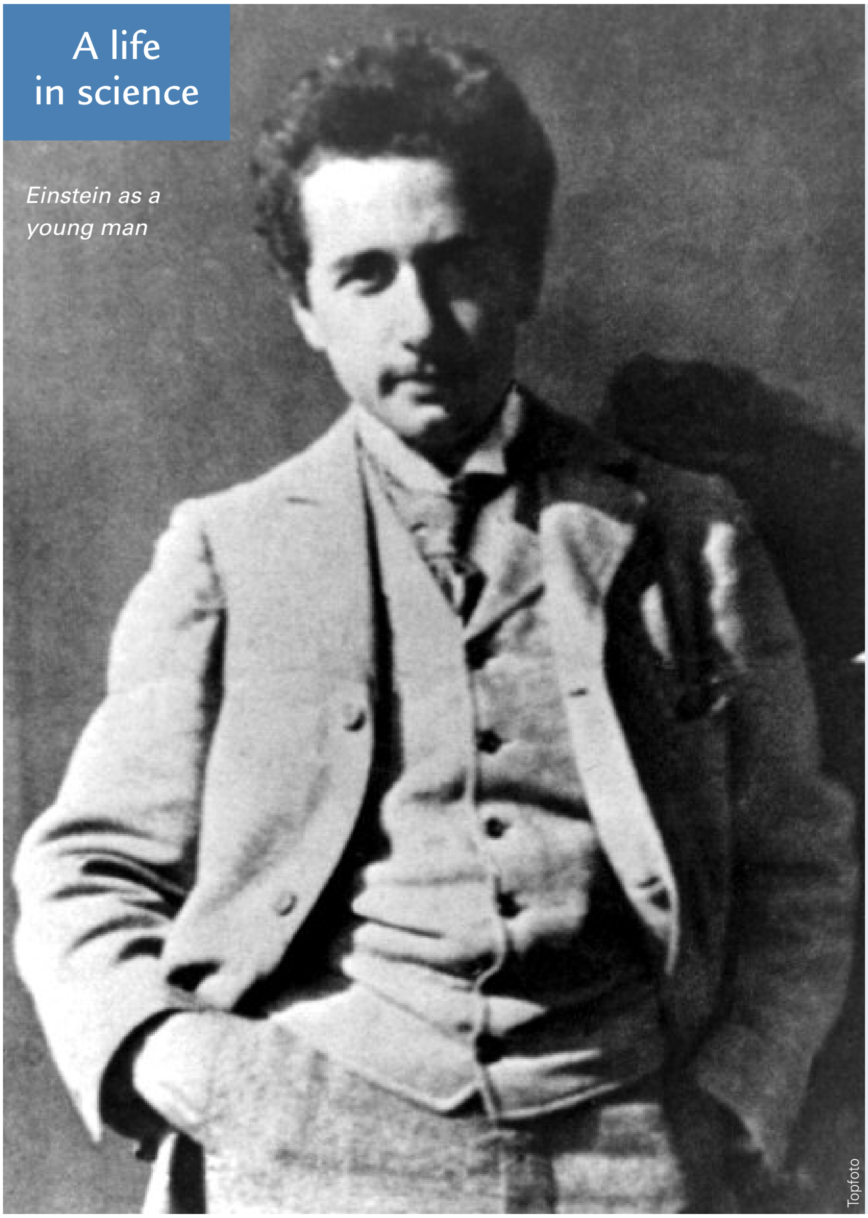
We wouldn't expect the low-energy radiation of radio waves to cause cancer, but there might be some mechanism we haven't thought of.

Scientific report

'There is no evidence that the use of mobile phones is leading to increased cancer rates.'

There might be a sub-group of the population who are more susceptible to the effects of low-intensity radiation. Should a small number of people be put in danger for the benefit of others?

A life in science


Einstein as a young man

Topfoto

Box 1 1905: Einstein's *annus mirabilis*

Albert Einstein published three important scientific papers in 1905, his 'year of wonders'. It is extraordinary that he could develop any new scientific theory in his spare time, while working at the Patent Office in Bern. But the most remarkable thing is that these papers cover three very different areas of physics.

Special relativity

In this theory, Einstein proposed that the speed of light was the greatest speed at which anything can travel. He showed that this idea has many consequences – for example, as an object accelerates towards the speed of light, its mass increases and time runs more slowly. It is relativity theory which gives us the equation $E = mc^2$.

Brownian motion

This is a phenomenon that was known from the nineteenth century. Tiny particles of smoke in air, or pollen in water, are seen to move about at random. Although most scientists believed that the particles were being buffeted by the random motion of the molecules of air or water, Einstein was able to analyse the way in which the particles moved and hence estimate the size of the molecules.

Photoelectric effect

When light shines on some metal surfaces, electrons may be released. The wave theory of light couldn't explain this; there didn't seem to be enough energy in light waves to help electrons escape from the metal. Einstein explained that light takes the form of particles (photons) when it interacts with atoms; one photon is all that it takes to release one electron. This is the basis of quantum theory.

Albert Einstein

It cannot have escaped your notice that 2005 is Einstein Year, or the International Year of Physics. Physicists around the world are celebrating Albert Einstein's great achievements of 1905, as well as looking ahead at the way new developments in physics will affect our lives over the next few decades.

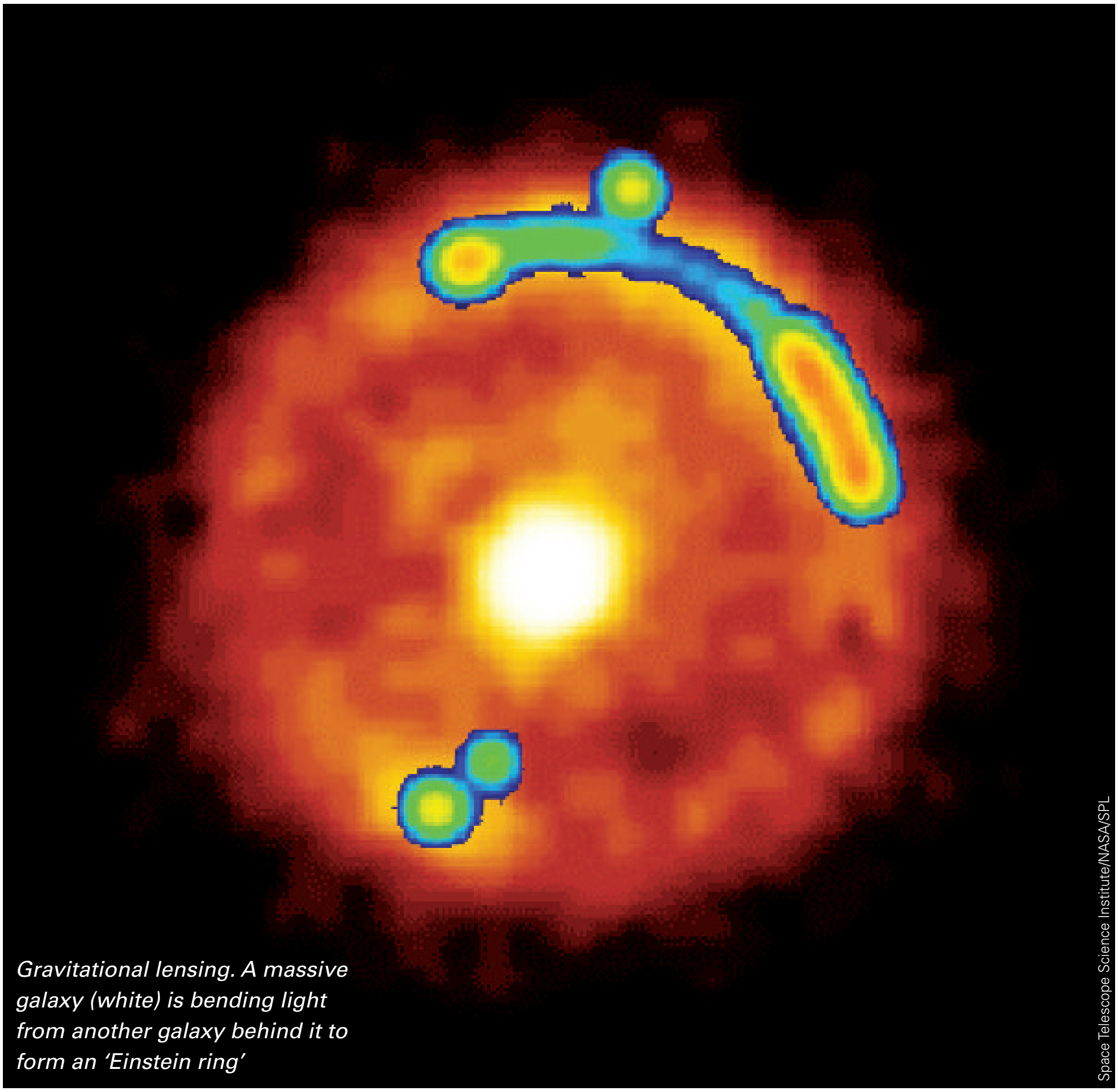
- **To find out more about Einstein log on to the Einstein Year website (www.einsteinyear.org).**

Albert Einstein (1879–1955) was born in Germany and spent most of his childhood in Munich. His parents encouraged him to be independent – they let him wander the streets when he was only 4 years old. He found the education system dull and conventional, and left school when he was 16. He followed his family, first to Italy, and then to Switzerland – this had the advantage that he avoided military service in the German army.

In Zurich, Einstein attended the Institute of Technology. He only just scraped through the final exams, not because he was stupid, but because he liked to sit around in cafés discussing the latest physics theories, rather than studying the official curriculum. He distracted the others in his class from their studies and his girlfriend failed the exams completely.

Going it alone

Einstein was confident that he could be a theoretical physicist, but the institute refused to keep him on. He got a job in the Patent Office in Bern and spent his spare time (and some of his working hours) developing his ideas about space and time. In 1905, he published the three important papers which eventually made him famous (Box 1).



Space Telescope Science Institute/NASA/SPL

Gravitational lensing. A massive galaxy (white) is bending light from another galaxy behind it to form an 'Einstein ring'

Box 2 Gravitational lensing

Gravitational lensing is an effect of **general relativity**. An astronomer sees two identical stars. There's really only one star, but light rays from the star are bent round either side of a massive object (such as a black hole), giving rise to a double image.

It is not unusual for a new theory to come from the fresh mind of a young physicist; but Einstein was unusual in that he kept on producing new ideas into his middle age. He later extended his ideas on relativity to form the **theory of general relativity**, in which he showed that gravity could be explained as the effect of large masses on space. A massive object such as a star distorts space, so that even light will follow a curved path near objects with mass (Box 2).

War and the bomb

Einstein was Jewish. In the 1930s, when war loomed in Europe, he left for America. He realised that physicists' new understanding of matter and energy meant that the atom bomb was a real possibility and that there was a danger that Hitler might get there first. He wrote a warning letter to Roosevelt, the US president.

After the war, Einstein worked with other scientists and politicians to try to control the spread of nuclear weapons. Joseph Rotblat, a British scientist who worked with him on this, said:

> Einstein was quite the opposite of what people think about scientists – being absent-minded and immersed in their work and naïve. He was fully aware of what was going on in the world and trying to do something about it. I admire him not only as a great man of science but as a great human being.

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

Answers to metals wordsearch, page 15

Aluminium	Al	Iron	Fe	Rhodium	Rh
Americium	Am	Magnesium	Mg	Scandium	Sc
Barium	Ba	Mercury	Hg	Sodium	Na
Copper	Cu	Nickel	Ni		
Gold	Au	Potassium	K		

Einstein was famous for his 'thought experiments'. He said to himself, 'What would an observer notice if…' and he developed his ideas from there. Subsequently, many practical experiments and observations have confirmed his ideas.

Scientific research is often described in a 'paper', published in a science 'journal'. This is the equivalent of an article in a magazine. In a science journal, papers are all laid out in much the same way, with the same sections – rather like your science coursework when it is written up, except often much longer!

In the equation $E = mc^2$, E is energy, m is mass and c is the speed of light.

$E = mc^2$ tells us how energy and mass are related. If we measure the mass of an object, we are measuring the total amount of energy in it.

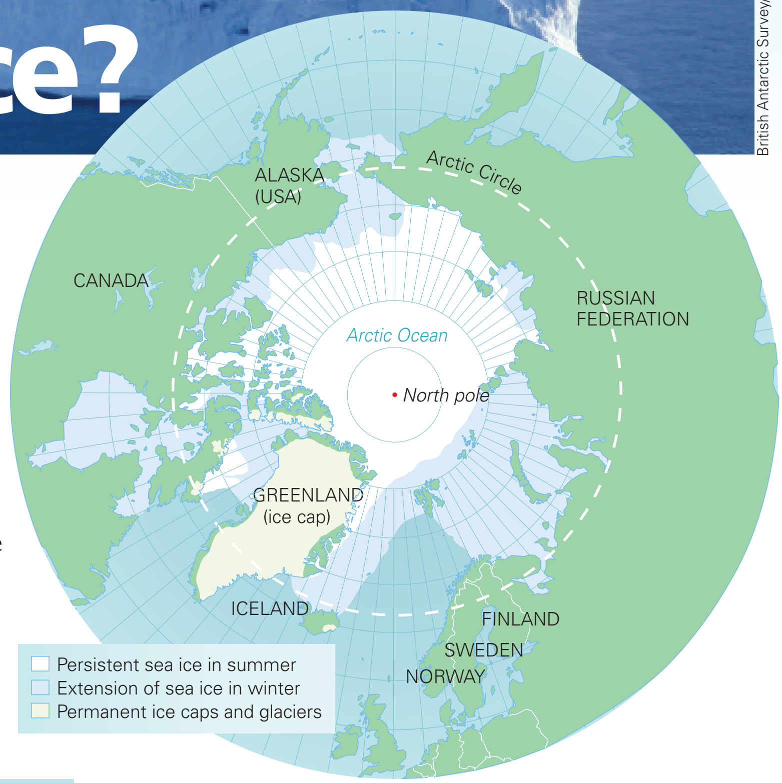
When an object gains energy, its mass increases. That's why a fast-moving object (with lots of kinetic energy) has a greater mass than when it is stationary.

British Antarctic Survey/SPL

Melting ice?

Many scientists believe that global warming may cause ice on high mountains (at high altitude) and in the polar regions (at high latitudes) to melt. There is already considerable evidence that glaciers are retreating in many parts of the world and ice shelves are breaking up around some parts of the Antarctic. What are the likely consequences of this melting?

Ice occurs in glaciers, in ice caps and where the sea freezes over. The north pole is located a few metres above sea level in the middle of a frozen ocean. The south pole, by contrast, is on the huge ice plateau of the Antarctic ice sheet, at an elevation of approximately 2850 m, most of which is measured in ice thickness. The Antarctic contains a lot of water locked up as ice, while the Arctic Ocean has relatively little. Most of the ice near the north pole is in the Greenland ice cap.



Look at the maps of the Arctic and Antarctic which make this contrast clear. If Arctic sea ice melts a lot more each summer it may affect the ocean currents of the thermohaline circulation (see CATALYST, Vol. 15, No. 4), but it will not add much to the world's sea level. However, if much ice on Greenland and the Antarctic melts it will raise sea level.

Activities

- Use a search engine to research **Arctic sea ice** and **Antarctic ice shelves**.
- Find out more about polar ice caps and read a discussion on the topic at: **www.unep.org/geo2000/english/0116.htm**
- Look at the current extent of sea ice at or around the poles at: **www.bsh.de/en/Marine%20data/Observations/Climate/Ice/index.jsp**
- Follow the ongoing discussion about the extent of Arctic sea ice at: **www.ukweatherworld.co.uk/forum/forums/thread-view.asp?tid=15024&start=1**