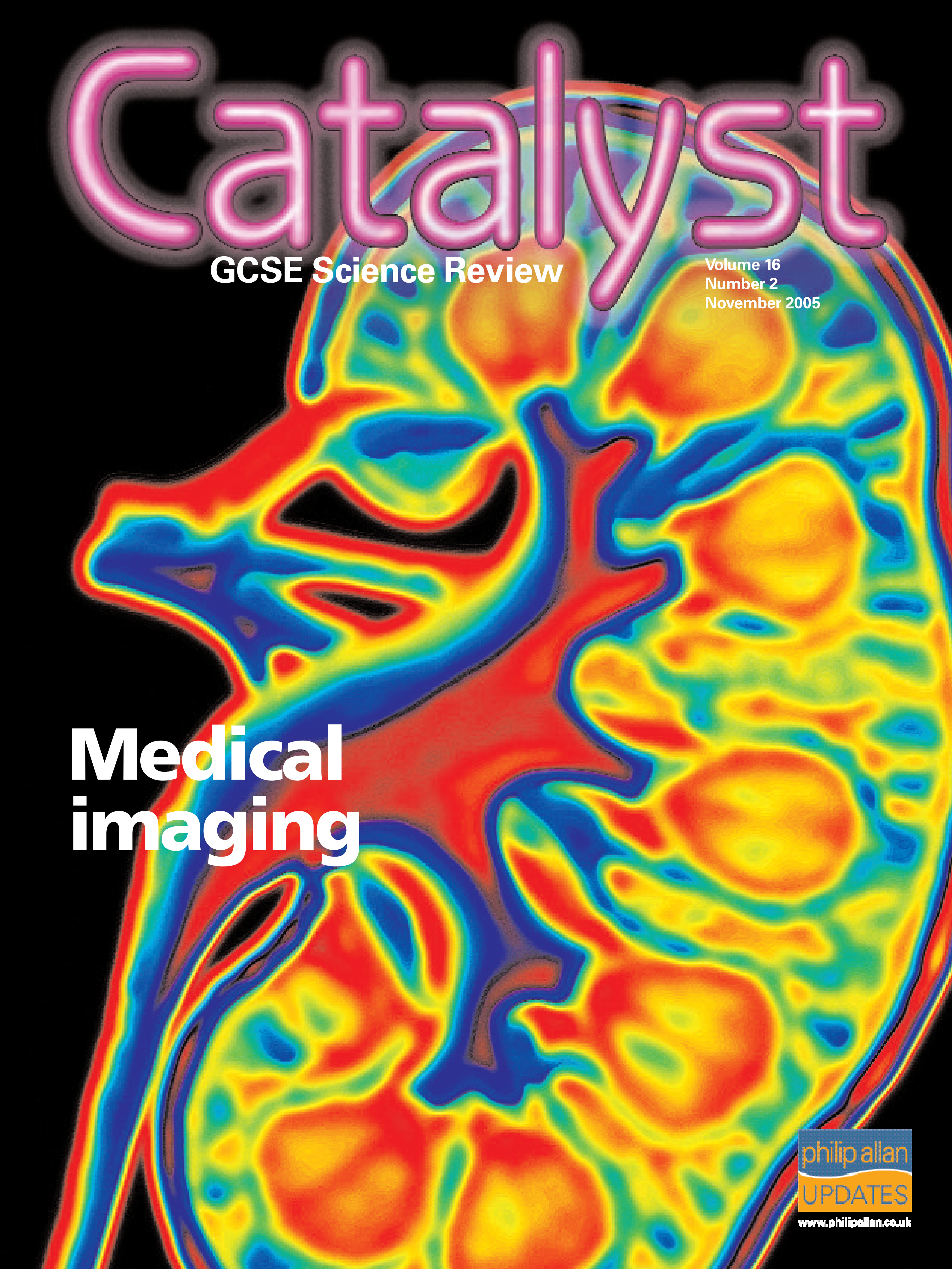
Catalyst

GCSE Science Review

Volume 16
Number 2
November 2005



Medical imaging

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www.philipallan.co.uk

Catalyst

Volume 16 Number 2 November 2005

The front cover shows a coloured CT scan of a section through a human kidney (Alfred Pasieka/SPL).

Contents

Using Catalyst

Welcome to the November issue of Catalyst. You should have received your free copy of the *GCSE Science Exam Revision Notes* with this issue. Both the *Exam Revision Notes* and Catalyst are designed to complement your learning and revision and help you broaden your knowledge of science. As you read each of the main articles in Catalyst, cross-refer to relevant sections in the *Exam Revision Notes* — the GCSE key words at the start of each article will help you to do this.

Don't forget the regular features though. 'Places to visit' describes somewhere you can see biology in action in a very innovative way. 'For debate' looks at a recent science news item. 'Your future' will make you realise that there is more to astronomy than just looking at the stars. And when you have finished reading all the articles, what about trying the puzzle — can you crack Chemdoku?

David Moore

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www.philipallan.co.uk

ISSN 0958-3629

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

Adam Gibson

Left: *Coloured three-dimensional computed tomography (CT) scan of the heart and its blood vessels*

GCSE key words
Electromagnetic spectrum
Radio waves
Microwaves
Infrared radiation
X-rays
Gamma rays

Medical imaging

Microwaves, infrared, ultraviolet and X-rays are all electromagnetic waves. Why are some used to create medical images and others to treat disease? Here, we focus on how the electromagnetic spectrum is used by medical physicists to create images of body organs. In the next issue, we will look at how radioactivity is used in diagnosis and therapy.

X-rays are produced by X-ray machines or linear accelerators; gamma rays come from radioactive sources.

Most people have had an X-ray. It might have been at the dentist's or to identify a broken bone. X-rays are particularly good at generating images of teeth and bones because they cannot pass easily through the calcium in these hard tissues. Bones and teeth absorb X-rays more than soft tissues, such as muscle and fat, so they show up on an X-ray image as shadows. In the 110 years since X-rays were discovered, they have become an important tool for doctors.

Left: *This fuzzy image is the first medical X-ray picture. It was taken by Professor Wilhelm Röntgen in 1895 and is an image of his wife's hand. The bones of her hand and her wedding ring absorb X-rays strongly so they show as a shadow in the image*

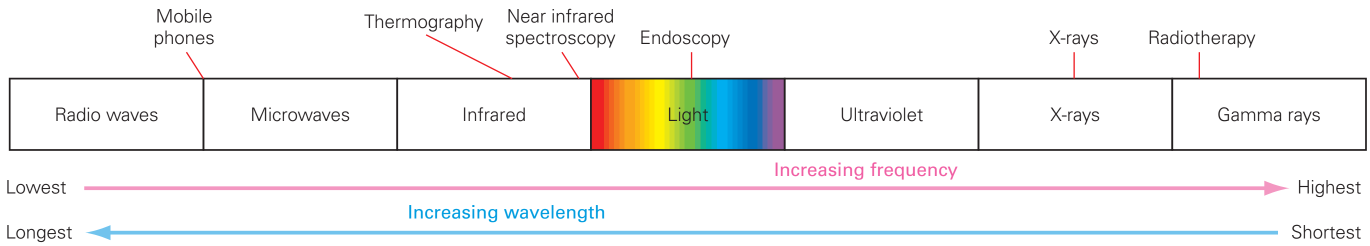


Figure 1 *The electromagnetic spectrum*

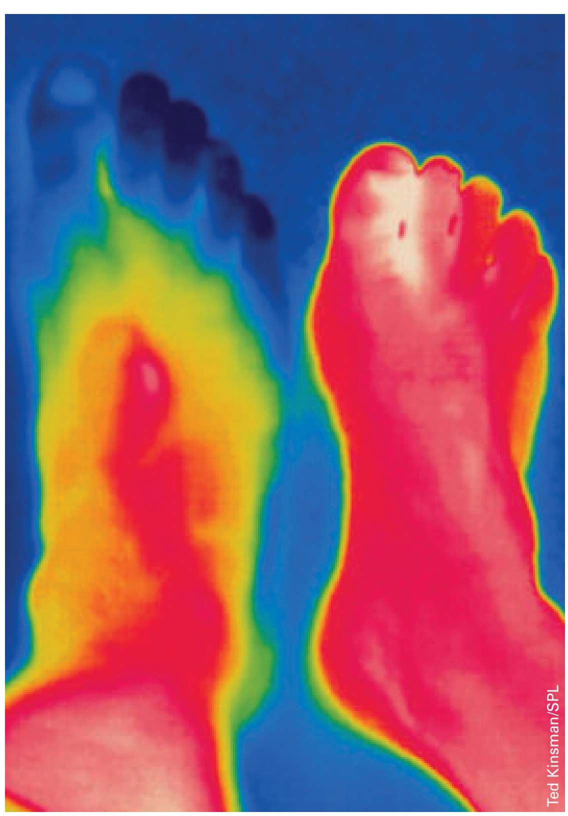
More recently, other parts of the electromagnetic spectrum (Figure 1) have been used by medical physicists to investigate the body (**diagnosis**) and to treat illnesses (**therapy**). This article looks at how extraordinary images of structures in the body can be created and how inaccessible parts of the body can be examined using various parts of the electromagnetic spectrum.

Thermography

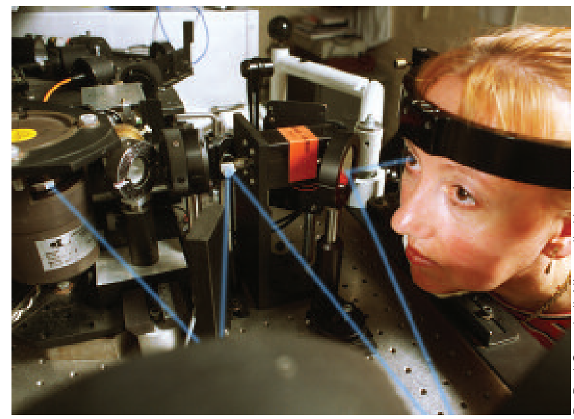
Blood comes from the core of the body and is warmer than the skin, so measuring skin temperature lets us determine whether the blood circulation is healthy or not. A thermogram is a picture of the body which shows the skin temperature.

The first thermogram was done by Hippocrates in Ancient Greece in about 400 BC, although he did not use a camera! He covered the body with clay and watched where it dried out first. The place where it dried out first was the warmest part of the body and might show an infection or other inflammation. Nowadays, we use a camera that is sensitive to infrared light.

Radiations in the electromagnetic spectrum all travel at the speed of light in space — 300 million m/s.



Right: *Thermogram of poor circulation in a human foot (left) compared to a normal foot (right). The temperature range goes from hot (white) to cold (blue)*



Dr Paul Campbell, Ninewells Hospital

A scanning laser ophthalmoscope

Lights in your eye

Bright light in visible wavelengths allows an ophthalmologist (an eye doctor) to examine a patient's eyes. A scanning laser ophthalmoscope, for example, detects light reflected from the back of the eye and can detect problems with the retina. Blue light gives information about the surface of the retina, while red light can pass through the first layers and tell us about deeper layers. It can help to prevent blindness due to retinal damage in people with diabetes.

Near infrared spectroscopy

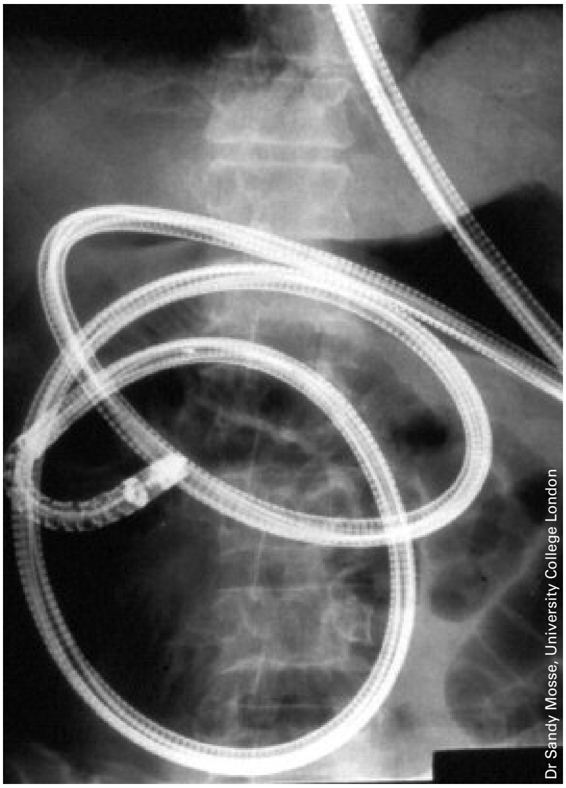
Psychologists would like to know how the brain develops from birth to adulthood. Like muscles, the brain needs blood to bring oxygen to parts which are active. Infrared light is absorbed very strongly by blood. If a region of the brain becomes more active, it receives more blood, and so it will absorb near infrared light more strongly.

Taking measurements of infrared light absorption tells us about the location of activity and the speed of activation in the brain. This is a safe way to detect brain activity, which can be used in children and adults. The system can also be used to monitor and check the blood flow in brains of premature babies.

Endoscopy

An endoscope is used to look deep inside the body. Traditional endoscopes were rigid and therefore uncomfortable. A modern endoscope is highly sophisticated and is so flexible it can even be steered around twists in the intestines.

The first flexible endoscopes used total internal reflection to direct visible light down an optical fibre



An X-ray image of an endoscope coming down the oesophagus, into the stomach and across into the small and then large intestines

***Left:** Coloured three-dimensional MRI scan of a human foetus in the uterus*

to illuminate the tissue, and then to carry light back up to the fibre to the viewer. Modern endoscopes may use miniature video cameras. They are used not only to make diagnoses, but also to guide instruments inserted through small incisions to carry out keyhole surgery.

X-radiography

Computed tomography (CT) uses X-rays to make a three-dimensional image of the body. It is easier to identify different tissues in a CT image than in a normal X-ray image. Medical physicists make use of the improved contrast in this type of image to extract the shapes of bones and muscles.

Mobile phones

In the September issue of CATALYST we described the working of and issues raised by the use of mobile phones. Medical physicists are involved in examining the possible effects of mobile phones on our brains.

Box 1 Useful websites

Take a look at:
www.crd.ge.com/esl/cgsp/projects/medical
where you will find some Quicktime movies constructed from CT scans.

See images from University College London at:
www.medphys.ucl.ac.uk/mgi

Mobile phones use electromagnetic radiation with a wavelength of between 30 cm and about 1 m, close to microwaves. Microwave ovens use higher energy radiation, with a wavelength of about 10 cm. If 10 cm waves can cook food, might wavelengths not that much longer heat you when you use your phone?

Medical physicists use computer programs to calculate the effect of mobile phones on our brains. Although their images show that any heating which may occur is not enough to worry about, mobile phone radiation may affect the brain in other ways. Therefore, following advice from medical physicists performing calculations like these, the government advises young people to make mobile phone calls only when necessary.

Magnetic resonance imaging (MRI)

The production of MRI images depends on a natural property of matter, called nuclear magnetic resonance. In strong external magnetic fields the atomic nuclei of some elements align themselves in the field, rather like bar magnets. If a radio wave of a particular frequency is applied, the nuclei may realign themselves in the field. The energy absorbed from the radio wave promotes the nucleus to a higher energy level. When the radio wave is switched off the nucleus reverts to a lower energy state. As it does this it emits radio waves at characteristic frequencies. The way this occurs is characteristic of the chemical and physical environment of the nucleus.

__Dr Adam Gibson__ is a research fellow in the Department of Medical Physics and Bioengineering at University College London.

The shorter the wavelength of the electromagnetic radiation, the more likely it is to cause ionisation as it passes through living tissue. This means that gamma rays and X-rays are the most hazardous to living organisms.

Mobile phones now have a published SAR (specific absorption rate) value, which shows energy absorbed during a phone call.

- **Tomography comes from a Greek word meaning 'to cut or slice'. It is linked to the word 'atom'. Find out how.**

Marc Hill/APEX

The Eden Project

Above: *Inside the humid tropics biome*

The original site of the project was no more than a sterile wasteland. In order to grow plants there 85,000 tonnes of soil had to be made from a special 'recipe' devised by a joint team of Eden's scientists and Reading University.

The lightweight steel roof structure of the biomes uses ETFE foil instead of glass. ETFE is not only strong and lightweight, it allows ultraviolet rays to pass through.

The Eden Project in Cornwall explores human dependence on plants, and in doing so reveals our global interdependence. A visit there will not only bring plant biology alive, but also increase your understanding of human impact on the environment — both part of your GCSE science course.

Hidden within a 60-metre deep, 15-hectare former china-clay pit (quarry) and surrounded by a dramatic horticultural landscape, Eden is home to the two largest conservatories (known as 'biomes') in the world. This spectacular global garden is a 'living theatre of people and plants' — dedicated to the appreciation and study of human dependence on plants. If you visit the Eden Project you can learn all about our relationships with plants from around the world, not only because of the huge plant collections but also through actors, art and sculpture.

Humid tropics biome

The humid tropics biome houses plants from tropical islands, Malaysia, west Africa and tropical South America. This biome (which could hold the Tower of London) is 50 metres high, 110 metres wide and

Box 1 Biome structure

Building a lean-to 'greenhouse' on an uneven surface that changed shape was tricky. The solution came in the form of designs first introduced by the famous architect, Buckminster Fuller — bubbles made from hexagons! The final design comprises a two-layer steel, curved space frame, the hex-tri-hex. It has an outer layer of hexagons (the largest of which is 11 metres across), plus the occasional pentagon, and an inner layer of hexagons and triangles — all bolted together like a giant Meccano kit.

Each hexagon is fitted with transparent foil 'windows', made of three layers of ETFE (ethylene-tetrafluoroethylene), forming inflated 2-metre deep pillows. This provides maximum insulation. The pillows were installed by 22 professional abseilers — 'the sky monkeys'.

ETFE was used because it:

- has a lifespan of over 25 years
- transmits UV light
- is non-stick and self-cleaning
- weighs less than 1% of the equivalent area of glass
- is tough (each hexagon can take the weight of a rugby team)

Box 2 Where did the plants come from?

Most plants at Eden were already in cultivation in Europe and came from other botanic gardens, research collections and private individuals, or from commercial nurseries. Very few were collected from the wild. Many plants arrive as seeds or cuttings and are grown on at Eden's own nurseries.

240 metres long. There are plants and crops from tropical environments and rainforests — including bananas, coffee, balsa, mahogany, bromeliads (orchids), spices and tropical ferns. Each plant has its own story and there are signs and guides to help you appreciate these.

You can experience something of the sights, smells and sheer scale of the rainforest in what is the world's largest greenhouse. The temperature within the humid tropics biome ranges from 18 °C to 35 °C. Humidity is kept up with automated misting nozzles (90% at night and 60% during visiting hours).

Warm temperate biome

The smaller warm temperate biome is 35 metres high and 140 metres long. Here you can encounter Mediterranean crops (orange and lemon trees, an old olive grove, herbs and vines), some of the rich variety of plants from the temperate parts of South Africa (proteas and aloes), drifts of colourful Californian annuals (poppies and lupins) and shrubs of the chapparal. There are also banks of fruit, vegetables, pulses and grains. The temperature within the warm temperate biome ranges from 8 °C to 25 °C.

Outdoor biome

Eden also has a huge outside landscaped area, known as the outdoor (or 'roofless') biome. This is mostly on crescent-shaped terraces around the pit. It tells the story of plants that have changed the world, including man's creation of crops, land use and cultivation. In it you will find sunflowers, lavender, hops, hemp and tea bushes. In spring, there is a fantastic display of 250,000 bulbs (daffodils and tulips) which start to bloom in February.

Keith Martin

Keith Martin

Above: *Big Build 2 — the new Education Centre as it was in May 2005*
Inset: *Workers installing photovoltaic cells on the roof of the new Education Centre in June 2005*

- **Encourage your school or family to organise a visit, especially after the new Education Centre has opened. We suggest you spend half a day at Eden. See Box 4 for visiting information.**

One of the white tree frogs released at the Eden Project as a measure against insects that eat the plants

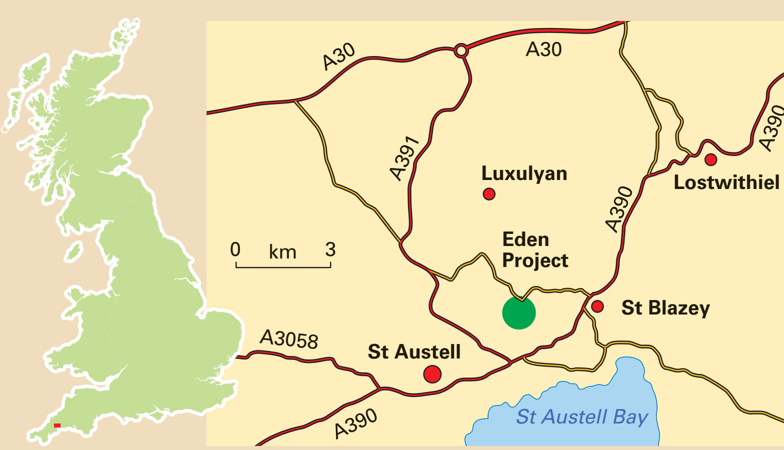
Nick Gregory/APEX

Box 3 Pest control

Wherever possible, bio-pest control is used — the humid tropics biome is currently home to a number of mini predators, including Sulawesi white eyes (tiny birds), tree frogs, geckos and bullfrogs, together with praying mantid and tiny predatory insects.

Box 4 Visiting information

The Eden Project is at Boldelva, Austell, Cornwall, PL24 2SG. Log on to www.edenproject.co.uk to find out more about costs, details of opening times and to take the virtual tour.



Sarah Hepple

Kidneys

Your body has to handle all sorts of variations, balancing its inputs and outputs, if it is to work efficiently. In this article we concentrate on one organ — the kidney — and the way it helps to keep things on an even keel.

GCSE key words
Homeostasis
Hormone
Kidney tubule
Diffusion
Osmosis

Our bodies work to balance their inputs and outputs in two ways. The processes involved are **homeostasis** and **excretion**.

Homeostasis

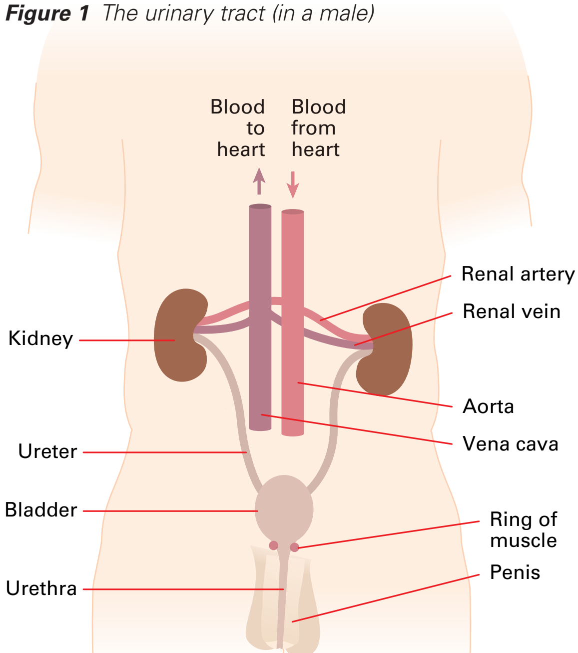
This involves various mechanisms that keep the body's internal environment in a state of relative stability. Your endocrine system helps to maintain this steady state by regulating body processes that affect the concentration of chemicals, such as potassium, sodium and chloride ions, in blood, lymph and tissue fluid. It also controls the way that proteins, lipids and carbohydrates are utilised by your body.

The endocrine system works through **hormones**. These are specialised chemical substances, produced by endocrine glands and then released into the blood. They circulate around the body to regulate the action of particular target organs. The production and release of these hormones is controlled by the brain, which receives inputs from receptors in blood vessel walls around the body and in the brain itself.

- **Look up the homeostatic mechanisms the body uses to keep your internal temperature just right.**

Anything to do with the kidney is described by the adjective *renal*, hence renal artery, renal dialysis, and the adrenal gland that sits on top of a kidney.

Figure 1 *The urinary tract (in a male)*



Excretion

This involves getting rid of waste materials, which would otherwise build up. These include carbon dioxide, which is excreted when we breathe out, and urea, which is excreted via the kidneys. Urea and other nitrogen-containing products are produced when the body breaks down proteins.

The role of the kidney

Kidneys are part of the urinary tract (Figure 1). They help to maintain the internal environment of our bodies by filtering the blood. Each kidney contains over a million kidney tubules or **nephrons**. These filter water and soluble components from the blood (about 1700 litres/day) and then reabsorb sugar and amino acids, as well as the dissolved ions and the water the body needs (Figure 2). At the same time, urea, excess ions and excess water are excreted as urine, approximately 1.5 litres/day.

Look at the list in Box 1 of all the other things that kidneys do — no wonder we can't survive without them working properly.

Thirsty work

We get rid of water via the kidneys as urine, but we also lose water through sweat, in faeces and as water vapour when we breathe out. What happens when you run a race? The further and the faster you go, the more you sweat and lose water through the skin. As a result your blood becomes more concentrated. This triggers two mechanisms:

- Receptors in your brain note the changed concentration and these trigger your thirst centre, which makes you want to drink.
- The pituitary gland in your brain releases a hormone called ADH into the blood which causes the kidneys to reabsorb more water from the filtrate.

When you have drunk some water and stopped sweating, less ADH is released into the blood. Therefore less water is reabsorbed and your urine becomes more dilute. These processes are examples of **negative feedback**.

Table 1 *The urinary system*

Structure	**Function**
Kidneys	Filter waste from blood and produce urine
Ureters	Transport urine from kidneys to bladder
Bladder	Stores urine
Urethra	Transports urine from bladder to outside of body

Box 1 Other functions of the kidneys

Kidneys are also involved with:

- the control of blood sodium level
- the control of blood pH
- blood pressure

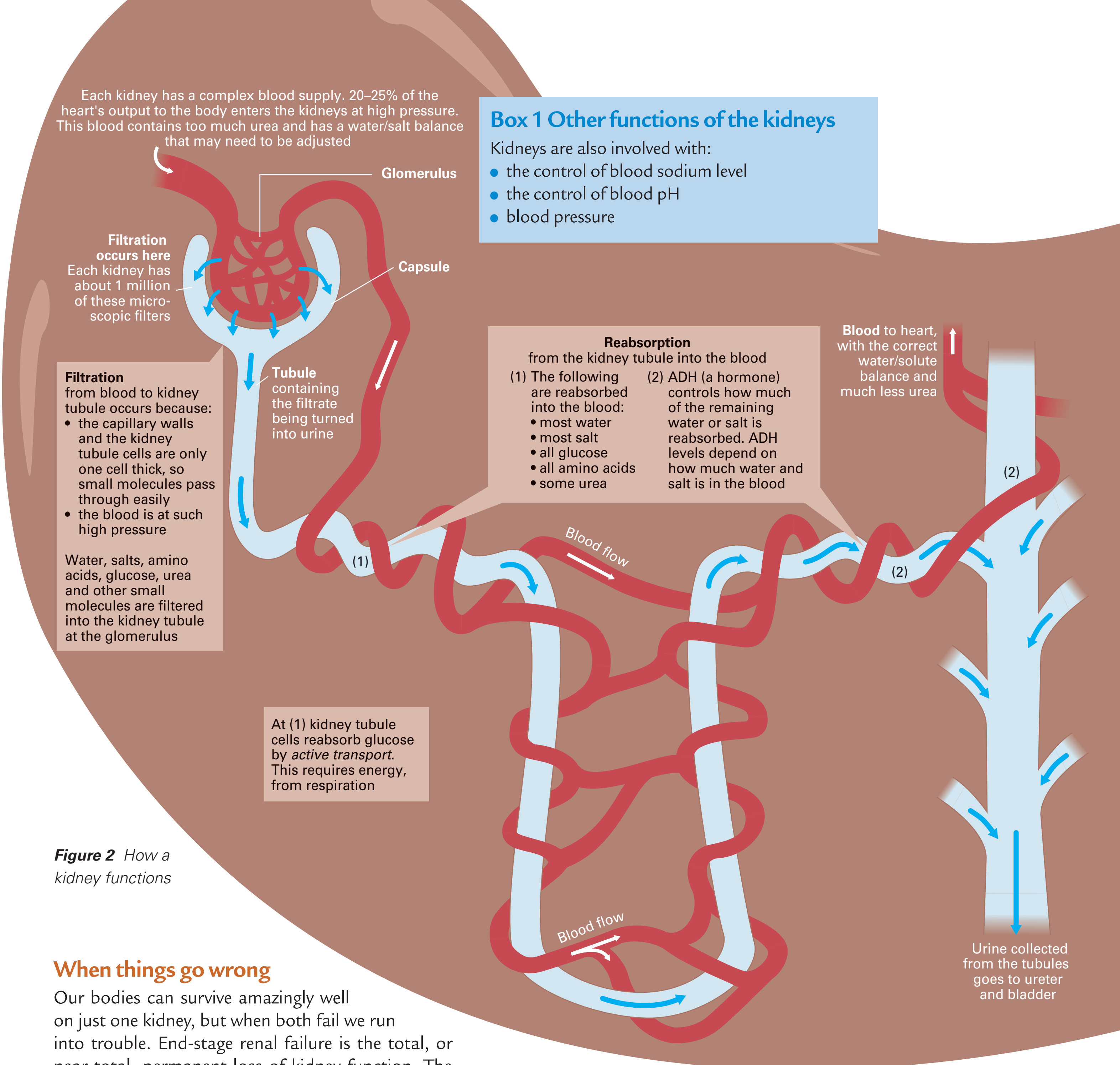


Figure 2 *How a kidney functions*

When things go wrong

Our bodies can survive amazingly well on just one kidney, but when both fail we run into trouble. End-stage renal failure is the total, or near total, permanent loss of kidney function. The commonest causes of end-stage renal failure in this country are diabetes, hypertension and glomerulonephritis (inflammation primarily affecting the glomeruli in the kidney).

It is important to monitor people with these conditions closely, so that if they start to develop renal failure, measures can be taken quickly to slow progression of the disease. This involves giving people medication to help keep blood pressure and diabetes as tightly controlled as possible. People may have renal failure for years (chronic renal failure) before they develop end-stage renal failure.

When kidneys fail they stop producing urine and we can no longer excrete urea and get rid of salts and water in excess of the body's needs. The body becomes uraemic — the waste products build up making you feel tired, sick, off your food, itchy and generally unwell. So what can be done to help the body combat these imbalances?

Dialysis

Unwanted substances can be filtered away artificially using a dialysis machine (Figure 3 on page 8).

Blood leaves the body in tubes, passes through a pump and into the dialysis machine. It then enters thousands of semipermeable microtubules which make up a dialysis membrane. Between these microtubules, running in the opposite direction to the flow of blood, is dialysis fluid. The dialysing membrane

- **Water is reabsorbed by osmosis — from the tubule into the blood. Make sure you understand why osmosis occurs.**

- **List the ways your life would change if you had to have dialysis — what would you do about holidays?**

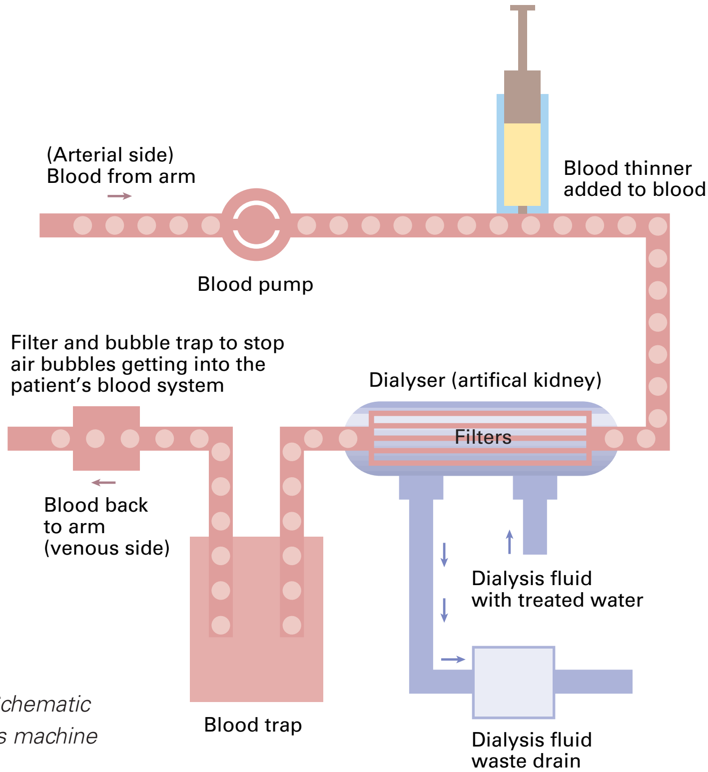


Figure 3 *Schematic of a dialysis machine*

Phototake Inc./Alamy

A dialysis patient

Box 2 Arteriovenous fistula

For patients requiring regular haemodialysis difficulties can arise when trying to gain access to their veins. One solution is to form an arteriovenous fistula, an artificial connection between an artery and vein which is made surgically. This creates a pool of blood, into which needles can be inserted repeatedly for dialysis (Figure 4).

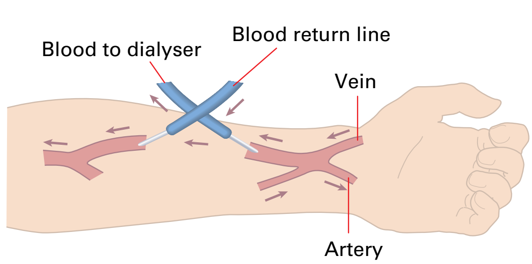


Figure 4 *A fistula*

- **Find out about another method of dialysis — continuous ambulatory peritoneal dialysis (CAPD).**

- **To find out more information on kidney donation see www.uktransplant.org**

allows small particles, such as water and urea molecules and sodium and chloride ions, to pass through it. The particles move randomly and can pass both ways through the membrane. However, more particles will meet the membrane on the side with a higher concentration and pass through, thus giving a net flow from higher to lower concentration. This is the process of **diffusion**.

The incoming dialysis solution contains water, glucose, salts and various substances at the correct concentration for the body. Diffusion continues until the concentrations are the same. The blood leaving the machine has all these substances in the same concentration as the dialysis solution. The fresh dialysis solution does not contain urea so this diffuses out of the blood and is effectively excreted and taken away by the flow of dialysis solution. Proteins and blood cells are too big to pass through the membrane so they stay in the blood.

People with end-stage renal failure need to have regular dialysis. Most of them have dialysis three times a week and it takes up to 4 hours each time. Think about the impact this must have on their lives.

Renal transplants

A renal transplant can give a whole new lease of life to someone who has spent a long period of time trying to keep things under control by having regular dialysis and a multitude of medications.

Transplanted kidneys currently come from one of two sources:

- **A dead person.** Sometimes in an accident a casualty may suffer permanent and irreversible brain injury. He or she may need to be maintained on a life-support machine, and be tested to certify brain death. If such casualties have previously consented to donate their organs, and relatives give their permission, kidneys and other organs can be removed when the life-support machine is turned off. Kidneys may also be taken from donors who have died from causes such as cardiac arrest, but this has to be done very quickly before irreversible damage occurs.
- **A living person.** Since we can survive with one kidney, it is possible to donate a kidney to a close relative.

There are problems with kidney transplants. A kidney cannot be transplanted from any donor to any recipient. Many tests are needed to check if the donor and recipient are compatible. It is important that lots of variables match up, such as tissue type and blood type, in order that the recipient's body does not reject the kidney. The recipient also has to take immunosuppressive drugs for the rest of his or her life. These help to stop the recipient's immune system rejecting the kidney.

Sarah Hepple *is a Senior House Officer in a large city hospital. She has spent time working with patients with kidney failure.*

Expanding marshmallows

There's some scientific fun to be had with marshmallows before you toast them on the bonfire.

- Look for marshmallows which are dry on the outside, not sticky. You may have to roll them in cornflour to prevent them sticking to the sides of the bottle.

Long, thin marshmallows are easiest to get into the bottle.

Activity

(1) Find an empty wine bottle, preferably made of colourless glass. It must be dry inside. You will also need a wine saver — a special stopper with a hand-operated pump (Box 1).
(2) Push some marshmallows into the bottle. Fit the stopper and start to pump out the air. You should see the marshmallows expand gradually as the pressure in the bottle drops.
(3) Let the air back into the bottle to see the marshmallows return to their original size.

How does it work?

Marshmallows are made of an elastic (springy) material which contains tiny air bubbles. As the air in the bottle is pumped out, the pressure on the outside of the marshmallows decreases. The inner pressure of the air bubbles is now able to push outwards, causing the marshmallows to expand (Box 2).

Box 1 How do wine savers work?

The wine saver stopper is a clever piece of design. It is made of flexible rubber, and there is a slit inside. When the bottle has been evacuated, the air outside presses on the stopper, forcing the slit shut.

To evacuate the bottle, the pump is pulled upwards. This creates a vacuum above the slit, and the pressure of the air in the bottle is great enough to push its way through the slit.

Box 2 What is the science behind this?

Remember the science behind this: it is not possible for a vacuum to suck on the marshmallows — by definition, there is nothing in a vacuum, so it cannot suck. It is the internal pressure that pushes the marshmallows outwards.

Astronauts in space

Now picture yourself as an astronaut on a spacewalk. Your spacesuit is pressurised to balance the internal pressure of your body. What happens if you damage your suit? If your suit rips, the air will rush out and you, like the marshmallows, will be in danger of exploding into the vacuum of space.

Corel

Improve your grade

The perio

To work out how the electrons are arranged: (you only need to know this up to element 20, calcium) count boxes in periods until you reach the element, e.g. Ca: 2, 8, 8, 2. Start with period 1 (H) and make sure you count the box containing the element you are interested in.

Use the periodic table to find out all sorts of useful chemical information to help improve your grade at GCSE.

To work out how many electrons there are in an atom: it is the same as the proton number (the smallest number in the element box).

Groups

Groups are vertical columns of elements which all have similar properties.

Periods are horizontal rows of elements

Elements in a period show a gradual change in properties across the period.

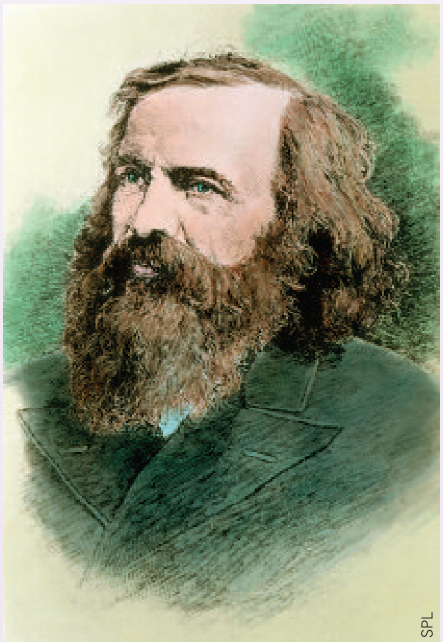
Reactivity of metals increases downwards

Period	1	2							
1	1 H Hydrogen 1								
2	7 Li Lithium 3	9 Be Berylium 4							
3	23 Na Sodium 11	24 Mg Magnesium 12							
4	39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Mangesium 25	56 Fe Iron 26	59 Co Cobalt 27
5	85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	99 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45
6	133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77

Transitional metals

Alkali metals

Alkaline earth metals



Dmitri Mendeleev (1834–1907) — the originator of the modern form of the periodic table

I began to look about and write down the elements with their atomic weights and typical properties, analogous elements and like atomic weights on separate cards, and this soon convinced me that the properties of elements are in periodic dependence upon their atomic weights.

(Mendeleev, *Principles of Chemistry*, 1905, Vol. II)

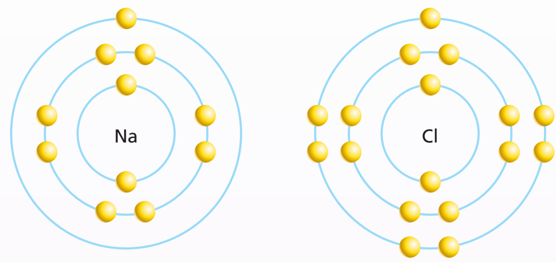
Subtract atomic number from atomic mass to get the number of neutrons in an atom.

Atoms with different numbers of neutrons are called **isotopes**.

Gaseous elements at room temperature: H, He, Ne, Ar, Kr, Xe, Rn, F, Cl, O, N
Liquid elements: Hg, Br

dic table

To work out common charges on elements:
(1) Metals are always positive and the charge is the same as the group number, e.g. Al^{3+}.
(2) Non-metals are always negative and the charge is (8 – the group number), e.g. O^{2-}.



Sodium Chlorine

The number of electrons in the outer shell confers the chemical properties of an element.

Fluorine — the most reactive non-metal. Reactivity of non-metals increases upwards

			3	4	5	6	7	0
								4 He Helium 2
			11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
			27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorous 15	32 S Sulphur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
59 Ni Nickel 28	63.5 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86

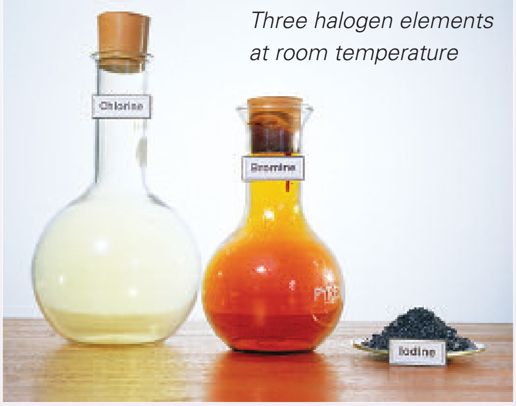
Halogens

Noble (inert gases)

Metals ← → Non-metals

Metals always lose electrons to form positive ions.

Non-metals always gain electrons to form negative ions.



Three halogen elements at room temperature

Andrew Lambert Photography/SPL

Noble gases have full shells of electrons and are unreactive.

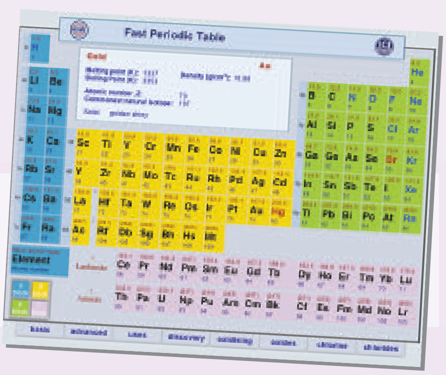
Atomic mass → 204

Tl

Thallium

Proton number or atomic number (number of protons and number of electrons in a neutral atom) → 81

Find out more about elements on an interactive periodic table at: **www.schoolscience.co.uk/periodictable.html**

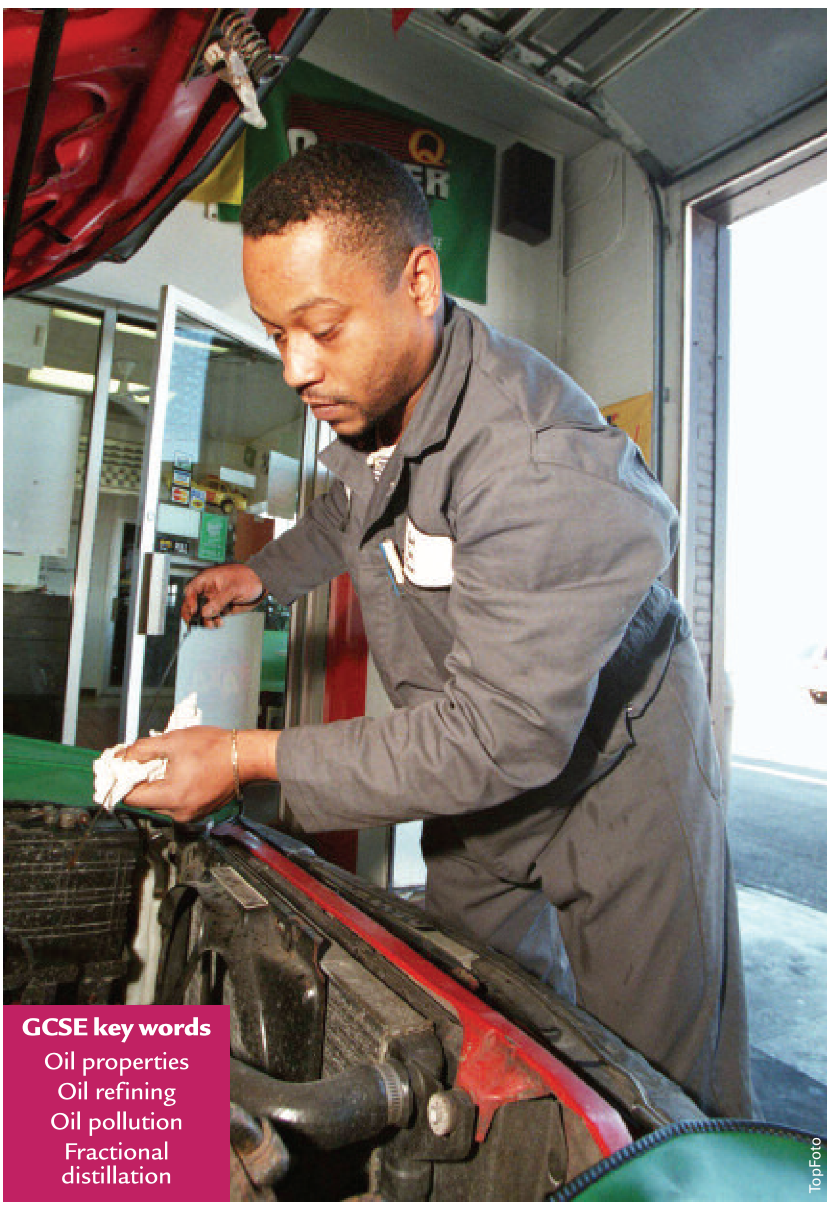


***David Moore** teaches chemistry and is an editor of CATALYST.*

Stefan Reeve

Keeping engines running smoothly

Modern car engines can run smoothly and propel you for thousands of miles without needing much attention, apart from refuelling with the diesel or petrol needed as a source of energy. The engine also needs oil. What is engine oil, how does it work and how can it be recycled or disposed of?



GCSE key words
Oil properties
Oil refining
Oil pollution
Fractional distillation

Oil is used as a lubricant in all internal combustion engines and in most machines with rotating parts. For the purpose of this article we are going to focus on car engine oil. Engine oil is a remarkable material — in modern car engines it can work as a lubricant without needing to be changed for thousands of miles. The purpose of engine oil is to minimise corrosion and wear by reducing friction, oil oxidation and deposit formation. A lot of sophisticated chemistry is required to do this.

What is engine oil made of?

Car engine oil is made up of petroleum base oil (80%) and a package of additives (20%). Petroleum base oil is made from the higher boiling point portions of crude oil, which remain after the lighter fractions have been removed (see Box 1). As crude oils are obtained from various parts of the world their chemical composition and properties can differ widely.

Box 1 Refining crude oil

Crude oil is refined by a continuous process called fractional distillation, which generates a variety of products (see Figure 1). This process divides the parts of crude oil by their boiling points.

The crude oil is heated and fed into the bottom of the distillation column. The gases rise up the column, passing through a number of 'bubble caps'. Here liquids with a high boiling point condense while those with a low boiling point continue further up the column, where they pass through further bubble caps.

In this way the mixture is separated into a number of different fractions. Those fractions at the top of the column have a low boiling point — and hence a low molecular mass — while those near the bottom have a high boiling point and high molecular mass. The part that is used to produce lubricants has a relatively high molecular mass.

Box 2 Useful websites

www.bp.com
www.shell.com
www.exxonmobil.com
www.environment-agency.gov.uk

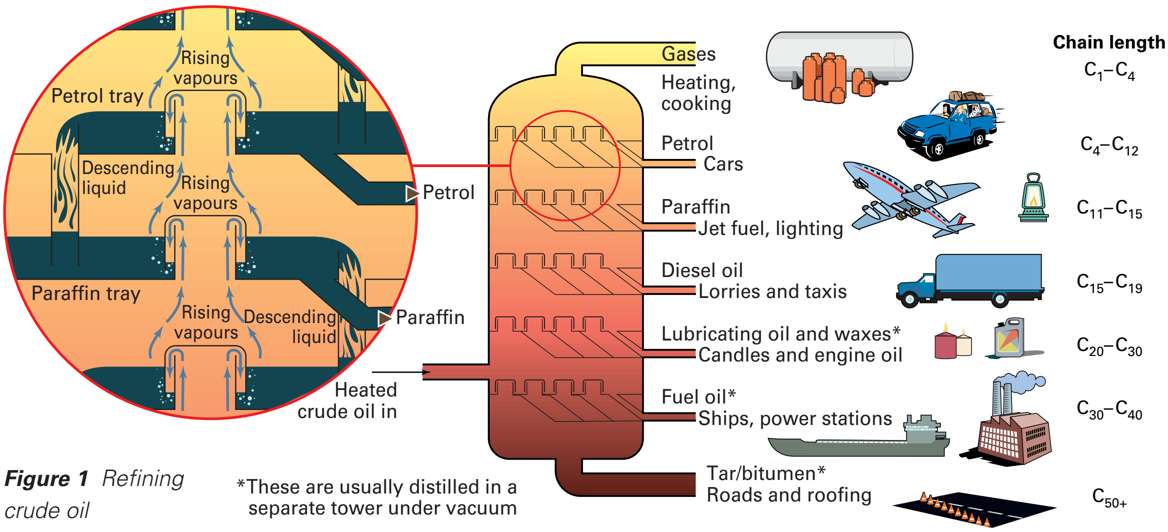


Figure 1 *Refining crude oil*

*These are usually distilled in a separate tower under vacuum

What is in the additive package?

This is where it gets interesting! The motor industry is extremely competitive – and not only in motor sport. Consumers have high expectations of performance and want value for money. Car manufacturers have to take into consideration all the factors that go into making their cars run well and efficiently for as long as possible. This means they choose and often recommend specific engine oils that have been developed to prolong the life and enhance the performance of their vehicles.

The additive package varies from oil to oil. The companies which produce the additive packages often keep their contents a closely guarded secret, but essentially they are made up of varying proportions of the following 11 components.

Detergents

These are surface active agents (similar to household detergents) which act to prevent deposit formation on engine parts. These deposits would form a 'lacquer' over the many parts of the engine, which in time would diminish performance.

Available in different strengths and degrees of 'over basing', detergents can both prevent deposits and clean up those that have already formed. The 'over basing' neutralises acidic impurities that accumulate in the engine oil over time, thus minimising engine corrosion and preventing a reduction in the oil's lubrication properties.

Dispersants

These molecules bond to the sooty contaminants in the oil that result from exhaust gas contamination and keep them from clumping together. The sooty contaminants are then kept suspended in the oil until they can be removed by a filter or oil change. Without dispersants, deposits would build up on the piston head and form a sticky mass, which could break loose and block ports and valves.

Anti wear/extreme pressure agents

These agents bond to the metal surfaces to create a strong lubricant film between the moving metal parts. This film can withstand extreme heat and mechanical pressure. It prevents the moving metal parts from coming into direct contact with each other, thus protecting them from scoring and seizing.

Friction modifiers

In effect, these make oil more slippery, thereby reducing the friction between moving parts. This both reduces wear and improves fuel efficiency.

Antioxidants

Even highly refined base oils contain some organic compounds that can decompose by oxidation (exposure to air) in the presence of heat. This destroys the oil's ability to lubricate and results in severe engine deposits. Antioxidants inhibit this process by 'locking up' the organic compounds.

Over time, acid will form in the oil. To pre-empt this, an alkaline 'base' is put into the oil to neutralise this acid as it develops. 'Over basing' is done to ensure that there is enough base present throughout the life of the oil.

Grangemouth refinery in Scotland

BP plc

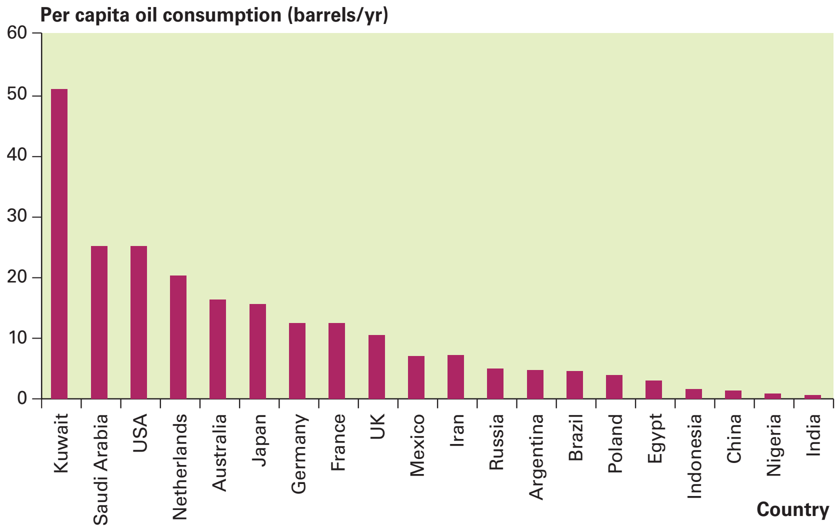


Figure 2 *International consumption of crude oil in 2001. This graph shows the amount of oil in barrels consumed per person per year by each country*

Right: *Engine oil is used to lubricate moving parts*

One barrel of oil weighs approximately 140 kg.

In the UK we consume an average of just over 10 barrels of oil per person per year.

'Cold cranking' is when you turn over the engine to start a car before it has warmed up or when the temperature is very low. Pour point depressants are very important in Canada and other countries which experience extreme cold for large parts of the year.

Rust/corrosion inhibitors

These prevent the corrosion and rusting of metal parts in contact with the lubricant. They work by neutralising the effects of water and acids formed as part of the combustion process.

Pour point depressants

Engine oils are effective at high temperatures in a running engine. When an engine is started from cold, oil still needs to flow freely to lubricate moving parts. Cold cranking is when the potential for engine wear is at its greatest. Pour point depressants allow the oil to flow better at lower temperatures as well.

Antifoam agents

These inhibit the formation of foam in oil that can result from the mechanical action of the engine and reduce the oil's ability to lubricate effectively. The antifoam agents reduce the surface tension of the fluid thus making it less likely to form foam.

Seal conditioners

Seal conditioners cause the engine's gaskets and seals to swell, creating a better join between the engine parts. This prevents fluid leakage.

Metal deactivators

These form an inactive film on metal surfaces that reduces the tendency of the metal to react with the oil in ways that increase the rate of oil oxidation.

Viscosity modifiers

Temperature affects viscosity grade, making oil either thicker or thinner. This lessens its ability to protect engine parts at temperature extremes. Viscosity modifiers are flow control agents that allow the oil structure to adapt to temperature changes, maintain its grade and retain its lubricating effectiveness. This is what makes multi-grade oils possible.

What happens to these oils after use?

Used engine oil poses a serious threat to the environment and wildlife if it is not disposed of properly. Just a few litres can form a thin film over a small lake! The oil industry is therefore under increasing pressure to find ways of recycling such materials so that they do not cause ecological harm.

There are two options for the reuse of waste oil:

- recovery of the petroleum base oil
- reuse as a fuel

Recovery of the petroleum base oil

If we choose to recover waste oil that has been drained from cars, then the water, dirt, heavy metals (such as magnesium, copper, zinc and others which are picked up from the engine), nitrogen, chlorine that is present in some dispersants, and oxygenated compounds all need to be removed through processing and refining.

At the end of these processes we are left with re-refined petroleum base oil. However, if this recovered base oil is to be reused it must meet the same standards as the original base stocks.

Reuse as a fuel

If we choose to reuse the waste oil as a fuel in industries such as power generation, the process is more straightforward, although water and particulates must first be removed.

The need for an alternative power source

It is worth noting that the recycling process itself is energy intensive and also produces waste and harmful pollutants, *so recycling is not always the most environmentally-friendly approach, even if it is still regarded as the ideal*.

Ultimately, an alternative power source is required if today's transportation systems are to become sustainable. However, in the meantime everyone can help to reduce environmental damage from used oils by following the Environment Agency's guidelines and disposing of their used engine oil at their local council's recycling centres.

Stefan Reeve *is a chemical engineer who works in the additive industry.*

Intensive crop production systems

Nigel Collins

Much of the food that we eat comes from systems in which large numbers of plants or animals are grown under closely controlled conditions, designed to maximise production. In this article we look at two intensive crop production systems which illustrate key points in your GCSE course.

GCSE key words
Factors affecting plant growth
Photosynthesis
Human impact on the environment

All green plants have certain basic requirements — oxygen, water, a source of mineral nutrients such as nitrate ions, space to grow and reproduce, suitable temperatures and, of course, a supply of carbon dioxide (CO_2) for photosynthesis. All plants compete with each other for these resources and are at risk from pests and diseases and extremes of weather.

When they grow plants as crops farmers intervene in various ways to optimise growth, so that the food is produced as quickly and cheaply as possible.

Temperature and carbon dioxide

Growth is dependent on chemical reactions, catalysed by enzymes. These reactions, which include photosynthesis and respiration, protein synthesis and the synthesis of all sorts of other chemicals, such as cellulose for cell walls or starch and oils stored in seeds, are all faster at higher temperatures. As a result, fruits or underground structures, like potatoes and carrots, develop and grow more quickly.

Plant growth is also often constrained by lack of carbon dioxide. It is difficult to raise carbon dioxide concentration outdoors, but in a greenhouse this is feasible. Carbon dioxide can be generated by burning a fuel — which also raises the temperature.

The combined effects of light intensity, carbon dioxide concentration and temperature on photosynthesis are shown in Figure 1. Initially, light intensity

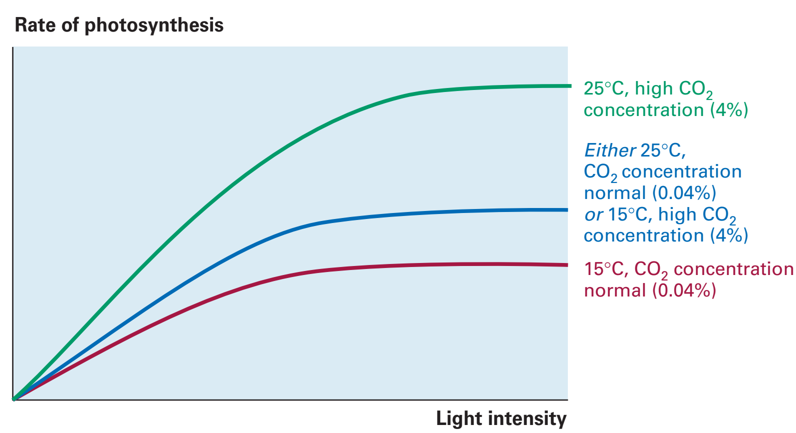


***Figure 1** Light, temperature and carbon dioxide concentration and photosynthesis. Raising* either *the temperature* or *the carbon dioxide concentration increases the maximum rate of photosynthesis possible at higher light intensities. Increasing* both *has the greatest effect*


Holt Studios

Growers planting seedling lettuces in soil blocks in hydroponic channels in a large glasshouse in Hertfordshire

limits growth, but above a certain light intensity photosynthesis reaches an upper limit and continues at a steady rate. To increase the rate of photosynthesis above this, the *limiting factors*, in this case temperature and/or carbon dioxide concentration, must be increased.

Salad and strawberries

Lettuces, tomatoes and strawberries can all be grown outdoors in Britain — indeed lettuces and strawberries are often produced in this way for a relatively short season. But growth is slower than if the plants are placed in a glasshouse or protected under polythene. In open soil the plants are also more likely to be eaten by slugs and snails. Under protection the plants can be more isolated from pests and the growing season can be extended significantly.

There is concern that in some parts of Britain the introduction of polytunnels covering large areas for up to 6 months of the year is spoiling the countryside.

A farm in Kent has the biggest single area under glass in Europe for growing strawberries across a 6-month season. A combined heat and power (CHP) plant that generates electricity for use on the farm also produces heat and carbon dioxide for accelerating photosynthesis and crop growth. Surplus electricity is fed into the National Grid. Box 1 describes another way to achieve higher temperatures and carbon dioxide concentrations which used to be used in kitchen gardens.

Box 1 Hot beds

Another way to achieve higher temperatures and carbon dioxide concentrations which used to be used in kitchen gardens is to set up a hot bed. This is a deep pit in a glasshouse filled with straw and animal dung — obtained from a stable or a shed for overwintering cattle.

Decomposition sets in as bacteria use the materials in the bed for food. As they respire the bacteria release carbon dioxide which is useful for the plants in the bed. They also release heat, which warms the bed.

When European plant hunters first brought them home, exotic plants such as pineapples were grown in this way.

Glasshouses and polythene tunnels (polytunnels) have a further use when growing strawberries. The UK crop has always been vulnerable to devastation by heavy rain, but polythene protects the crop from this risk.

You might expect that supermarket strawberries or salad crops grown in the much hotter climate of southern Spain would be grown outdoors, but in fact they are also grown under polythene. Hectare after hectare of the arid countryside, which has very thin soils, is covered in polythene. The polythene used in Spain is often much less transparent than in Britain, to provide shade in the daytime from the full strength of the Mediterranean sun. This is important because at *very* high light intensities chlorophyll molecules can be damaged, which will affect photosynthesis. The polythene also helps to retain warm air at night, because in the open air temperatures can drop quickly at night under clear skies. Plants here are often grown in 'artificial soil', an inert material such as rock wool, with water and added fertilisers trickling through it. This technique of **hydroponics** will be described in the next issue of CATALYST.

Controlling pests and diseases

Problems with this method of growing crops include the fact that large expanses of a single variety can be vulnerable to infections which may spread quickly and ruin a crop. *Elsanta*, a widely grown strawberry variety, is prone to such infection. One solution is to sterilise the soil using chemicals. In Britain, the industry currently makes use of methyl bromide — an ozone-depleting chemical which other countries have phased out. This chemical is not selective — it kills all soil organisms, rather than just the nematodes and fungi that cause problems for strawberry growers. Methyl bromide use is now being phased out in Britain.

One advantage available to growers of crops under glass is that if there is an infestation by some pests such as mites or small flies, biological control can be used (see CATALYST Vol. 16, No. 1). Predatory insects are released to catch the pests. This is not often a viable proposition with crops grown outdoors.

Mushrooms

Mushrooms are the fruiting bodies of certain fungi. They may be gathered wild or grown under cultivation. The most commonly cultivated mushroom species is *Agaricus bisporus*. The annual worldwide production of this species of mushroom is 2 million tonnes which is worth £3 billion. In the UK we consume more than 100 000 tonnes of mushrooms each year — a significant proportion of which is imported.

How do mushrooms grow?

Mushrooms cannot trap energy from the sun because they do not contain chlorophyll. Instead, mushrooms extract their carbohydrates and proteins from a rich compost of decaying plant matter and manure. They are grown in the dark under carefully controlled conditions of light, heat and moisture.

Preparing the compost

Preparation of the compost is quite complex. The compost is pasteurised to kill harmful organisms by heating it to 60 °C for at least 2 hours. Temperatures are not high enough for complete sterilisation.

A fungal innoculum or 'spawn' is added to the compost in containers or beds and very fine fungal hyphae then grow to form a network of strands (mycelium) which spread through the compost. After 12–15 days a layer of peat or soil (the 'casing') is added.

Harvesting mushrooms

The fruiting bodies begin to appear about 6 weeks after spawning and continue to appear in flushes about 7–10 days apart for the next 6–8 weeks. Mushrooms are harvested over a period of 2–4 days within each 7–10-day period. The cap and a small section of connected stem are usually harvested before the caps are fully expanded.

Box 2 Mushroom fly pests

Small flies found in mushroom houses:

- reduce yield by damaging the compost and feeding on the mycelium
- act as vectors of diseases
- are a nuisance to pickers
- can cause rejection of pre-pack mushrooms at market

Researchers at Warwick HRI are trying to work out whether some fungal strains possess natural resistance to mushroom fly pests.


Holt Studios

Mature mushrooms inhibit the growth of more in their vicinity, so when they are picked off another flush can mature. The first three flushes are the most productive.

Ventilation

The amount of fresh air entering the room and temperatures within it are controlled automatically. Carbon dioxide concentration is also monitored. Ventilation rates depend on the amount of mushrooms being grown on the beds and on heat and carbon dioxide production (which increase as respiration speeds up). If stale air with high carbon dioxide levels builds up around the mushrooms, quality suffers.

Under ideal conditions mushrooms can double in size every 24 hours.

Pests and diseases of mushrooms

Various small fly and midge species are pests of mushrooms (see Box 2). Depending on the species, larvae feed on the compost or on fungal mycelium in the compost. They may also tunnel into the fruiting bodies.

A range of mite species may affect the yield and quality of the mushroom crop. Some damage the fruiting bodies directly, others attack the mycelium. Mycelium-eating mites can cause high yield losses. Nematodes cause a loss in yield and brown, watery mushrooms, and, in extreme cases a soggy, smelly compost. Peat added to the casing layer is a common source of nematodes and has to be treated before use.

Even though the mushroom itself is a fungus, it can in turn be affected by a range of fungal pathogens. Managing this is difficult because fungicides cannot be used! Bacteria and a range of viral diseases can also attack mushrooms. The best way for a farmer to counter diseases is to be very strict about hygiene at all stages of production.

- **When you next eat strawberries or tomatoes think of all the applied science involved in their production.**

- **You can read about intensive meat production systems in CATALYST Vol. 12, No. 2.**

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

A salmon farmer holds a young fish at Strondoir Bay fish farm in Scotland

TopFoto

Is salmon good for you?

GCSE key words
Bioaccumulation
Risk analysis

We are often told that we should eat more oily fish because of their health benefits. What do we do when we are told that they may contain harmful chemicals? Do the benefits outweigh the dangers?

We know that there are benefits from eating healthily and getting the correct balance of nutrients. Fats and oils — collectively called lipids — are important components of cell membranes, which contain molecules called phospholipids. But far too many of us eat too much of the wrong sort of fats.

At 20°C (room temperature) a fat is a solid and an oil is a liquid.

Omega-3 fatty acids

Oily fish such as salmon, tuna, sardines and mackerel contain plenty of protein, vitamins and the right sort of fats — and they are not too pricey for a family on a budget. The oils in these fish are rich in omega-3 fatty acids which are released when fats are digested.

- **Find out the UK government's view at www.food.gov.uk by typing *salmon* into the search box.**

Salmon fillets on sale at a fish market

TopFoto

We use these fatty acids to make cells, especially the fat-rich cells of the nervous system. Omega-3 fatty acids are thought to reduce the risk of heart disease and stroke. Some people think they help protect against Alzheimer's disease too.

Salmon scare

Recently there was a 'scare' about salmon. A report in the USA showed that salmon from fish farms contained higher levels of chemicals called organochlorines, particularly polychlorinated biphenyls (PCBs) and dioxin, than wild salmon. PCBs and dioxin are known to be a health hazard and they are persistent environmental pollutants.

How do these chemicals get into salmon?

Dioxin is a by-product of several industrial processes. PCBs were used for products such as the paint used to stop marine organisms growing on the hulls of ships. This fouling slows ships down.

These chemicals end up polluting water and are taken in by animals near the beginning of a food chain. They are not broken down inside these organisms but pass up the food chain and **accumulate** at each step in the chain. Because this involves biological processes, you will see it described as **bioaccumulation**. Salmon are top predators and accumulate the poisons most of all. Processed foods fed to salmon in salmon farms include organisms that have accumulated these chemicals.

Is anything being done about these poisons?

The World Health Organization has set a limit to how much of these chemicals we should be eating each month (70 picograms). In some parts of the world people are eating more than this and action is being taken to reduce contamination of the environment.

So is it dangerous to eat salmon?

There is a risk analysis to be made – is the risk from eating farmed salmon greater than the health risk from not eating it? Two 100 g servings a week are thought to reduce the risk of CHD by 30%. Eating one or two portions of fish a week keeps you below the limit for organochlorines set by the World Health Organization – *providing* the chemicals are not in any other food you eat.

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

PCBs were banned in most countries 20 years ago, but still persist in the environment.

A persistent pollutant is one that is not easily broken down in soil or water.

CHD is short for coronary heart disease.

- **Use an internet search engine to find out more about PCBs and dioxin.**

Puzzle

Chemdoku

Sodoku is one of the latest crazes – but have you tried our version – Chemdoku?

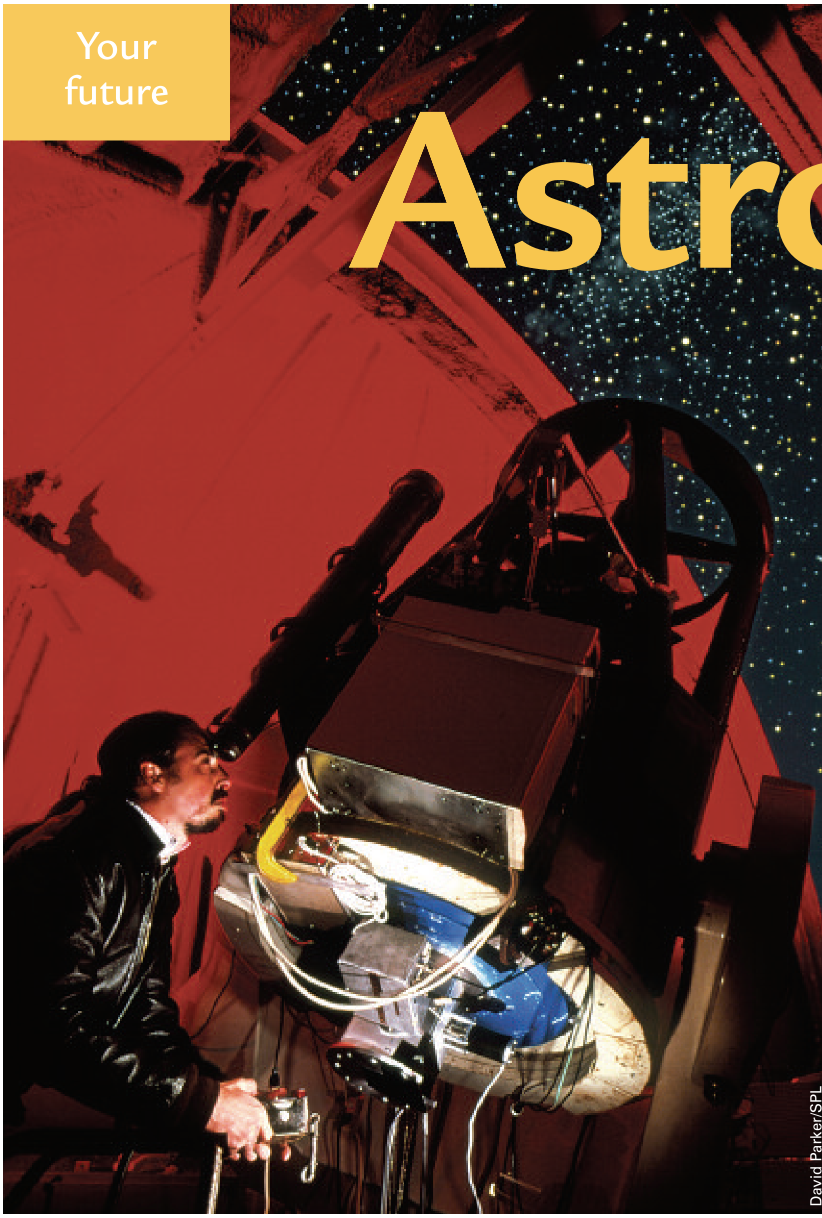
H				He			N	
		He				B	O	
	F				Be			C
He				Li			H	
		Li				C		
	C				He			B
Li				Be			He	
	N	Be				O		
	He							Be

Fill in the grid so that every row, every column and every 3 x 3 box (the smaller inner grids) contains each of the first nine elements of the periodic table (see Improve Your Grade, pages 10–11).

Answers on page 21.

Your future

Astronomy



David Parker/SPL

Above: *Astronomer using an optical reflecting telescope at the Leuschner observatory near San Francisco in the USA*

Astronomy appeals to many young people, but there are several different courses available. Here we take a look at what astronomers do all day — and all night.

Telescopes scan the skies gathering radiation in all parts of the electromagnetic spectrum — from radio waves to X-rays and gamma rays. Other instruments detect high-energy particles arriving from space, known as cosmic rays.

The UK is a world leader in astronomy, and has been for three centuries. Today, British scientists lead the field in many aspects of observational and theoretical astronomy and cosmology. Many universities have important departments of astronomy, and several British observatories are famous around the world — think of Greenwich, Jodrell Bank, Edinburgh and Armagh.

Astronomy is a cooperative affair and there are a lot of shared facilities around the world. So, as an astronomer, you might find yourself working alongside people of many different nationalities at an observatory high up on one of the Canary Isles or in Chile's Atacama Desert.

Box 1 Rocket science

Astronomers observe space, using ground-based telescopes as well as instruments on board spacecraft. They may also be involved in planning, making and testing the instrumentation and spacecraft before their launch.

The UK has a great reputation for devising and building instrumentation for all types of astronomical observation. The Astronomy Technology Centre is based at the Royal Observatory in Edinburgh. Computing has a big part to play, too. Most observations are now recorded electronically, and the vast quantities of data can only be analysed by computer.

What about making spacecraft? EADS Astrium is a European company concerned with building spacecraft. It has three sites in the UK, and has contributed to many of the European Space Agency's missions.

Key astronomy terms

There are many different strands in astronomy — perhaps you have wondered what some of the following terms mean?

Astronomy

This is a general term. Astronomers make observations of whatever is of interest in space — planets, moons, stars, galaxies, black holes, quasars — and try to explain what they see.

Astrophysics

Astrophysics is more to do with studying the stars — what they are made of, their life cycles and so on. There is a strong link with chemistry here, since most of the elements in the universe were formed in stars.

Cosmology

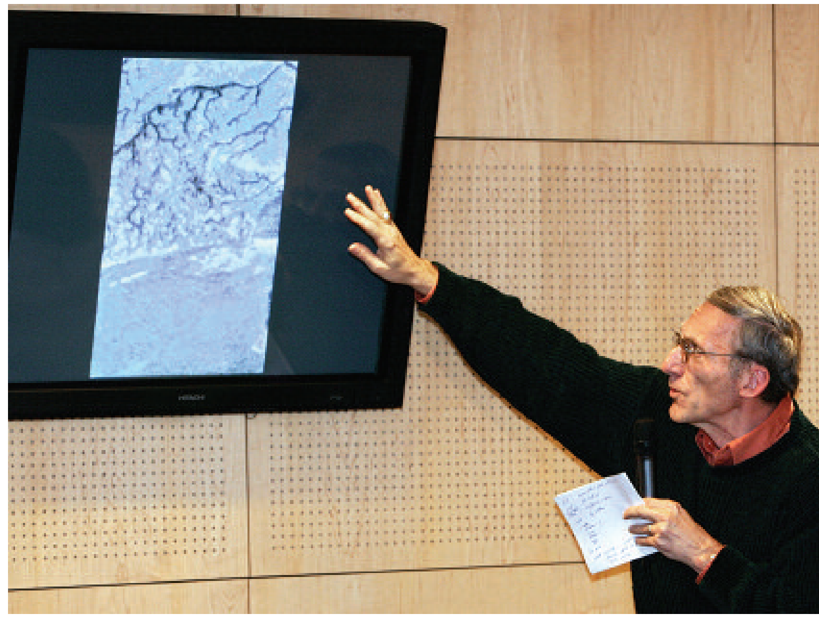
This is concerned with the big picture. What is the history of the universe? How is it structured? How will it all end?

Space science

Space science is harder to define. Space scientists are concerned with our exploration of space, and how our knowledge can be used. They are interested in visiting other planets and their moons, and the use of satellites to tell us more about our own planet, the Earth (see Box 1).

The first colour picture from Huygens *of the surface of Saturn's moon, Titan*

Getty Images



Jack Guez/AFP/Getty Images

John Zarnecki, the principal investigator of the surface science package of the Huygens *mission at a press conference of the European Space Agency presenting the results of the Titan mission*

Box 2 Astrology

Though astrology is an old belief system there is no scientific evidence to support it and astrologers do not usually have scientific training. For some people, it has proved a good way of making a fortune out of other people's desire to believe pseudo-science.

Courses to look out for

Many universities offer courses in astronomy or astrophysics. Often these are joint courses with physics, which give you the chance to include different proportions of astronomy modules in your course. Many include the opportunity to study abroad for a year.

Traditionally, these courses lead to a BSc degree. However, there are also many MPhys (Master in Physics) degree courses. MPhys courses are at the same level as a BSC, but last 4 years and allow you to study at a deeper level, with more specialisation. It is usually possible to switch between these courses in your first year of study.

Physics and maths are generally required at A-level. Chemistry is useful for astrophysics.

Box 3 Places to visit

Astronomers are always happy to discuss their subject, and you will usually find an enthusiast if you visit a planetarium (www.planetaria.org.uk). Many observatories have open days (and open evenings for looking at the night sky) — we have featured some visitor centres in earlier issues of CATALYST.

The Monument in the City of London was designed by Robert Hooke and Christopher Wren, both architects and scientists. Essentially, the Monument is a hollow cylinder, 202 feet tall, which could be used as an 'azimuthal telescope'. An astronomer at the foot of the tube could observe and time the passage of stars directly overhead.

Find out more from the useful booklet *Physics on Course*. This lists all physics and astronomy courses in the UK and is available free from the Institute of Physics (e-mail: **education@iop.org**).

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

Astrology is a belief system that argues that the positions of the stars and planets at the time of someone's birth determine aspects of their life (see Box 2).

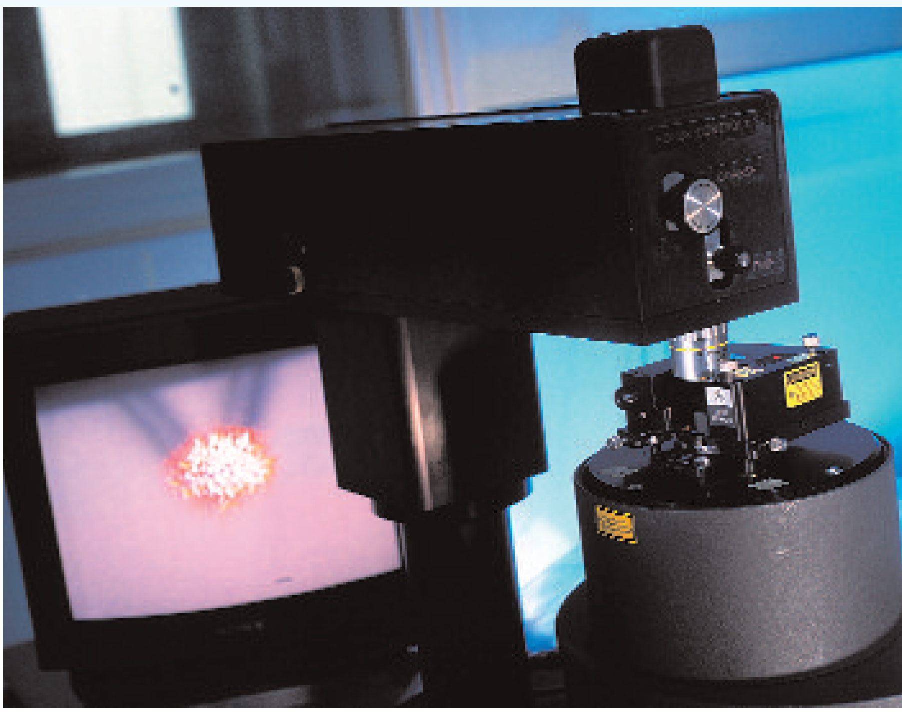
- **Take a trip to the Monument in the City of London. It was built to commemorate the Great Fire of 1666 — and is a telescope (see Box 3).**

Answers to Chemdoku, page 19

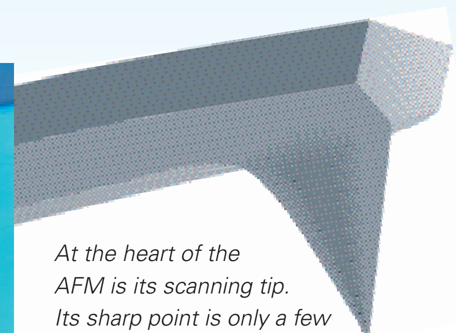
H	Li	B	C	He	O	Be	N	F
C	Be	He	Li	N	F	B	O	H
N	F	O	H	B	Be	He	Li	C
He	B	F	Be	Li	C	N	H	O
O	H	Li	B	F	N	C	Be	He
Be	C	N	O	H	He	Li	F	B
Li	O	C	F	Be	B	H	He	N
F	N	Be	He	C	H	O	B	Li
B	He	H	N	O	Li	F	C	Be

Atomic Force Microscope (AFM)

Twenty years ago, your science teacher might have said, 'Atoms are so small, it will never be possible to see them.' Now, thanks to a new generation of microscopes, we can create images of atoms and molecules and see how they are arranged.

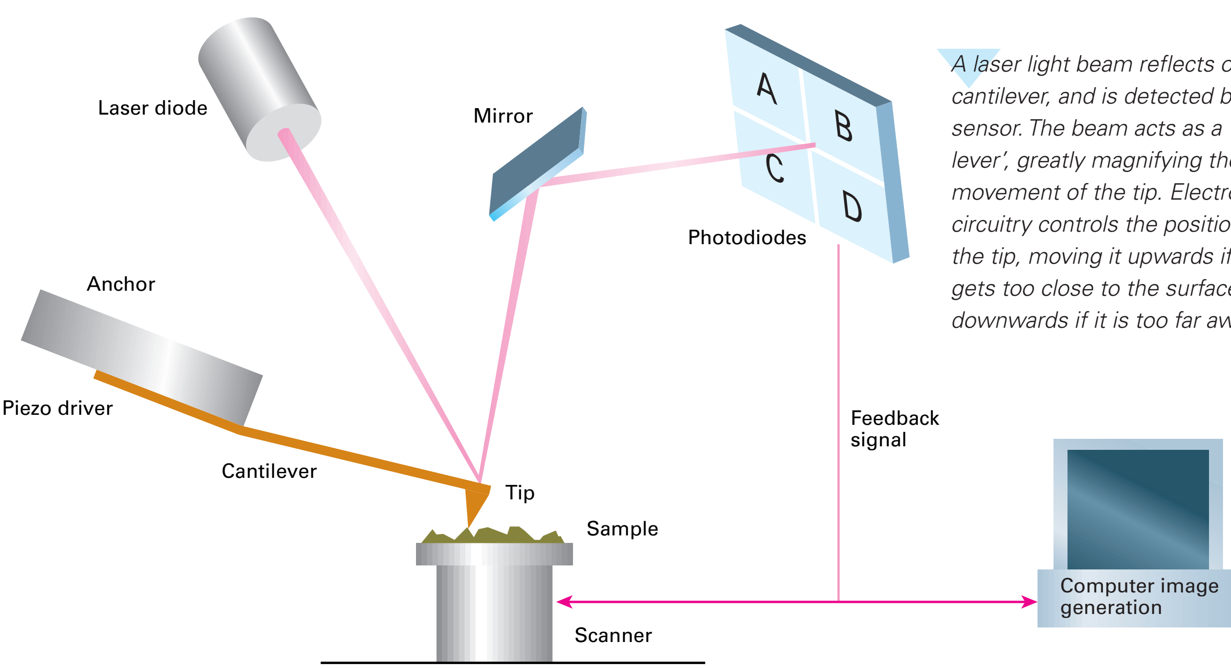


Tek Image/SPL



At the heart of the AFM is its scanning tip. Its sharp point is only a few atoms across. To study a surface, the tip is moved steadily across it, pressing down with a force of one billionth of a newton. The tip is mounted on a springy beam or cantilever. As the tip moves over the bumpy surface, the cantilever bends up and down

As the tip scans across the sample, a computer builds up an image of the surface



A laser light beam reflects off the cantilever, and is detected by a sensor. The beam acts as a 'light lever', greatly magnifying the movement of the tip. Electronic circuitry controls the position of the tip, moving it upwards if it gets too close to the surface and downwards if it is too far away