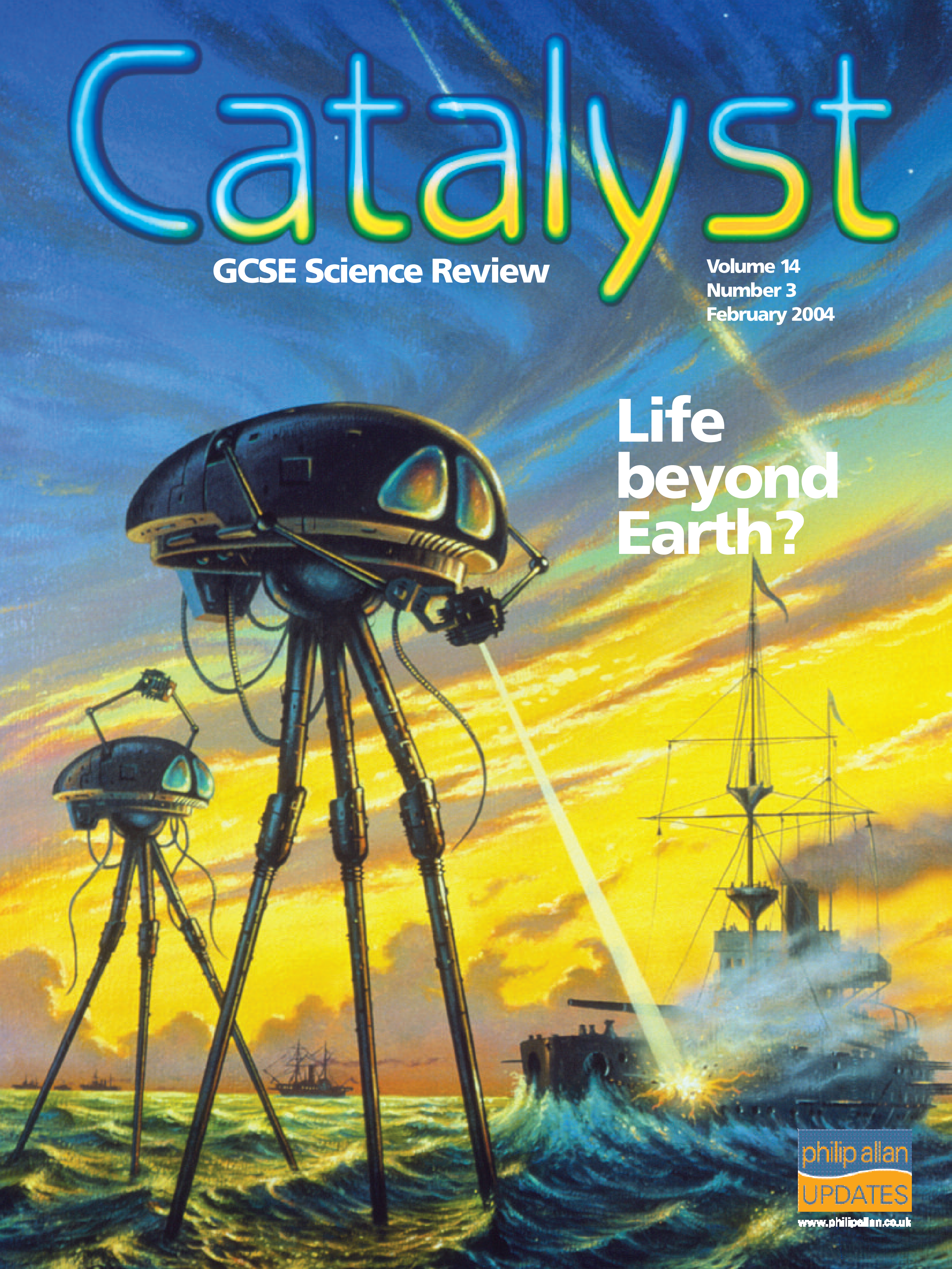
Catalyst

GCSE Science Review

Volume 14
Number 3
February 2004

Life beyond Earth?



philip allan UPDATES
www.philipallan.co.uk

ISSN 0958-3629

Publishing Editor: Jane Buekett.

Artwork: Gary Kilpatrick.

Reproduction by De Montfort Repro, Leicester.

Printed by Raithby, Lawrence and Company, Leicester.

Printed on paper sourced from managed, sustainable forests.

Catalyst

The front cover shows invading Martian tripods, from The War of the Worlds*, written by H. G. Wells in 1898 (David Hardy/SPL).*

Enquiries
For more information or to place an order, contact CATALYST Subscriptions at Philip Allan Updates.
tel: 01869 338652 fax: 01869 337590
e-mail: sales@philipallan.co.uk www.philipallan.co.uk
Published by Philip Allan Updates, Market Place, Deddington, Oxfordshire OX15 0SE.

Editorial

Bioinformatics

In the September 2003 issue of CATALYST (Vol. 14, No. 1) we celebrated the fiftieth anniversary of the discovery of the structure of DNA by Francis Crick and James Watson. The first draft of the human genome was published in February 2001. By April 2003 the project was completed, more than 2 years ahead of schedule. The DNA making up the human genome is distributed across 22 pairs of chromosomes and the X and Y chromosomes. Of the 2.9 billion bases of DNA code that have been read, scientists working at the Wellcome Trust Sanger Institute near Cambridge have contributed more than 0.8 billion — 30%. They have decoded one-third of the genome, that of chromosomes 1, 6, 9, 10, 13, 20, 22 and the X chromosome. The level of accuracy is astounding — less than one error in every 100 000 bases.

A colossal amount of information has been collected and people are developing ways to investigate what the coding reveals. A new area of science is opening up to handle this — it involves biology, mathematics and computing. New university courses have titles like biocomputing but the clear favourite seems to be bioinformatics.

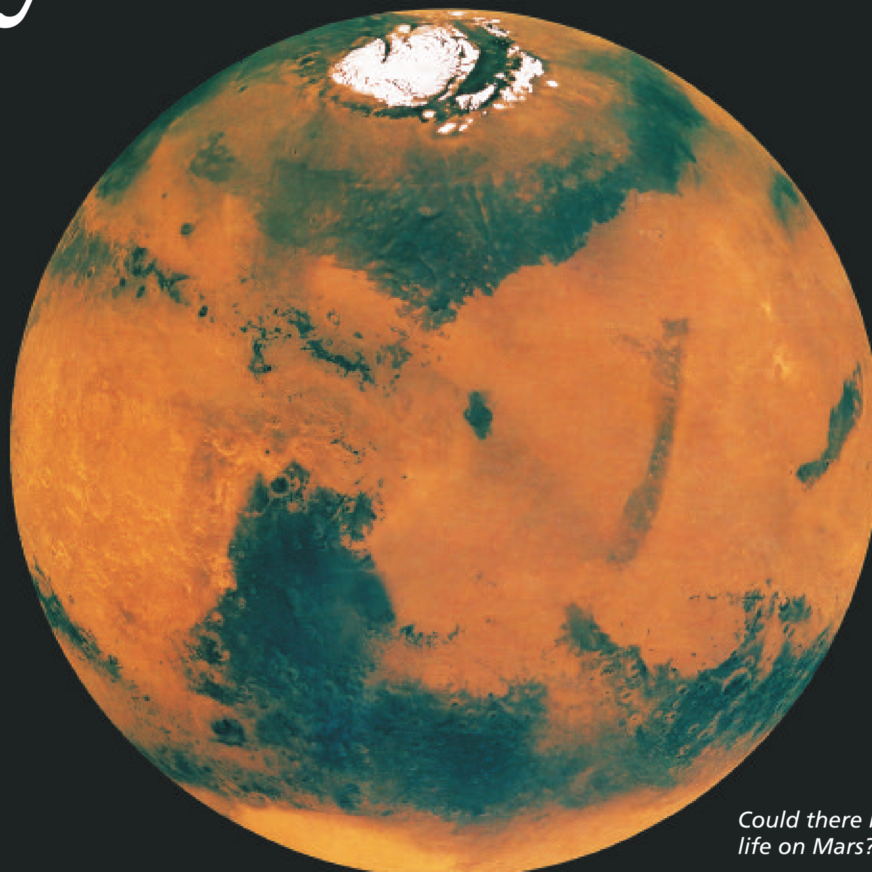
You will be well aware that mathematics is important in GCSE science, whether in manipulating formulae in physics, working out rates of reaction in chemistry or calculating averages in biology coursework. In 2 or 3 years time you may well be applying for university courses. If biology, mathematics and computing are a combination you enjoy, log on to **http://www.ucas.com** and look for the 14 bioinformatics courses on offer this year. It is certain that the choice of courses will increase to support exploration of the amazing terrain mapped by the Human Genome Project.

Nigel Collins

MIKE FOLLOWS

Life beyond Earth

Is there life elsewhere in the universe? Science fiction takes it for granted and scientists have found many different ways of looking for life out there. They are still looking!



US Geological Survey/SPL

Could there be life on Mars?

Here is the recipe for life on Earth:

- Liquid **water** is essential because it is the solvent in which biochemical reactions happen. Water is only liquid between its freezing and boiling points, that is between 0°C and 100°C.
- **Sunlight** provides the energy for life on Earth — but do other sources of energy exist?
- The element **carbon** is the basis of life on Earth. Each atom of carbon can bond with to up four other atoms. This leads to an almost infinite variety of compounds.

This recipe makes Mars an obvious candidate in the search for extraterrestrial life. It is the only other planet that orbits within the habitable zone — not so close to the Sun that water boils and not so far away that water is permanently frozen.

WHAT DO WE KNOW ABOUT MARS?

James Lovelock, famous for the Gaia hypothesis, made himself unpopular with NASA by suggesting that its *Viking* missions to Mars in 1976 were a waste of time and money. Looking at the spectrum of light from Mars allows astronomers to work out the composition of its atmosphere. The almost total absence of oxygen in the Martian atmosphere, shown in Table 1, led Lovelock to predict that the *Viking* missions would find nothing.

We don't know whether there are 'aliens' on Mars, but about 20 bits of rock chipped from the surface of Mars have landed on Earth as meteorites (Box 2). Speculation about life on Mars increased in 1996 when NASA scientists announced that the Martian meteorite ALH84001 contained fossils of bacteria.

Table 1 *The composition of our atmosphere compared to that of Venus and Mars*

	Venus	Earth, with life	Mars
Carbon dioxide (%)	96.5	0.03	95
Nitrogen (%)	3.5	79	2.7
Oxygen (%)	Trace	21	0.13

BOX 1 COMPARING ATMOSPHERES

Look at the figures in Table 1. There is no oxygen in the Martian atmosphere because it has reacted with iron to form iron oxide or rust on the Martian surface. This is why Mars looks red. In contrast, photosynthesis on Earth tops-up oxygen levels.

GCSE key words
Solar system
Respiration
Microwaves
Isotopes

Terrestrial comes from the Latin word *terra*, meaning earth, and is often used to describe life on Earth, especially that on land. *Extra* can mean outside or beyond so the term extraterrestrial means life beyond Earth.

- **Find out about the Gaia hypothesis.**

Is there any reason why we might doubt these data? The meteorite, which was found in the Antarctic, might have been sitting there for millions of years waiting to be discovered. There is a chance that one of our own (terrestrial) bacteria decided to live on ALH84001.

IS THERE EVIDENCE OF LIFE ELSEWHERE?

Microwaves are next to radio waves in the electromagnetic spectrum but have a shorter wavelength.

SETI (the Search for Extra Terrestrial Intelligence) seeks signals from extraterrestrials. It 'tunes in' to 1420 MHz in the microwave part of the electromagnetic spectrum. Microwaves are not absorbed much by interstellar gas and dust and the universe is very 'quiet' in the microwave part of the spectrum, so any signal would stand out. It is thought that other intelligent life would also know this and use microwaves to communicate. So far nothing has been detected.

GOING FOR A VISIT

We can send spacecraft to investigate likely planets. However, until we can find a quicker way of getting around, manned missions will be limited to our own solar system. Light takes 4 years to reach Alpha Centauri, the nearest star outside our solar system. This trip would take a spacecraft 12 600 years.

NASA sent two *Viking* spacecraft to Mars in 1976. They carried out experiments designed to look for evidence of photosynthesis and respiration. Robotic arms sampled Martian soil. Half the samples were kept as controls while a mixture of water and nutrients — 'chicken soup' — was added to the others.

BOX 2 METEORITES

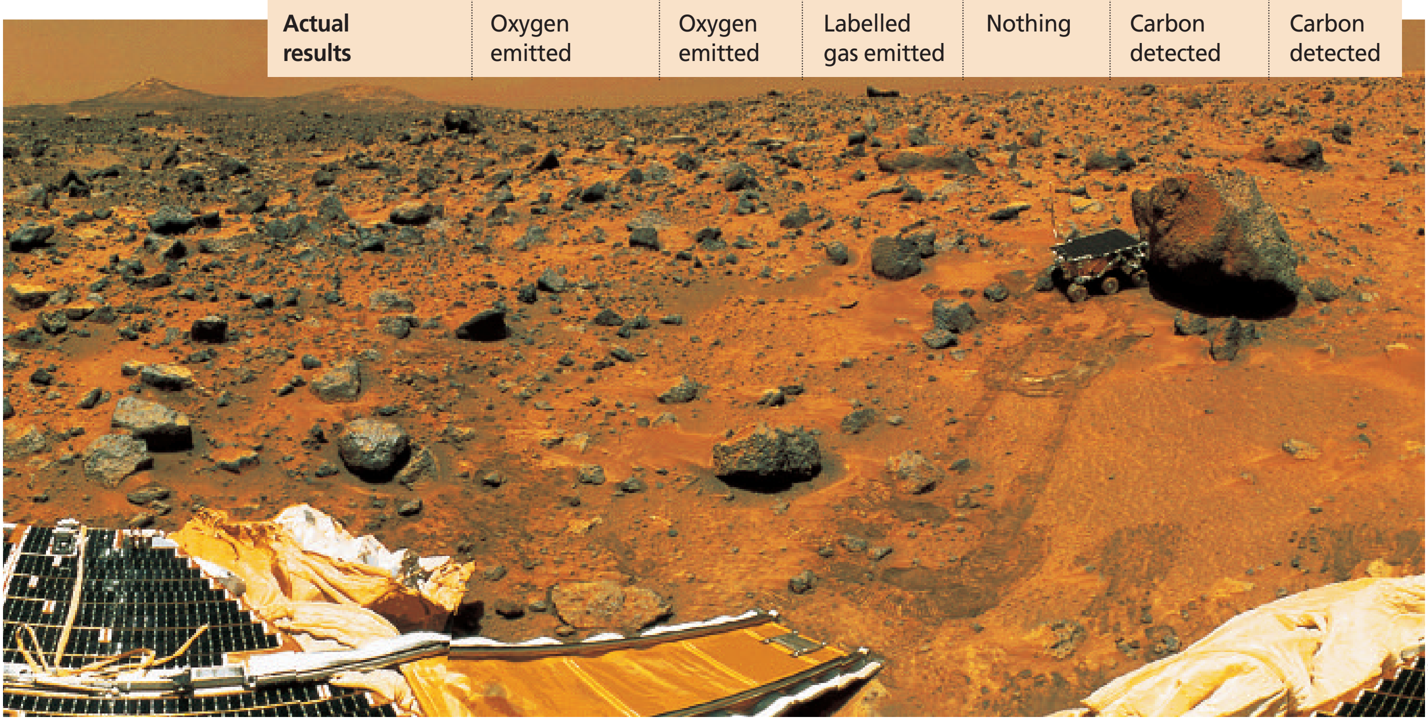
'Shooting stars' are really **meteors** — specks of rock that enter our atmosphere. They experience friction that generates heat and they burn up. We see them as streaks of light across the night sky. The few that reach the ground are called **meteorites**. Most meteorites come from the asteroid belt but scientists are studying about 20 that came from the Moon and a similar number from Mars.

Each meteorite is given a unique label. The letters state where it was found and the first two numbers give the year it was discovered. ALH84001 was the first meteorite (001) to be found in 1984 (84) in the Allan Hills ice-field in Antarctica (hence ALH).

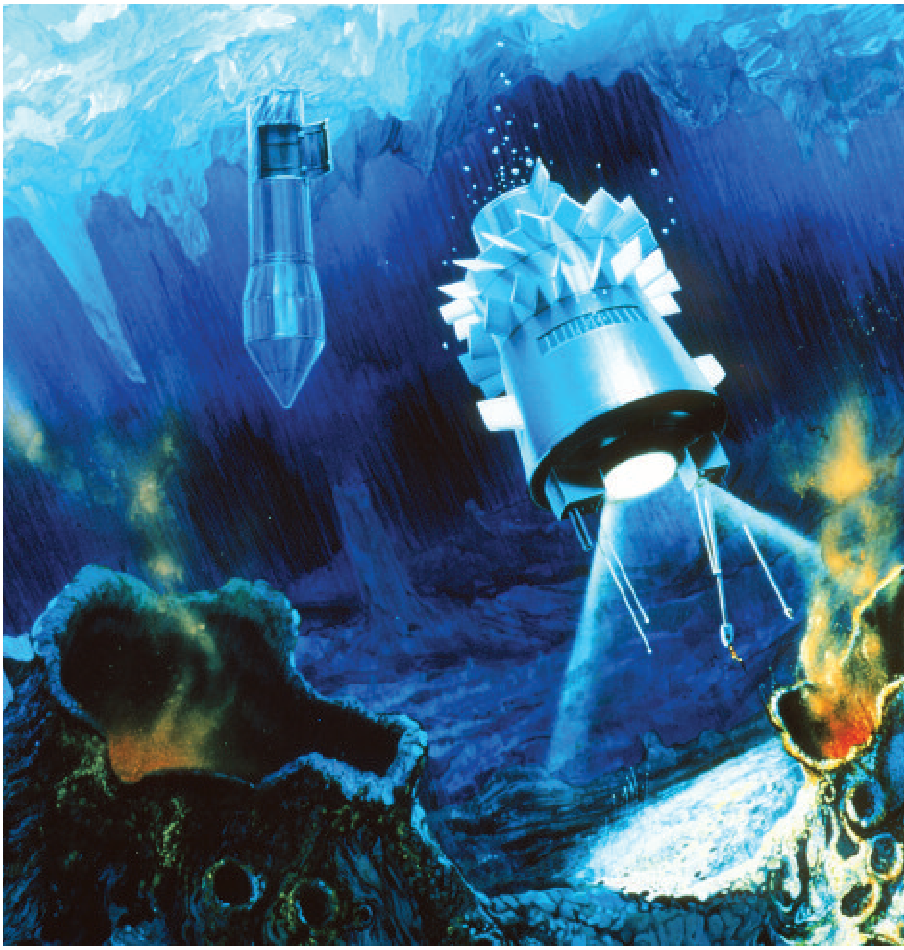
Table 2 Results of the Viking *experiments*

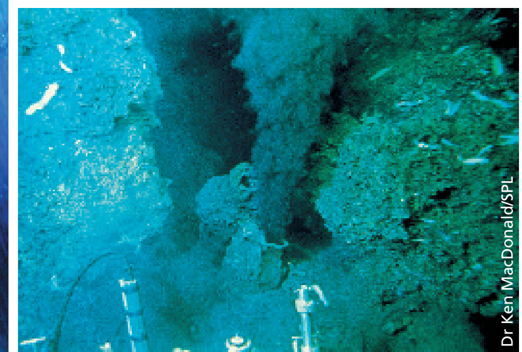
	GEX		LR		PR	
	Sample	Control	Sample	Control	Sample	Control
Results expected if there is life on Mars	Oxygen and carbon dioxide emitted	Nothing	Labelled gas emitted	Nothing	Carbon detected	Nothing
Results expected if there is no life on Mars	Nothing	Nothing	Nothing	Nothing	Nothing	Nothing
Actual results	Oxygen emitted	Oxygen emitted	Labelled gas emitted	Nothing	Carbon detected	Carbon detected

Below: *A robot investigating the surface of Mars after riding down the ramp from the lander (foreground) in a 1997 mission*



NASA/SPL





Above: *A 'black smoker' on the Earth's ocean floor, which supports life without sunlight*

Left: *An artist's impression of hydrobots being deployed beneath the ice of Europa*

The mix provided two of the three requirements for life. Several experiments were carried out:

- The GEX (gaseous exchange) experiment tested for evidence of respiration.
- In the LR (labelled release) experiment, chicken soup which had been 'marked' with carbon-14 was added to soil samples. This radioactive isotope of carbon was used as a tracer. The appearance of radioactive carbon dioxide was monitored to see if Martian life-forms had broken down the radioactive chicken soup.
- The PR experiment looked for microbes taking up radioactive carbon dioxide.

Look at the results of these experiments in Table 2. Would you conclude from these that there might be life on Mars? The tests appeared to detect respiration but the *Viking* mission did not find any organic molecules, let alone any creatures. In the end scientists rejected the evidence because it suggested that life forms could survive over too wide a range of conditions.

WIDENING THE SEARCH

In 1977, after the *Viking* missions, scientists discovered life in an unexpected place right here on Earth — next to hydrothermal vents called 'black smokers' at mid-ocean ridges (see CATALYST Vol. 11, No. 4).

These black smokers are several kilometres below the ocean surface, far deeper than light can reach. Life here cannot be driven by photosynthesis. So where does the energy come from? In a process called **chemosynthesis**, bacteria get energy from the chemical reaction between oxygen and hydrogen sulphide, which is emitted by the black smoker. Other creatures feed on the bacteria. Scientists now accept that starlight is no longer essential for life and are looking for life in places they had previously dismissed as too hostile.

The search for life is one of the reasons why an armada of spacecraft has been racing to rendezvous with Mars at the end of 2003. This includes Britain's *Beagle* 2 lander aboard the Mars Express spacecraft.

Scientists also have high hopes of discovering life on Europa, one of Jupiter's moons. They believe that it is like the Arctic, an ocean of liquid water covered in ice. The tidal energy from Jupiter is thought to prevent the ocean freezing and might provide the energy to sustain life. Scientists are already developing hydrobots which they plan to test in the Arctic.

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

● **For more about *Beagle* 2 and about the bacteria found on a Martian meteorite see 'Mars Express' in the previous issue of CATALYST (Vol. 14, No. 2).**

IMPROVE your grade

Making notes

As a GCSE student you should have started to develop the skills needed to make your own notes about the topics you are studying. This Improve Your Grade gives you some help with making notes for your coursework and revision.

Making notes takes time. You have to find the information in several sources, read, watch or listen to each, and then write or type the useful stuff. It sounds simple, but it's all too easy to get it wrong. The two commonest mistakes are to compile too much information and not to put enough in! Put in too much and you get lots of unwieldy information, you can't find the important bits, and it has taken too long. Leave out too much and the information you want is not there! How can you get the balance right?

Memory cue: we remember things better when they are linked to images.

THE RIGHT NOTES FOR THE RIGHT SITUATION

Revising for a test

You should have the information you need already. Making revision notes helps you refresh your memory and put things in bite-sized chunks that are easier to remember. The best notes are short, limited to key points, and include cues to help you recall the data. Bullet points, spider diagrams, tables and flow charts are all good for revision. Figures 1–3 show you some ways of learning the electromagnetic spectrum. Which suits you best?

Finding information for homework

Each book, CD-ROM or website you use tells you what the *author* thinks you should know — this is not the same as what you *need* to know for your task. Each book or website will cover just a limited amount of the information available. You need several sources of information from which you can select the most relevant data for your task.

Have a notebook and pencil to hand. Think carefully about what you want to know and put headings down the page, leaving plenty of space between each. Alternatively you can divide the page up into boxes. As you read each reference or source, select and scribble down any relevant points under the

Figure 2

1	gamma	highest frequency	treating cancer
2	X-ray		examining broken bones
3	ultraviolet		sterilising labs
4	visible		photography
5	infrared		heating
6	microwaves		communications
7	radio	lowest freq	broadcasting

Memory cues: there are seven to remember, put them in order, highest frequency first, make a mnemonic of the initials GXUVIMR.

Figure 1
These notes suit visual learners

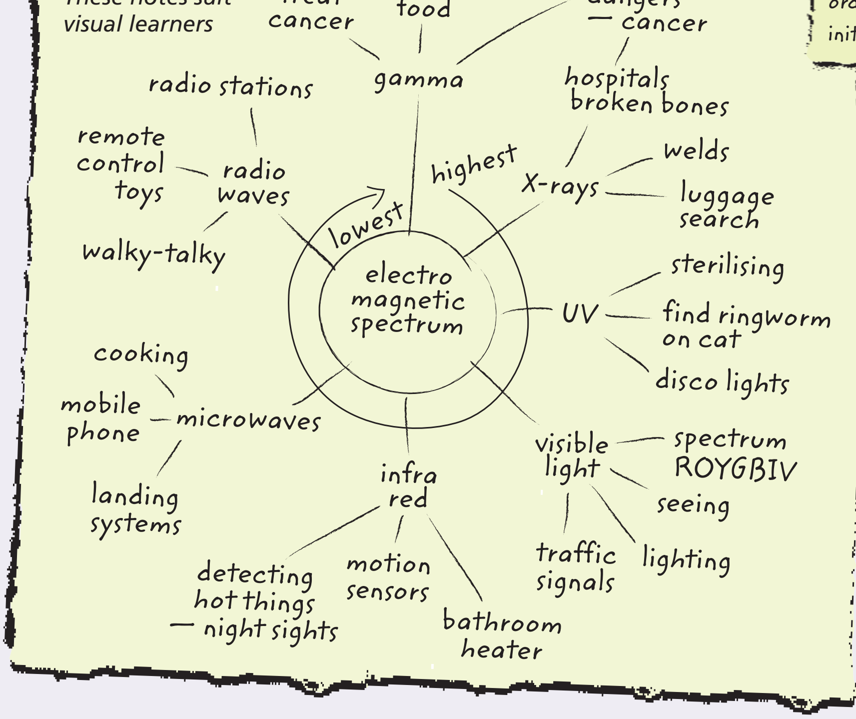
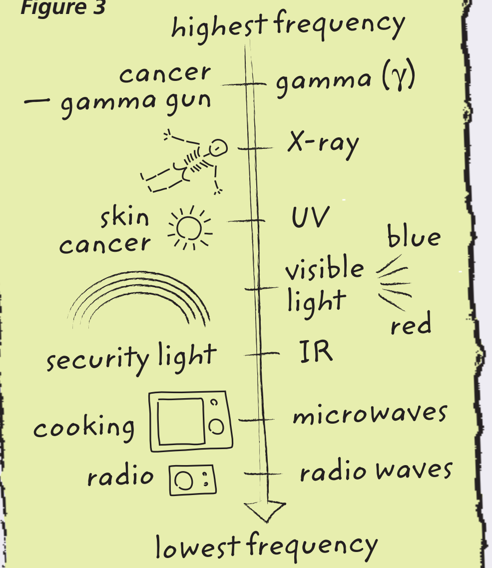
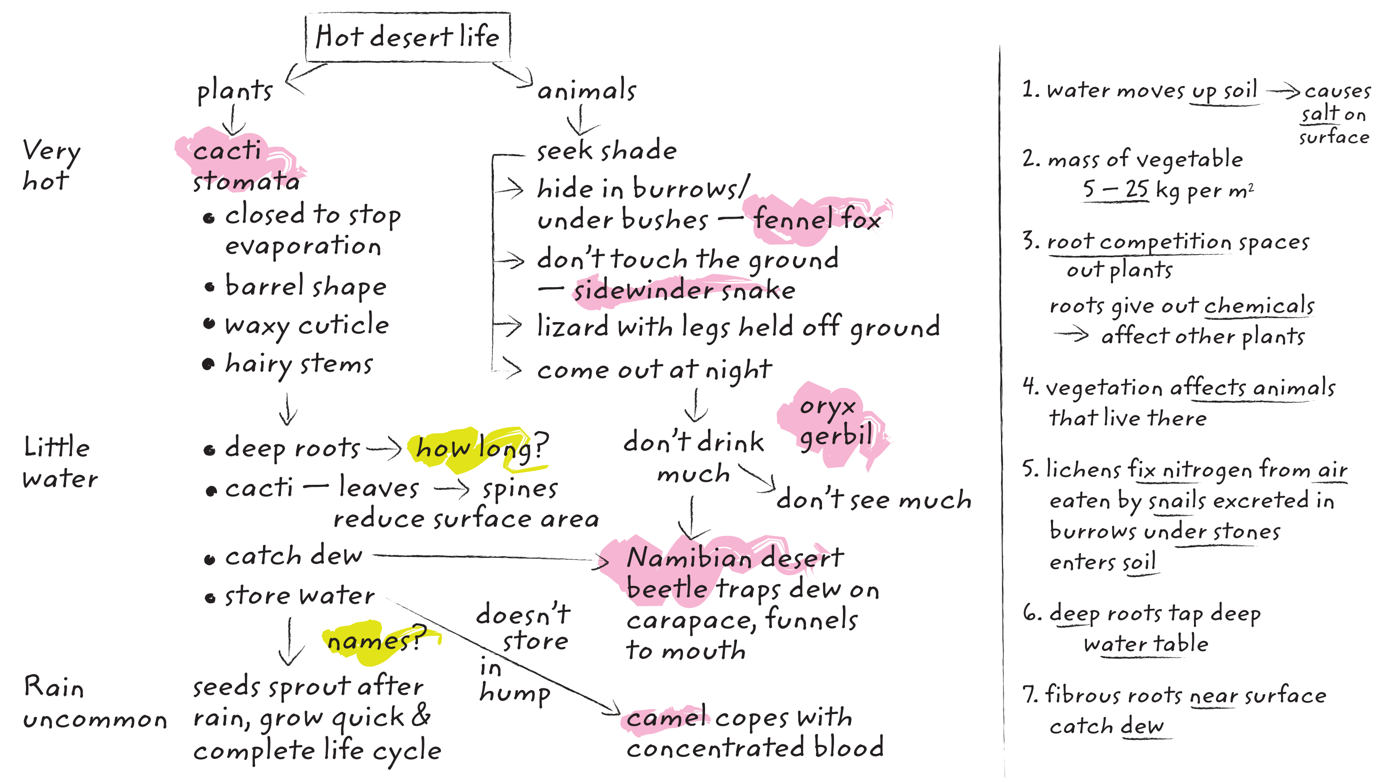


Figure 3



BOX 1 MAKING NOTES FOR A HOMEWORK



appropriate headings. This organises your information and prevents duplication. You don't need to use whole sentences — bullet points and linked words are fine. Once you have looked at three or four sources you should have enough information to tackle your homework. Box 1 shows some raw notes for a homework on making a poster about how animals are adapted for life in the desert.

INTERNET AND CD-ROM NOTES

The web is a fantastic source of information, but you can waste a lot of time when your search engine comes up with thousands of useless sites. Searching for elephants I found sites where I could buy books about elephants, read jokes about them, but nothing about how long an elephant's pregnancy is — which is what I wanted to know. I should have put [elephant gestation] into the search.

Once you have found a useful website or CD section use a word-processing program to open a second window for cutting and pasting useful stuff into. Copy and paste useful sentences and images.

Now you need to **select**, **edit** and **rewrite**, particularly if your work is to be given in as homework. Teachers know *Encarta* entries off by heart because of the number of pupils who copy anything remotely useful and hand it in as their own work. You won't get credit for copying — you must make your information address the task you have been set.

Don't be tempted to include interesting but irrelevant material. For example if you have to write about Marie Curie and the significance of her work it is relevant to mention why she had to move to France from Poland to study, but not that she was a governess for a time. She was exploring energy travelling from the interior of the atom at a time when people thought the atom was an indivisible solid — this is more important than how her husband died in a road accident.

RESEARCHING COURSEWORK

Many of the older science textbooks tell you how to carry out practical work on particular topics. You can make notes on quantities, procedures and times needed for activities. You will need to go further for coursework and decide how to turn a practical exercise into a valid and reliable investigation. Many students find A-level texts useful for the scientific background to the investigation. Just use the parts that are relevant to your investigation.

Teachers and examiners are very aware of coursework copied from the internet. It is usually detected when work goes to moderators and examiners who see thousands of pieces of work each year — don't be tempted.

Jane Taylor teaches biology and is an editor of CATALYST.

You learn a lot by making notes and they mean more to you than anyone else reading them — so it's not worth 'borrowing' anyone else's notes.

PLACES to visit

Seeing stars

ROE

THE ROYAL OBSERVATORY, EDINBURGH

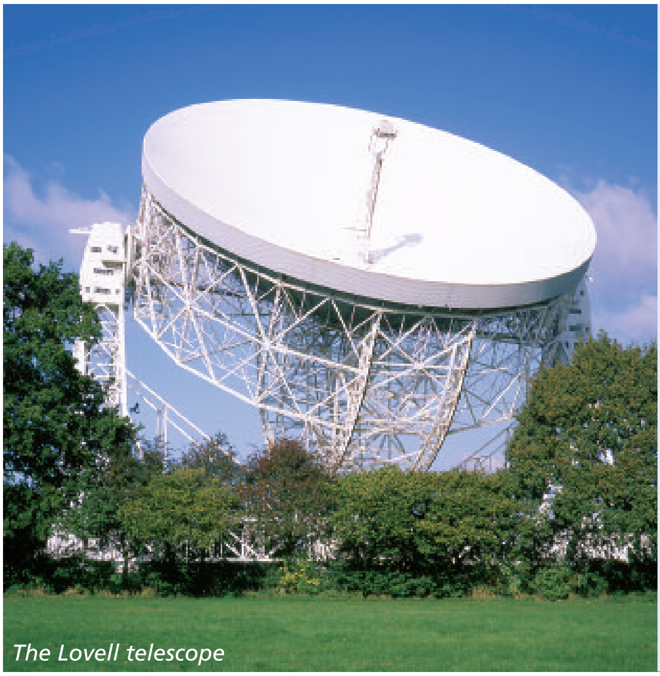
Edinburgh has two observatories. The Royal Observatory (ROE) is famous for the green domes which house its working telescopes. The visitor centre gives you the chance to see inside the domes. There are exhibits explaining the telescopes, and there's a computer gallery where you can try out some of the latest software. There are great views over the city, too.

On winter evenings, there's a chance to join in observations of the night sky using the observatory's 36-inch telescope, and to meet practising astronomers.

The ROE is the UK's centre for astronomy technology. There are expert teams who work on optics, electronics, computing and photography, developing new instruments and software which are used in observatories around the world.

The City Observatory in Edinburgh has more telescopes, and group visits can be arranged.

With a flotilla of spacecraft converging on Mars, there's a lot of interest in space at the moment. The UK is a great place for astronomy and space research, and the astronomy community has put a lot of effort into explaining what it does. Several observatories have visitor centres, and there are planetaria dotted around the country.



The Lovell telescope

Ian Morison/Jodrell Bank Observatory

JODRELL BANK, CHESHIRE

Jodrell Bank is famous for its radio telescope. You may have seen this giant dish, looming up next to the M6 in northwest England. This is the Lovell telescope, named after Sir Bernard Lovell, the scientist who established the UK as a world leader in radio astronomy.

The Lovell telescope has been working since 1957, and recently underwent a major upgrade to keep it functioning well into the twenty-first century. Its dish is 76.2 m in diameter, and has a surface area of 4560 m^2 to collect radio waves. (Because radio waves have much longer wavelengths than light waves, a much bigger collector is needed.) The Lovell telescope is linked to other radio telescopes around the world, making it more sensitive, as it looks at some of the strangest objects in the universe — black holes, quasars, pulsars and radio galaxies.

As well as a working radio observatory Jodrell Bank, which is part of Manchester University, has a science centre which attracts over 140 000 visitors each year. Its galleries explain the workings of a radio telescope, and lots more of the science relevant to astronomy. There are a theatre and a planetarium too.

Armagh Planetarium

Left: *Students from the Royal School, Armagh, at the Armagh Planetarium*

THE ARMAGH PLANETARIUM

Northern Ireland has had its own observatory since 1790, at Armagh. Astronomers here are actively investigating the solar system, the physics of stars, and the Earth's climate. Next to the observatory is the planetarium, together with an open-air model of the planets and a stone calendar.

Below: *Dr Tom Mason, Director of the Armagh Planetarium, with students*

Armagh Planetarium

BOX 1 PLANETARIA

A planetarium is a good place to learn about the stars and planets we see in the night sky. Elaborate computer-controlled projectors can show views of the sky at any time, as seen from any point on Earth. A planetarium show usually includes slides, animations and movies, and is likely to bring you up-to-the-minute news about some of the latest discoveries.

The most famous planetarium in Britain is in London, next to Madame Tussaud's, but there are many others, from Chichester in the south to Aberdeen in the north. And there are mobile ones, too!

Visit **http://www.planetarium.org.uk** to find the one nearest you.

BOX 2 WEBSITES

Armagh Planetarium:
http://www.armaghplanet.com

Jodrell Bank:
http://www.jb.man.ac.uk/scicen

Royal Observatory Edinburgh:
http://www.roe.ac.uk/vc
(click on buttons at bottom of page)

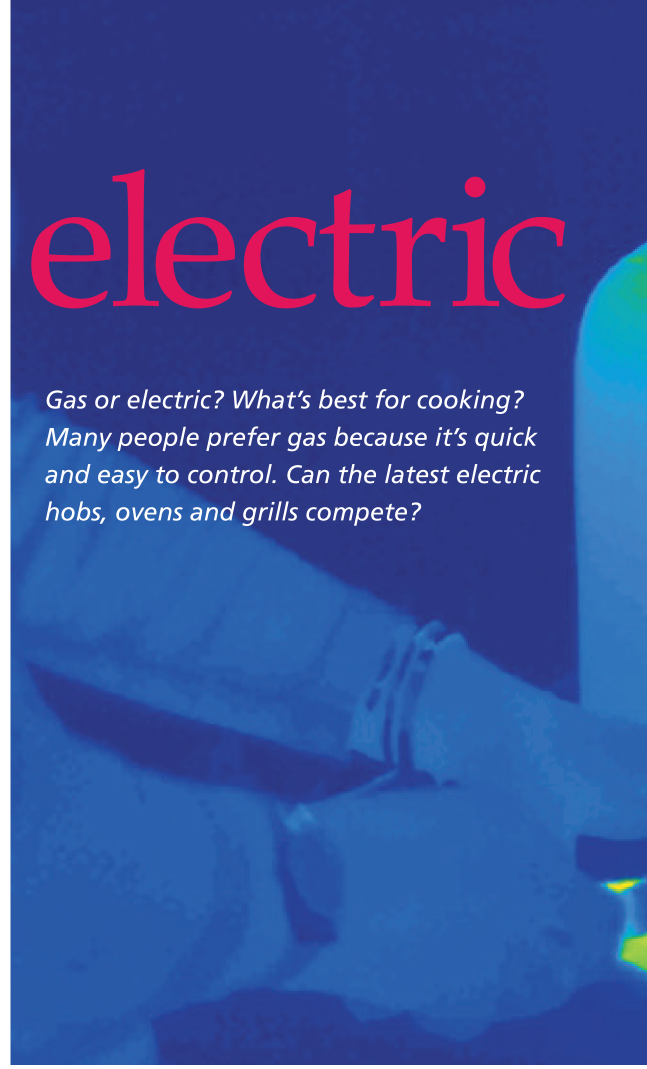
If you want to visit one of these observatories, phone first to enquire. Some are only open to pre-booked parties of visitors.

In CATALYST Vol. 13, No. 4 we told you about the Observatory Science Centre at Herstmonceux.

David Sang

DAVID SANG

Cook electric



Gas or electric? What's best for cooking? Many people prefer gas because it's quick and easy to control. Can the latest electric hobs, ovens and grills compete?

GCSE key words
Conduction
Radiation
Efficiency
Electromagnetic induction

Cooking can be messy and time-consuming — even dangerous. So the ideal hob should have the following features:

- speed — it should heat up and cool down quickly
- controllability — it should be easy to set the desired temperature
- cleanability — it should be easy to clean up any spills
- efficiency — it should not waste energy (and money)
- safety — the user should be safe from high temperatures

Cooking requires heat energy to be transferred from a source to the food. Heat can travel by conduction, convection and radiation, and electric cookers make use of all three of these mechanisms.

INSIDE THE HOB

● How does a gas hob compare with a ceramic hob in terms of cleanability?

Many new kitchens are fitted with ceramic hobs ('cooktops'). A ceramic is a hard, brittle material such as glass, and the heating elements of ceramic hobs are embedded in tough, heat-resistant glass. This means that the hob is smooth and flat, and easily wiped down.

How do the heating elements work? Three different types of element are used in modern hobs — radiant, halogen and induction — and they all work in rather different ways.

Radiant heating

In radiant hobs a metal ribbon spirals round to form the element. When the element is switched on, an electric current flows through the ribbon and, because of the metal's resistance, the ribbon heats up. Almost instantly, it starts to glow red hot and the user can see that it is functioning. Its temperature reaches about 1000°C; 97% of the energy it supplies is heat, and just 3% is light.

Electronics is having a great impact on the cooker market. Over 30% of ceramic hobs now incorporate electronic control systems.

Heat and light from the ribbon **radiate** up through the ceramic material of the hob, and are absorbed by the base of the pan. Radiation accounts for 40% of the energy supplied. The remaining 60% is heat which **conducts** upwards through the solid ceramic.

Of the energy supplied 65–70% is transferred to the pan — that's efficient. The energy conducts through the metal of the pan and into the food.

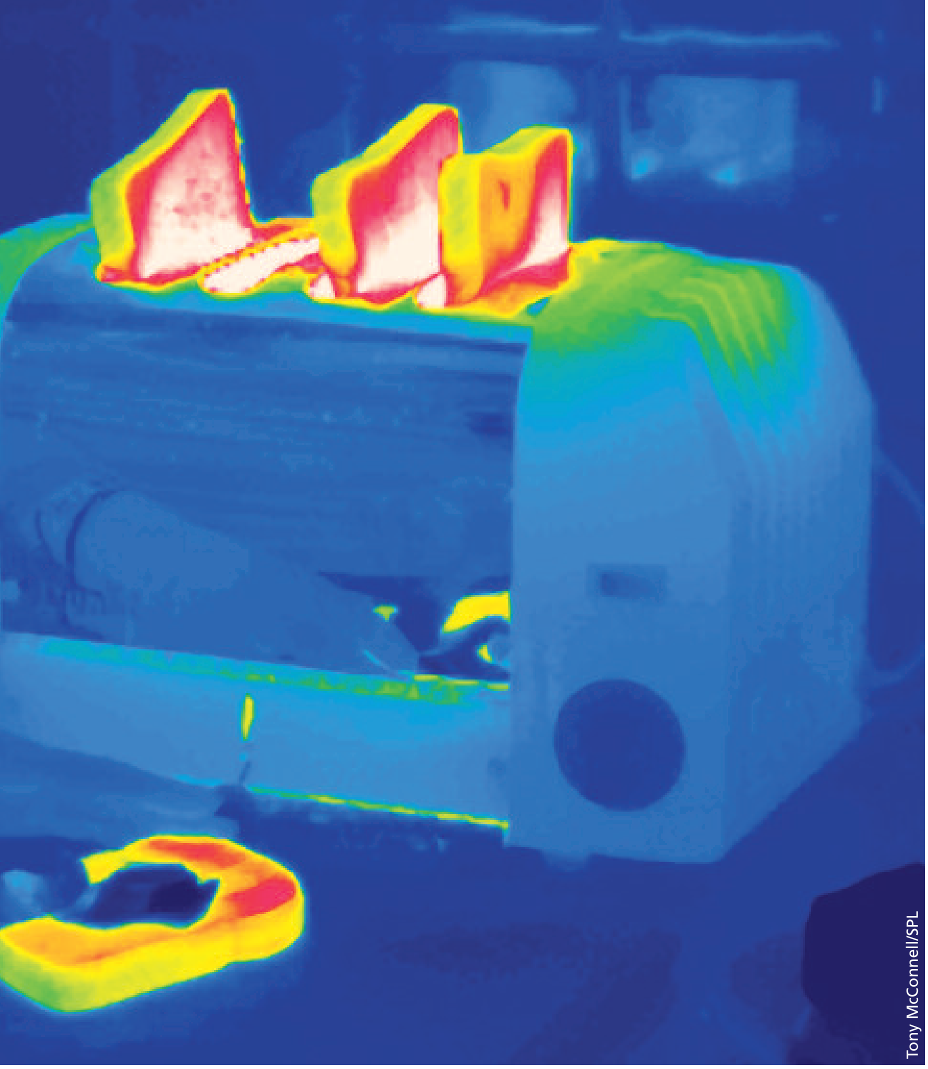
There's a lot involved in the design of a good radiant heating element:

- The ribbon is arranged to supply more heat around the edges than near the middle. This is known as 'edge-weighting', and gives a more uniform temperature across the base of the pan. The result is faster boiling times and more evenly-cooked pancakes.
- The ribbon is mounted in an insulating moulding. This prevents energy from escaping downwards or sideways, and reflects radiation up towards the pan.
- A modern element is fitted with an electronic sensor which detects excessive temperatures and switches off the current. Older elements used a cruder, less sturdy electromechanical control system.

Halogen heating

Halogen hobs use tungsten filament lamps to supply energy. The lamp is in the form of a ring, so that the glowing filament matches the shape of the base of the pan. A halogen lamp is designed to have a much longer life than a standard light bulb. The filament is closely surrounded by a quartz envelope capable of withstanding high temperatures. The envelope is filled with a halogen gas; if tungsten atoms evaporate from the filament, they combine with the halogen atoms and are deposited back on the filament when it cools down. This can give a lifetime of 10 000 hours, compared with 1000 for a conventional light bulb.

Users of halogen hobs like the way the element glows brightly, and can be seen to change instantly as



Tony McConnell/SPL

Ceramaspeed

Ceramaspeed

Above left: *Kitchen appliances are designed to help the user avoid getting burnt. They are checked using thermal imaging, in which infrared radiation is detected by a camera to create a 'thermogram'. This thermogram of a toaster shows that its sides (blue) are cold even though the heating filaments and the toast are hot (red, white). You can see that the butter is cold, and there is an image of the hot toast, reflected in the side of the toaster.* ***Above right:*** *Radiant heating elements on hobs*

they alter the controls. Modern halogen elements incorporate ribbon heating as well, to give the best of both worlds.

Induction heating

Induction heating is different. The element is a coil of wire that carries an alternating current, with frequency 25–50 kHz. That means that the current flows back and forth up to 50 000 times each second. The coil acts as an electromagnet. Because the current flows back and forth, the magnetic field through the coil keeps reversing. The changing field penetrates the metal of the pan and causes an alternating current to flow in it. Because the pan itself has resistance, it gets heated by the current.

If you know about transformers, you will find this easier to understand. In a transformer, an alternating current flows in the primary coil. This produces a varying magnetic field which induces a current in the secondary coil. In induction heating, the pan takes the place of the secondary coil. Pans must be made of steel (because steel is mostly iron, a magnetic material).

Induction heating transfers almost all of the electrical energy supplied to heat the pan. This makes it highly efficient, and it is fast, too — more than 50% faster than gas or other electrical methods. It is highly controllable, so the user can cook sauces gently, or melt chocolate without burning it. And the surface of the hob does not heat up, so spills don't stick and the whole thing is much safer.

RESEARCH AND DEVELOPMENT

Is there anything new to be achieved in designing hobs and ovens? Ceramaspeed is a leading British

● Find out where else halogen lamps are used, and why.

Some electric toothbrushes are recharged by electromagnetic induction.

Halogens are elements of group 7 in the periodic table, including fluorine, chlorine, bromine and iodine.

BOX 1

Electric cookers usually have their own cable running direct from the fuse box. This is because a large current — up to 40 A — flows when they are fully in use.

They operate from the 230 V mains, so their maximum power is:

230 V × 40 A = 9200 W

or about 9 kW. Each ring might have a power rating of 2 kW, so the current flowing through it would be:

2000 W/230 V = 8.7 A

Ceramaspeed

Ceramaspeed

Ceramaspeed

Above: *The research laboratory at Ceramaspeed*
Top right: *An engineer at work in Ceramaspeed's design office*
Right: *The temperature of a ribbon heating element being measured with a pyrometer*

company in this field, based in Kidderminster, Worcestershire. It manufactures radiant, halogen and induction heating elements, and has sold over 80 million in the last 25 years.

Peter Wilkins is Director of Research and Development at Ceramaspeed. Here, he describes his department's work.

Our development activity is generally split into two areas. We are continually developing new versions of our **core product** — principally new radiant heater designs for hobs and oven grills. Typically we launch 15 major new products per year — some for specific customers, some with wider applications.

The other area is **advanced system development**: the main thrust here is our intelligent cooking systems programme. This makes use of advanced high temperature sensors combined with sophisticated control techniques. We are developing complex control algorithms which are taken up by our electronic controls partners to incorporate into software. Typical features we have developed through sensor/controls integration are automatic boil-dry detection (to be launched with a major European manufacturer later this year), and highly accurate and sensitive temperature control for consistent pre-set frying and simmering cooking cycles.

We are working on a pan-sensing system for conventional radiant heaters. This uses the induction principle — a sensor loop is mounted on the heater top surface, under the glass, with a small alternating current flowing through it. When any metallic cookware is placed on top, the current changes and this is easily detected.

An algorithm is a set of rules which is carried out in sequence to solve a problem. Computers make use of algorithms for calculations and to control systems.

We have a total R&D team of around 25 people in the UK and five at our North American operation. The disciplines are varied: a team of seven mechanical engineers and a design manager support new product development; there's a mix of materials scientists and physicists for advanced technology programmes; the lab team is mainly physics orientated; and we now have electronics skills for controls systems and interfaces.

Project management skills are also important because it is imperative to deliver new products to meet timescale, cost and quality targets.

Computer design techniques are vital. We use a computer-aided design and manufacturing (3D CAD/CAM) system called Solidworks for product design, rapid prototyping and internal tooling requirements. Twelve people can work with this at any one time.

We also have simulation and modelling tools which we have developed ourselves. We use a database combined with Excel spreadsheets to design heating elements and to model the way heat flows from the heating elements.

David Sang *writes textbooks and is an editor of* CATALYST. *He is grateful to Peter Wilkins and colleagues at Ceramaspeed for help in writing this article.*

NIGEL COLLINS

Keeping things steady

Go for a walk on a crisp winter's morning and the chances are that the only animals you'll see will be mammals or birds — certainly no lizards or frogs. How is it that birds and mammals are up and about, whatever the weather? This article looks at why homeostasis matters.

Mammals and birds are able to be active on cold days because they have the capacity to maintain a more or less steady body temperature. Why is this an advantage? For the most part, the rates of chemical reactions increase with increasing temperature — and this is true of chemical reactions within organisms as well as in test tubes.

Chemical reactions in organisms almost always involve enzymes. Enzymes **catalyse** — speed up — reactions which otherwise would be very very slow. But enzymes are proteins and above a certain temperature their molecular shape starts to change. Once this happens they lose their ability to catalyse the reaction, which slows and stops. The enzyme may be irreparably damaged, in which case it is said to be **denatured**.

So, as Figure 1 shows, there is a huge benefit in maintaining a body temperature that allows reactions to proceed quickly but without running the risk of damaging enzymes. It is not just the temperature of cells that is kept pretty steady, other variables in the environment of the cell are important too (Box 1).

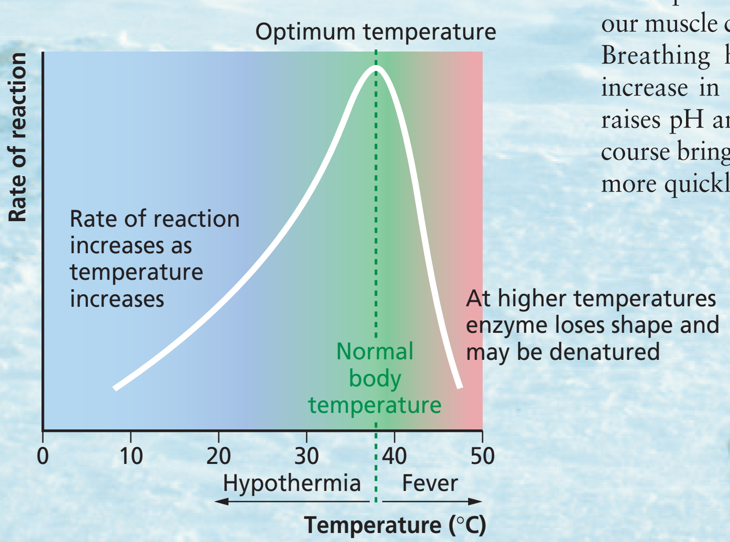


***Figure 1** Why a more or less steady temperature matters. What happens to the rate of reaction if you experience the range of temperatures described in Box 2?*

KEEPING ENZYMES IN SHAPE

As well as temperature, pH has a direct effect on the shape of a protein. If an enzyme is at the wrong pH its shape changes and it won't work. Our bodies work to maintain the optimum pH for our enzymes in the surroundings of our cells. This *internal* environment of our bodies — the tissue fluid that bathes our cells — is derived from our blood. Constant monitoring and regulation of the composition of our blood, its temperature and its pH is therefore the order of the day. In fact, the blood pH is affected greatly by how much carbon dioxide is dissolved in it as carbonic acid:

water + carbon dioxide ⟶ carbonic acid

Blood pH changes when we exert ourselves because our muscle cells are producing more carbon dioxide. Breathing harder and deeper, together with an increase in heart rate, gets rid of carbon dioxide, raises pH and helps keep enzymes in shape (and of course brings in more oxygen which is being used up more quickly). Neat.

GCSE key words
Homeostasis
Internal environment
Enzymes

● Why do you feel the need to urinate on a cold day? A clue or two: to reduce heat loss less blood circulates near the surface of the body. This blood is redistributed to deeper blood vessels but there is a limit to the volume that can be fitted in and blood pressure will be rising. The solution is to reduce blood volume.

A polar bear in the snow. How does it maintain its body temperature?

Ingram

In *Life at the Extremes: the Science of Survival*, Frances Ashcroft tells fascinating stories about the effect on people of extreme conditions: cold, hot, low pressure, high pressure, intense exertion.

Right: *Andre Agassi working up a sweat at Wimbledon*

BOX 1 HOMEOSTASIS

All the cells in our bodies are surrounded by a liquid called **tissue fluid**, derived from blood. Our bodies use a number of mechanisms to maintain this fluid in a more or less steady state in terms of:

- carbon dioxide concentration (which also has a significant effect upon pH)
- oxygen concentration
- ion concentration
- sugar concentration
- water concentration, compared with dissolved substances
- temperature

This article is not about the mechanisms which control these factors but about why maintaining a near steady state matters. You can find information about the mechanisms of control in your *GCSE Science Exam Revision Notes* (received free with the November issue of CATALYST) or at the following websites:

http://www.bbc.co.uk/schools/gcsebitesize/biology/humans/homeostasisrev1.shtml
http://www.s-cool.co.uk/subject_index.asp?stage=G
http://www.biologyonline.org/4/1_physiological_homeostasis.htm

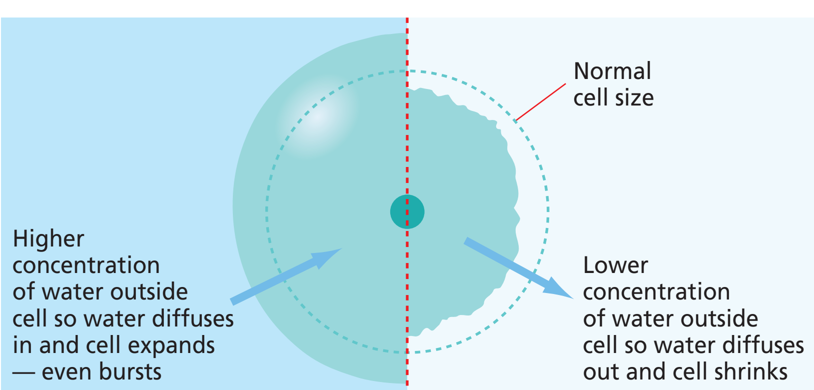
CELLS DON'T SWELL

Diffusion is the tendency for particles (atoms and molecules) of liquids, gases or solutes to disperse randomly. It results in net movement from areas of high concentration of the particles to areas of low concentration.

Box 1 lists the concentration of water in the tissue fluid (and blood) as something which is kept more or less steady in the body. Why? You need to recall that cell membranes have a special property — they are semi-permeable. Water can pass freely across the membrane, but larger molecules may not. If there is a greater concentration of water molecules in the tissue fluid (and blood) than in the cells it bathes (forget all other molecules, concentrate on water!), then more water molecules will diffuse into the cell than out and the cell will expand — and in theory explode. In fact this is what happens when blood cells fall into water.

The consequences for an animal cell are potentially dire (Figure 2). But this doesn't happen of course, because another homeostatic mechanism is operating all the time. You can look up how kidneys work to ensure that the water/salt balance in our blood — and the water concentration — is kept more or less steady by checking your textbook or logging on to the web addresses in Box 1. But the body's capacity to regulate its water/salt balance can be instantly recognised by the fact that if you drink a lot, you pee a lot and if your body is short of water, you develop a thirst.

Figure 2 *Why it is important to keep the concentration of the tissue fluid steady*



DISSOLVED SUBSTANCES

What about other molecules in the blood? Some are needed by cells. **Glucose**, the essential fuel for respiration in all living cells, all the time, in all living things, is regulated closely. Levels are controlled by various hormones produced by the body, including

BOX 2 WHY WALKING ON FROZEN PONDS IS A BAD IDEA

If you fall through ice into a pond you will seriously mess up enzyme-controlled reactions in your body! Your core temperature is normally between 36 and 38°C and **hypothermia** occurs when it drops below 35°C.

Even at this temperature you start to slip down the curve in Figure 1. You become clumsy and shiver, your reaction times slow without you realising it, your speech becomes slurred, you feel tired. Below 32°C you stop shivering because shivering has used up your energy reserves — muscles need glucose to contract. You are likely to become unconscious at around 30°C. Your heart slows right down, together with your breathing rate. Below 28°C the heart's rhythm is broken and heart muscle may twitch in an uncoordinated way. The heart usually stops when the body temperature reaches 20°C.

BOX 3 DRINKING WATER

Fifty years ago a Canadian study showed that we need about 2 litres of water per day. The study pointed out that we get most of this from our food. However, only the first part of the study's findings has entered the mythology of healthy diet, and it is much promoted today, particularly by producers of bottled water.

insulin and glucagon, so that cells receive a steady supply, whatever they are up to. What might a cell be doing that requires extra glucose? And where and how does the body store this sugar? (Find out more from your *GCSE Science Exam Revision Notes*.)

Oxygen is also needed all the time, in greater or lesser amounts, again depending on what the cells are doing. Active muscle cells need lots of both glucose and oxygen. **Amino acids**, for making proteins, and **lipids** are also needed but other molecules are not. These include **carbon dioxide** above a particular concentration and **urea**. Homeostatic mechanisms are involved in excreting them.

A BALANCED SYSTEM

It's a beautifully integrated system — pH is important for enzyme function and is determined by how much carbon dioxide is present, which in turn reflects the level of oxygen. These homeostatic mechanisms maintain optimum conditions for cell function. And if you are a mammal, you've evolved the extra homeostatic temperature control trick that allows you to appreciate the beauty of a snowy morning as birds visit a bird table when most other animals are merely ticking over.

Nigel Collins teaches biology and is an editor of CATALYST.

The planets puzzle

Here are the names of the planets of the solar system:

Mars, Uranus, Jupiter, Venus, Pluto, Earth, Mercury, Saturn, Neptune

Uranus has five major asteroids:

Miranda, Oberon, Umbriel, Ariel, Titania

- Arrange the planets in order of distance from the Sun (closest first).
- Turn the names of the planets into anagrams and use them to fill in the grid provided.

But first make sure that you have the correct anagram!

To help you make the anagrams here are some clues (in the order that the planets occur outwards from the Sun):

1 Hot food, myself (5, 2)
2 Raised red skin blemish (5)
3 Centre of a city (bloody) (5)
4 You have two of these (4)
5 Tear string fibres (3, 4)
6 Centre of the solar system, painting (3, 3)
7 Move quickly, major world power (3, 3)
8 Musical female swan (4, 3)
9 Not down, not a little (2, 3)

Turn the Uranus asteroids into anagrams — here are some clues:

10 Dry person (4, 3)
11 Country near Sumatra (6)
12 One's stomach churns (1, 6)
13 Me? A Shakespearean King ? (1, 4)
14 Within a (mis-spelt) London Art Gallery (2, 1, 4)

Now fit the anagrams into the grid below. The letters in the shaded squares can be rearranged to form the way bacteria may have first reached Earth.

1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

Mystery word: ____________________

Answers on page 15.

● See 'DNA fingerprinting' in CATALYST Vol. 14, No. 1 (September 2003) for a description of how Dolly's genetic profile was checked by Dr Esther Signer and colleagues at the University of Leicester.

Dolly the sheep

Roslin Institute

Lynne Elvin

Above: Dolly with Ian Wilmut

In 1996 Ian Wilmut and his colleagues at the Roslin Institute in Edinburgh successfully cloned a sheep which they named Dolly. She was the first cloned mammal. In this, our first non-human A Life in Science, we tell Dolly's story.

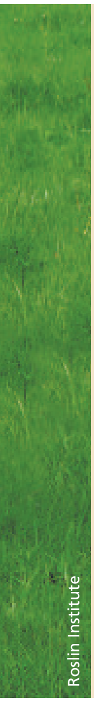
To produce Dolly, Bill Ritchie, a technician working with Dr Keith Campbell and Professor Ian Wilmut, removed the nucleus from an egg that had been taken from a Scottish Blackface ewe. He then transplanted a mammary gland cell of a 6-year-old Finn Dorset sheep, a pure white breed, into the enucleated egg of the Blackface ewe. The mammary gland cell–egg combination was stimulated with electricity to fuse the two and to start cell division. The new cell divided and was placed in the uterus of a Blackface ewe to develop.

An enucleated egg is one from which the nucleus has been removed.

After 148 days, a normal length of time for the Finn Dorset breed of sheep, Dolly was born. Although her gestation proceeded to plan, 276 other embryos created in the same experiment failed to produce pregnancies. Dolly was shown to be genetically identical to the Finn Dorset ewe that had provided the mammary cells and not to the Blackface ewe to whom she was born — her surrogate mother. This clearly demonstrated that she was a successful clone.

A FULL LIFE

Dolly grew into a mature ewe and produced six offspring of her own in three pregnancies through normal sexual means. In many respects she was a normal viable, healthy animal. Dolly died at the age of 6½. She was found to be suffering from a lung cancer tumour and put to sleep. But you can see her today, preserved by taxidermy as a specimen animal at the Royal Museum in Edinburgh. A sweater made from her wool is on display in the Science Museum, London.


Roslin Institute

BOX 1 TIMELINE

Date	Event
1996	Dolly created by nuclear transplantation
5 July 1996	Dolly, a white Finn Dorset sheep, born to a surrogate Blackface sheep mother
27 February 1997	Dolly's origins described in the science journal *Nature*
November 1997	Dolly mated with David, a Welsh Mountain breed ram. The choice of mate was deliberately designed to produce a smaller lamb so that any birthing difficulties would be minimised
13 April 1998	Bonnie born at 4 a.m., after 143 days gestation, weighing 2.7 kg
27 July 1998	Dolly's DNA fingerprint checked against DNA from frozen tissue from the 6-year old ewe from which the nucleus was taken, confirming that she is a clone
November 1998	Dolly mated again with David
24 March 1999	Dolly has triplets, two male, one female
1999	Dolly reported to have shorter than normal telomeres, sections of chromosomes that decrease in size with each successive cell division across an animal's life. The difference matches the fact that the nucleus from which she grew came from a 6-year old sheep
19 March 2000	Two more lambs born
4 January 2002	Arthritis described in Dolly's left hind leg
14 February 2003	Dolly put to sleep at 3.30 p.m. after vets discover from X rays, including a CT scan, that she has diseased lungs. The autopsy shows that this was a virus-induced lung tumour. She also had bad arthritis in her hind legs
2003	Dolly preserved by taxidermy

Dolly was not the first clone produced from a mature cell. John Gurdon produced tadpoles which grew into adult frogs by transplanting nuclei from specialised tissue in frog's intestines into enucleated eggs in the 1970s.

Above left: *Dolly with her triplets, April 1999*

Left: *Dolly as a lamb with her surrogate Blackface mother*

Right: *Dolly is now on display at Edinburgh's Royal Museum*


Topham

THE IMPORTANCE OF DOLLY'S LIFE

A fertilised egg contains in its DNA all the information needed for making an organism and making it work. As a multicellular organism grows and develops, cells end up with different jobs — they differentiate. A lot of the information stored in DNA is not in use. A mammary gland cell will use different parts of its DNA to make milk, compared with a small-intestine cell secreting digestive enzymes or a white blood cell involved in defending the body against disease. Dolly's creation showed that all of the DNA in a differentiated cell could be reactivated to create an entirely new organism.

At the time of Dolly's death her creators argued, 'In 20 years time, Dolly won't be remembered for the practical applications that she led to, but for opening our eyes to the idea that the cells in our bodies are much more flexible than we had thought.'

BOX 2 WEB ADDRESSES

http://science.howstuffworks.com/cloning2.htm is a useful address at which to find out more about cloning.

http://www.biozone.co.uk is a great gateway into biology. Although it is flagged for A-level students it is useful when you want to find out more about a subject. Go to *Biolinks*, then *Biotechnology*, then *Cloning and Tissue Culture*.

Answers to planets puzzle, page 13

1	C	U	R	R	Y	M	E
2	N	E	V	U	S		
3	H	E	A	R	T		
4	A	R	M	S			
5	R	I	P	J	U	T	E
6	S	U	N	A	R	T	
7	R	U	N	U	S	A	
8	T	U	N	E	P	E	N
9	U	P	L	O	T		
10	A	R	I	D	M	A	N
11	B	O	R	N	E	O	
12	I	R	U	M	B	L	E
13	I	L	E	A	R		
14	I	N	A	T	A	I	T

Mystery word: METEORITES

DICK FINCH
AND
DAVID MOORE

Fertilisers

GCSE key words
Fertiliser
Ammonia
Nitric acid
Eutrophication

As plants grow they remove compounds of nitrogen, phosphorus and potassium from soil. These essential elements must be replaced to maintain the soil's fertility. For centuries farmers have used organic manures, rotated their crops or ploughed in specially grown crops to enrich the soil. A more modern method is to use chemicals called fertilisers.

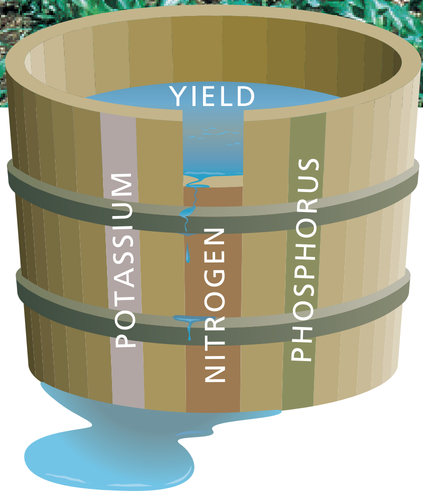


Figure 1 Liebig's barrel, a diagram he used to show how the loss of one nutrient decreases the overall yield of a crop

Justus Liebig, in 1842, was the first chemist to recognise that essential elements in the soil should be replaced (Figure 1). He patented and manufactured a manure — one of the first artificial fertilisers — containing these elements. The first permanent agricultural experimental station was set up in 1843 by John Lawes at Rothamsted in Hertfordshire, to study the effect of fertilisers on crops.

The huge growth in the use of fertilisers in developing countries during recent years is shown in Figure 2.

• Find out about the life of Baron Justus von Liebig (1803–1873) and his other contributions to science.

ESSENTIAL ELEMENTS

Nitrogen (**N**) is absorbed by plant roots as either nitrate (NO_3^-) or ammonium (NH_4^+) ions. A multi-stage reaction in the plant converts these ions to a form which can react with compounds derived from glucose (produced by photosynthesis) to make amino acids. These are the building blocks of proteins. Applying nitrogen fertiliser thus increases the protein content of plants and adds to their food value, as well as producing a bigger, lusher, crop.

Phosphorus (**P**) stimulates healthy root development, improves plants' ability to take up other nutrients and is important in crop ripening. Naturally occurring phosphate rock is insoluble and so is treated with sulphuric acid to produce soluble phosphoric acid.

BOX 1 AMMONIA MANUFACTURE

Ammonia is produced by reacting the elements nitrogen and hydrogen over an iron catalyst:

$$N_2 + 3H_2 \xrightleftharpoons{\text{catalyst}} 2NH_3$$

Hydrogen is made by passing methane (natural gas) and steam over a catalyst in a reformer. Air is added to supply the nitrogen. The ratios of methane, steam and air are varied to ensure that hydrogen and nitrogen are in the correct ratio of 3:1. Carbon dioxide is a by-product which is sold or used to make urea ($CO(NH_2)_2$), another water-soluble fertiliser.

In modern manufacturing plants the mixture of hydrogen and nitrogen is compressed to 150–300 times atmospheric pressure and then circulated rapidly through a reactor containing the iron catalyst and various promoters (these enable the catalyst to work more efficiently). The reaction is exothermic and produces enough heat to maintain the temperature at between 350 and 500°C. The yield of ammonia is approximately 18%, and it is removed from the unreacted gases by condensation. Unused nitrogen and hydrogen are returned to the converter.

Ammonia plant

Terra Nitrogen

Even though **potassium** (**K**) compounds are soluble in water, potassium ions do not leach out of the soil as they are readily held within clay particles. Potassium is important for photosynthesis and other chemical reactions involving carbohydrates in plants.

The fertilisers that farmers apply make good the gap between the minerals available from the soil and the nutrients the plants need. Although soils may contain reserves of NPK, every time a crop is

BOX 2 NITRIC ACID MANUFACTURE

To make nitric acid, ammonia is oxidised to nitrogen monoxide, helped by using a catalyst. Further oxidation to nitrogen dioxide, followed by absorption in water, gives nitric acid.

The three main reactions are:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$
$$2NO + O_2 \longrightarrow 2NO_2$$
$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

The oxidation is very rapid and yields of 96–98% are achieved by passing the ammonia and air over a platinum/rhodium gauze catalyst. The reaction is highly exothermic and so the temperature has to be controlled to maintain it at 800–900°C.

The manufacturing processes are strictly controlled to limit the amount of noxious gas released from the tall waste-gas chimney.

Nitric acid plant

Terra Nitrogen

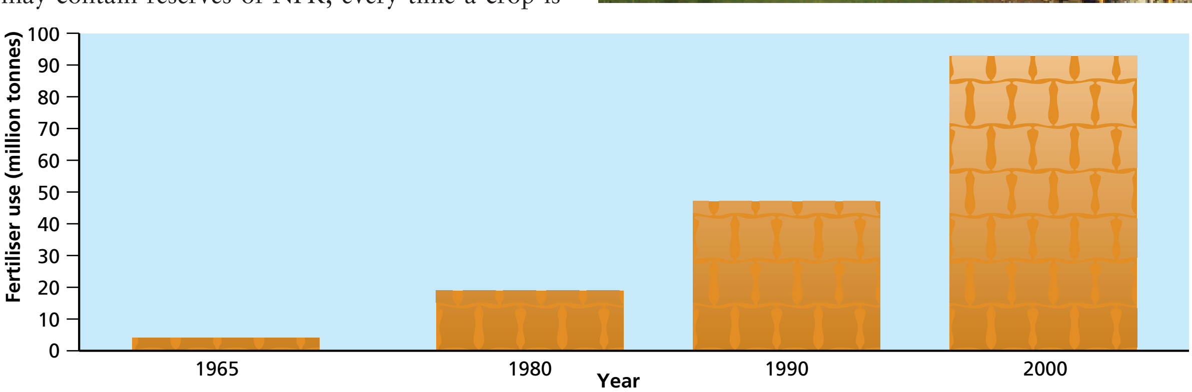
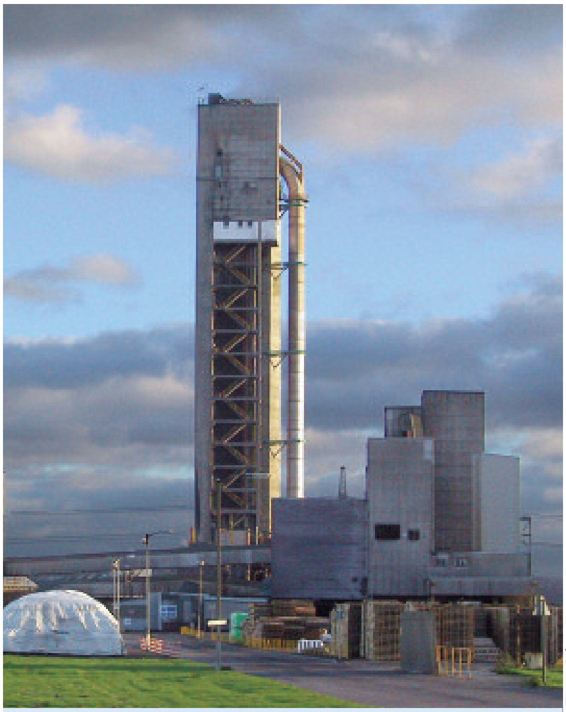


Figure 2 *Changing use of fertilisers worldwide. This increase has come about as developing countries adopt the more intensive farming practices of the developed world*

● In which other countries can minerals containing potassium chloride be found?



Terra Nitrogen

Right: *A prilling tower*

BOX 3 AMMONIUM NITRATE MANUFACTURE

Ammonium nitrate is most useful as a fertiliser in the form of prill — dense spheres, 1–3 mm in diameter. Gaseous ammonia and 55–65% w/w nitric acid are reacted to give ammonium nitrate solution:

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

After neutralisation, the concentrated ammonium nitrate solution is sprayed down a 100-metre high tower. The solution crystallises on the way down and is further agitated and cooled by a flow of air. The prill forms a fluidised bed. It is then sieved before weighing and packaging.

● Find out what eutrophication and algal bloom are, and how they can be related to fertiliser use.

1 hectare = 100 m × 100 m

harvested, nutrients are removed from the soil (Table 1) and probably need replacing.

MANUFACTURING PROCESSES

Nitrogen in fertilisers is in the form of nitrates, made from ammonia and nitric acid. Phosphorus is added in the form of phosphoric acid (see above) and potassium in the form of potassium chloride, obtained from the ore sylvinite. This is mined at Boulby near Whitby in North Yorkshire.

The manufacturing processes are illustrated in Figure 3. The compounds described above, and others, are blended to make compound fertilisers (Box 4) which contain varying proportions of nitrate, phosphate and potassium (described as the N:P:K ratio), according to the needs of particular crops. A typical fertiliser might contain 15% N, 7% P and 17% K by mass. Fertilisers are made 24 hours a day all year round, in order to meet the huge demands of the growing season, and have to be stockpiled in vast storage areas.

Farmers have to be careful when using fertilisers. Excess nitrate is not held by the soil and can be leached into groundwater and streams. The problem is worst in the autumn and winter after the fertiliser has been applied. Leaching can lead to serious pollution problems but farmers can take measures to prevent it, such as leaving an uncultivated buffer strip between the edge of the field and a river or stream.

Table 1 The nutrients removed when a typical crop of 50 tonnes of sugar beet is harvested off 1 hectare of ground

Element	Amount removed when roots are harvested and leaves ploughed back in to rot (kg/hectare)	Amount removed when roots are harvested and leaves removed as well (kg/hectare)
Nitrogen (N)	65	170
Phosphorus (P)	30	65
Potassium (K)	90	235

BOX 4 BLENDING PLANT

The blending plant is used to produce fertilisers which contain other nutrients in addition to the nitrate provided by ammonium nitrate. Terra Nitrogen, for example, produces Nitram (mostly ammonium nitrate) which contains 34.5% N. Addition of ammonium sulphate gives Sulphur Gold — a spring fertiliser for arable crops; addition of sodium nitrate produces Grazemore — especially suited for grassland grazed by cows; and potash (potassium carbonate) is blended with Nitram to form Kaynitro — an early top-dressing fertiliser for cereal and oil seed rape.

The blended fertiliser is packaged in bags of up to 1 tonne in mass.

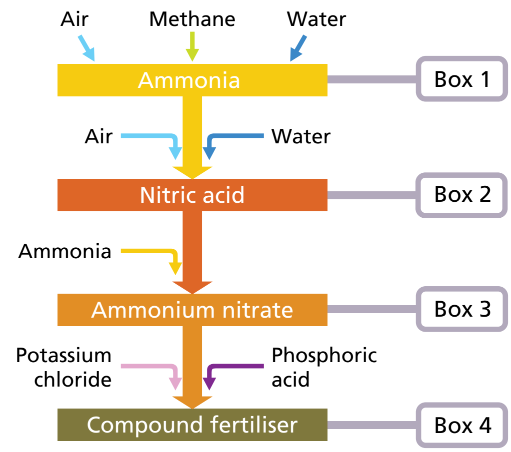
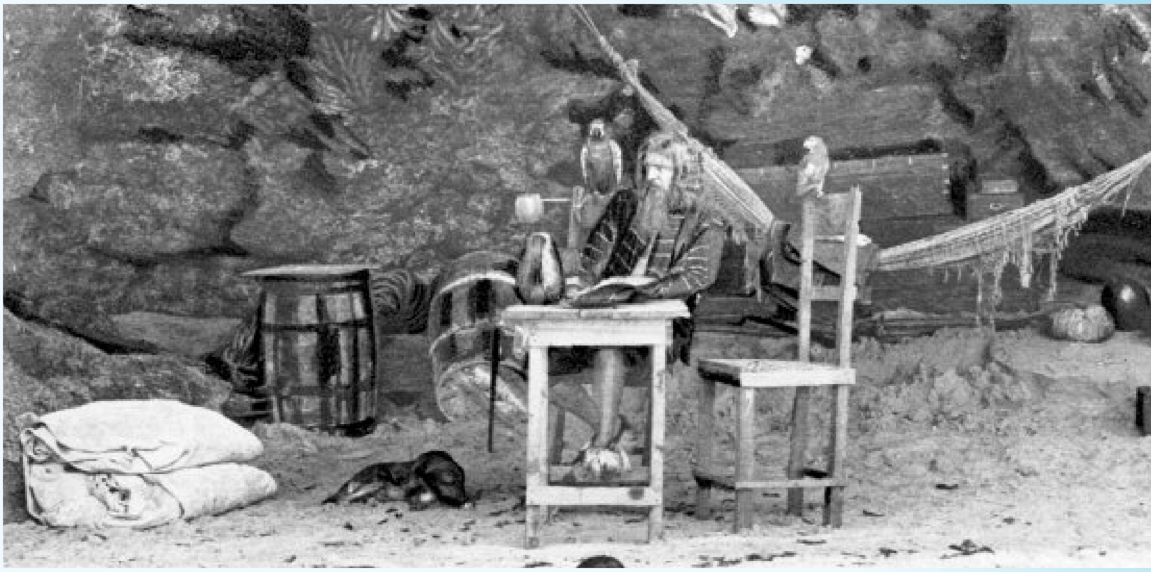


Figure 3 *Flow diagram for a fertiliser plant*

Dick Finch *is a personnel manager at Terra Nitrogen (Severnside) Fertiliser Works.*
David Moore *is an editor of* CATALYST.



Topham

Left: *Selkirk's story was the basis for the novel* Robinson Crusoe

Would you have survived?

Try This usually suggests a practical activity you can try but this time we want you to use your brains instead of your hands. You know far more science than people did 300 years ago, but can you use what you know?

Figure 1 *Map of the Juan Fernández Islands. Selkirk was marooned on the largest, now known as Robinson Crusoe Island*

Alexander Selkirk was a Scottish sailor who was put ashore on Juan Fernández Island in the Pacific Ocean off Chile in 1704. Selkirk sailed in a privateering expedition against the Spanish. He was unhappy with his ship's captain and the state of the ship, the *Cinque Ports*. He insisted he be put ashore on the island — a wise decision as the ship sank a few months later.

Juan Fernández Island, now renamed Robinson Crusoe Island, was very different from the Caribbean island where Crusoe was marooned. For a start it was uninhabited. It is small, rugged, volcanic, and has steep sea cliffs. It is cold, windy and rainy on the mountains but mild enough for tree ferns, cabbage palms and humming birds lower down. In the eighteenth century ships occasionally anchored in the bay. They took on fresh water from a river and caught wild goats, seals and sea lions, shellfish and lobsters for fresh meat.

Selkirk thought it would be just a few months before another ship came to the island, but in fact he spent 4 years there before he was rescued. Before his ship sailed he had been given a musket and some shot, a Bible, and enough quince marmalade and jam to last a day. Selkirk soon ran out of shot so his musket was useless. He had to survive using the ordinary knowledge of a sailor living in the 1700s, along with stone-age technology.

THE CHALLENGE

Imagine you are Alexander Selkirk. How would you survive? You can't have a musket and shot but you can have the clothes you are wearing today, a box of matches, a portable CD player with a few of your favourite CDs, and a recently dead sea lion as your resources — and of course your twenty-first century science knowledge.

The problems to solve are:

- Water — what is your source? How will you carry, store and purify it?
- Shelter — Selkirk started in a cave at the foot of the sea cliffs before moving to a safer and warmer site. How will you build your shelter?
- Food — what will you eat? How can you find, catch and, if you are to eat meat, kill your food? How will you prepare, cook and store the food?
- A signal — you don't want that passing ship to sail on by!

What's your plan?

Privateering was a form of authorised piracy to harass a country's enemies and cut supply lines.

• Watch out for television repeats of the series *Rough Science* in which a group of scientists go a stage further than merely surviving in such circumstances. Using everyday items and things from their surroundings they make all sorts of useful devices and products.

Chemistry

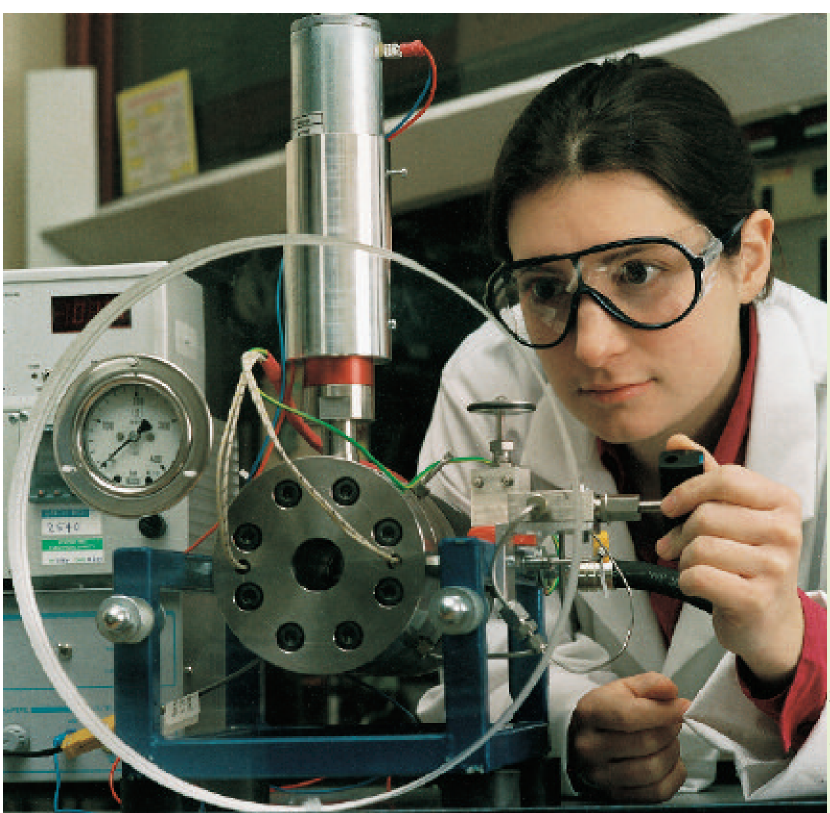
Will and Deni McIntyre/SPL

Above: *Pharmaceutical researchers setting up glassware to conduct research into new antiviral drugs*

Everything is made up of atoms. Chemists use their understanding of atoms to make a huge range of things — flavours and fragrances, health and beauty products, medicines, plastics and new clothing fabrics, paints and dyes, and catalysts to speed up reactions. By understanding the chemistry of the body they can make drugs that work at the right place and by understanding the chemistry of chocolate they can make new tastes and textures for us to enjoy.

BLONDE BY DAY, BRUNETTE BY NIGHT!

Imagine that a chemical company had done some market research and decided the public wanted a hair dye that changed colour in the evening. The company would need to employ people who come up with a lot of ideas as well as people who like to develop and perfect one idea into a product that works well, people who want to make the final product on a big scale and those who like to use state-of-the-art equipment to analyse it.



Anne-Katrin Purkiss

BOX 1 LUCINDA DUDD, PhD STUDENT, UNIVERSITY OF NOTTINGHAM

At school I liked politics and foreign languages but I thought that by studying science I could get a job which used what I had learnt more directly. During my chemistry A-level I visited a pharmaceutical company and saw the process involved in making medicines. My chemistry degree involved spending four afternoons a week in the university laboratory. I made paracetamol and rubber and extracted caffeine from coffee. As my knowledge of chemistry grew, I realised how amazing the subject is: there are theories to explain many things and it's not all unrelated facts to learn.

I took French as an optional module of my degree and in my final year I went to France to work in a research laboratory. Outside of study I got involved in student politics and now I am interested in green issues. The chemical industry is becoming more environmentally friendly and so I wanted to carry out a PhD, 3 years of research, into green solvents (see CATALYST Vol. 14, No. 1). After my PhD I will be a doctor of chemistry. I could get a job in industry or I could continue researching at university and maybe one day become a professor!

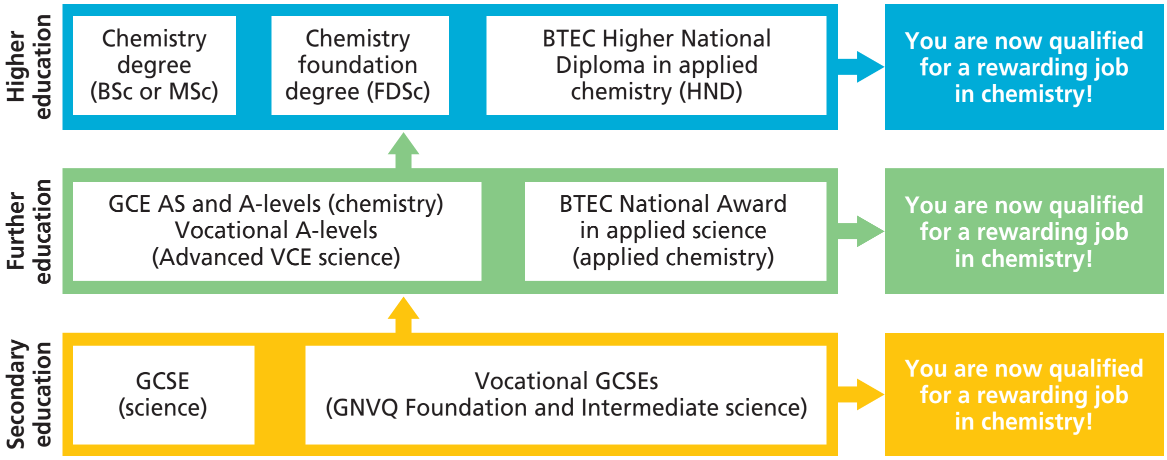


Figure 1 *Routes to working in chemistry*

BOX 2 SONIA GARCIA, RESEARCH SCIENTIST, INNOVATIONS GROUP, JOHNSON MATTHEY

When I was at school, I liked chemistry because it was fascinating to understand how and why things changed. Besides, the experimental part was always really good fun. I studied a chemistry degree, which included spending some time in industry. During my time at university, I realised that chemistry was a wide subject and there were plenty of opportunities to interact with other fields, like ecology, archaeology or biology.

Chemistry can give you the opportunity to travel to different countries and meet people from all around the world. At the moment, I am working for Johnson Matthey at Reading in the UK making nanoparticles for use in catalysis. The products are about 1 million times smaller than a millimetre, producing a very high surface area and high activity in catalytic processes. These nanocatalysts will be used in different applications, for example in fuel cell cars (see CATALYST Vol. 12, No. 3) which have low emissions. My job involves research into new routes to produce the catalysts and testing of the final products. I work with enthusiastic people, which makes the challenges attractive. I am also part of a team, in which everybody's participation and effort are crucial for the success of the projects.

Sonia Garcia

Studying chemistry develops the skills of logical thinking, problem solving and numeracy, so chemists are also employed in sales (persuading shops to sell the product), marketing (advertising the product and designing the packaging), accountancy, and law (stopping other companies copying the product).

BOX 3 WEBSITES

For more information on all chemistry qualifications (except degrees) look at the websites of the examination boards. Edexcel (**http://www.edexcel.org.uk**) includes BTEC courses. To find out where these courses take place across the UK see **http://www.learndirect.co.uk**

The university and colleges admissions service website, **http://www.ucas.com** lists all the degree courses in the UK. If you are thinking about higher education a good place to start is **http://www.aimhigher.ac.uk/dontstop/en/home/index.cfm**

The Royal Society of Chemistry promotes chemistry and it has a website specifically for students at **http://www.rsc.org/lap/educatio/studentzone.htm**

Which job would suit your personality best? Big chemical companies are organised into teams of people, each with different roles, whereas in smaller companies you can get involved in the whole process. In industry the work has to be commercially useful, whereas research chemists in universities can do more experiments based on their own ideas.

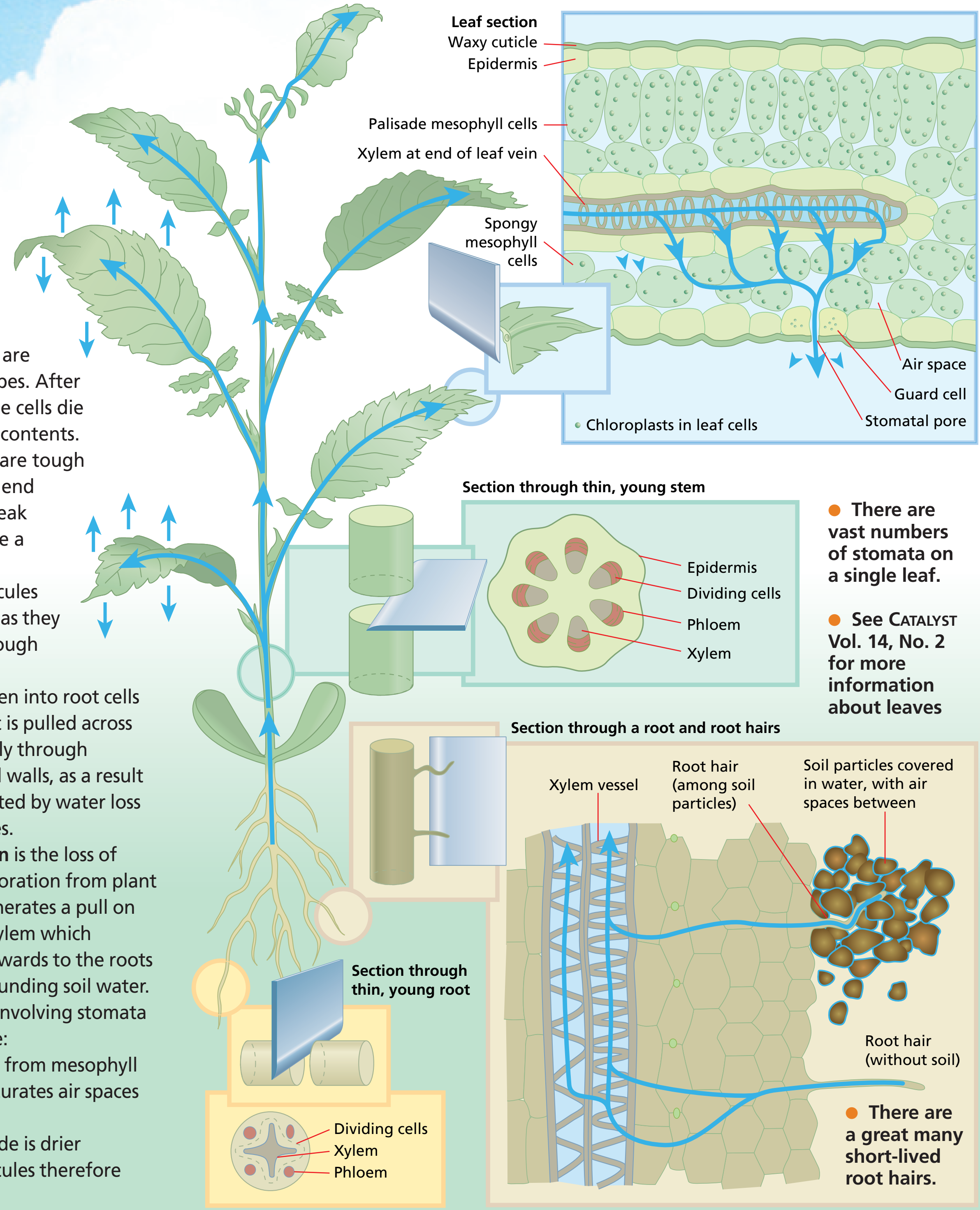
Which sort of job would suit you best?

HOW TO BE A CHEMIST

You can start a chemistry career at any stage of your education. Figure 1 shows some typical routes people follow. There are over 900 chemistry degrees available across the UK, a few of which specialise in a particular area (colour chemistry or computational chemistry for example) or combine chemistry with another subject such as business studies or even dance. Foundation degrees are new 2-year courses designed to train people to work as technical support staff in industry, in the health service and in schools and universities.

Lucinda Dudd

Movement of water in plants



Xylem cells are hollow tubes. After elongating, the cells die and lose their contents. All that is left are tough cell walls. The end walls often break down to create a long tube.

Water molecules hold together as they are pulled through the xylem.

Water is taken into root cells by osmosis but is pulled across the root, mostly through permeable cell walls, as a result of pull generated by water loss from the leaves.

Transpiration is the loss of water by evaporation from plant surfaces. It generates a pull on water in the xylem which extends downwards to the roots and into surrounding soil water. Transpiration involving stomata occurs because:

- evaporation from mesophyll cell walls saturates air spaces in the leaf
- the air outside is drier
- water molecules therefore diffuse out

- **There are vast numbers of stomata on a single leaf.**

- **See CATALYST Vol. 14, No. 2 for more information about leaves**

- **There are a great many short-lived root hairs.**