Catalyst

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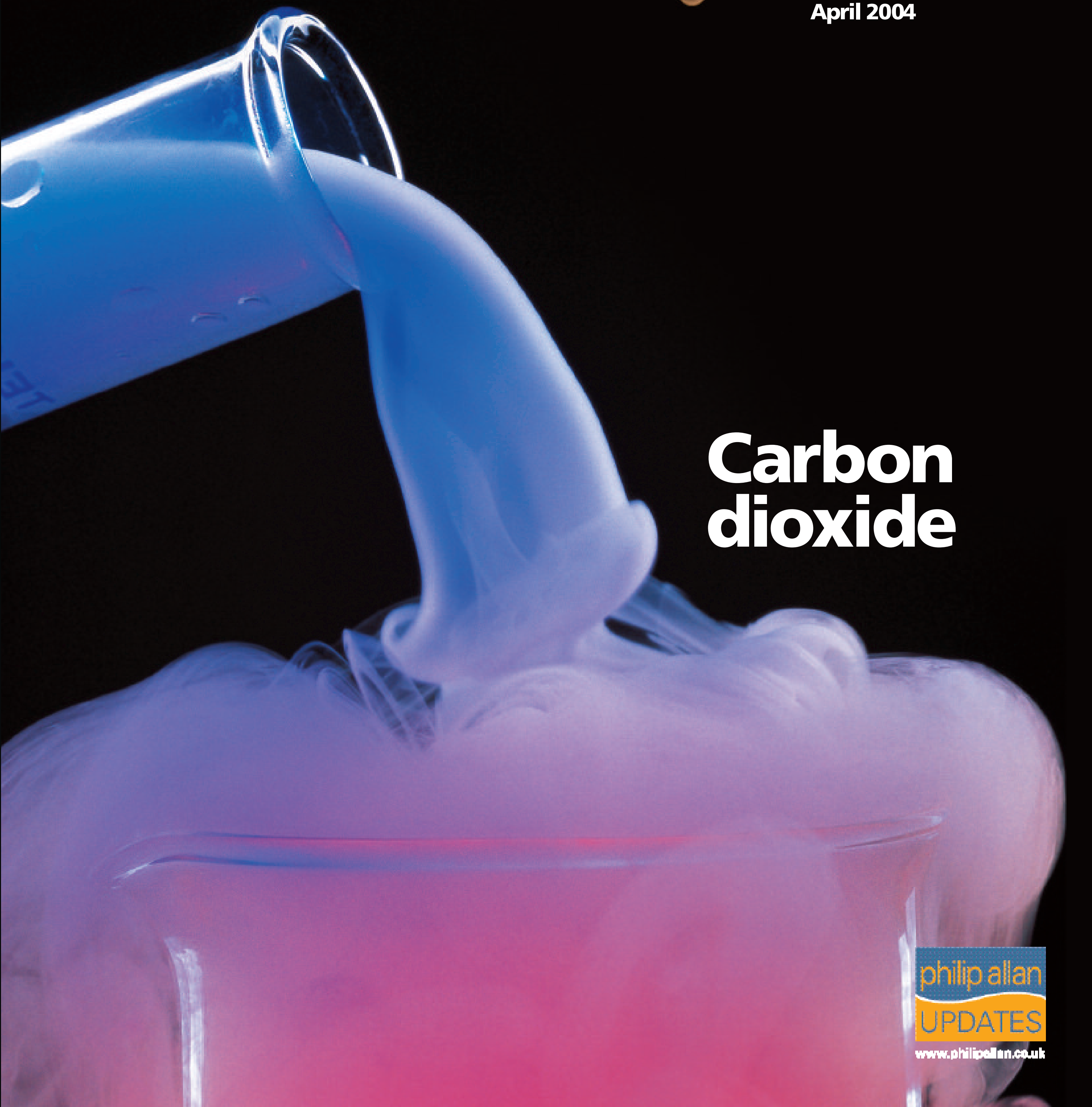

Carbon dioxide

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Catalyst

The front cover shows vapour from a test tube of dry ice, which is solid carbon dioxide (Matt Meadows/SPL).

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Editorial

What do you need to know?

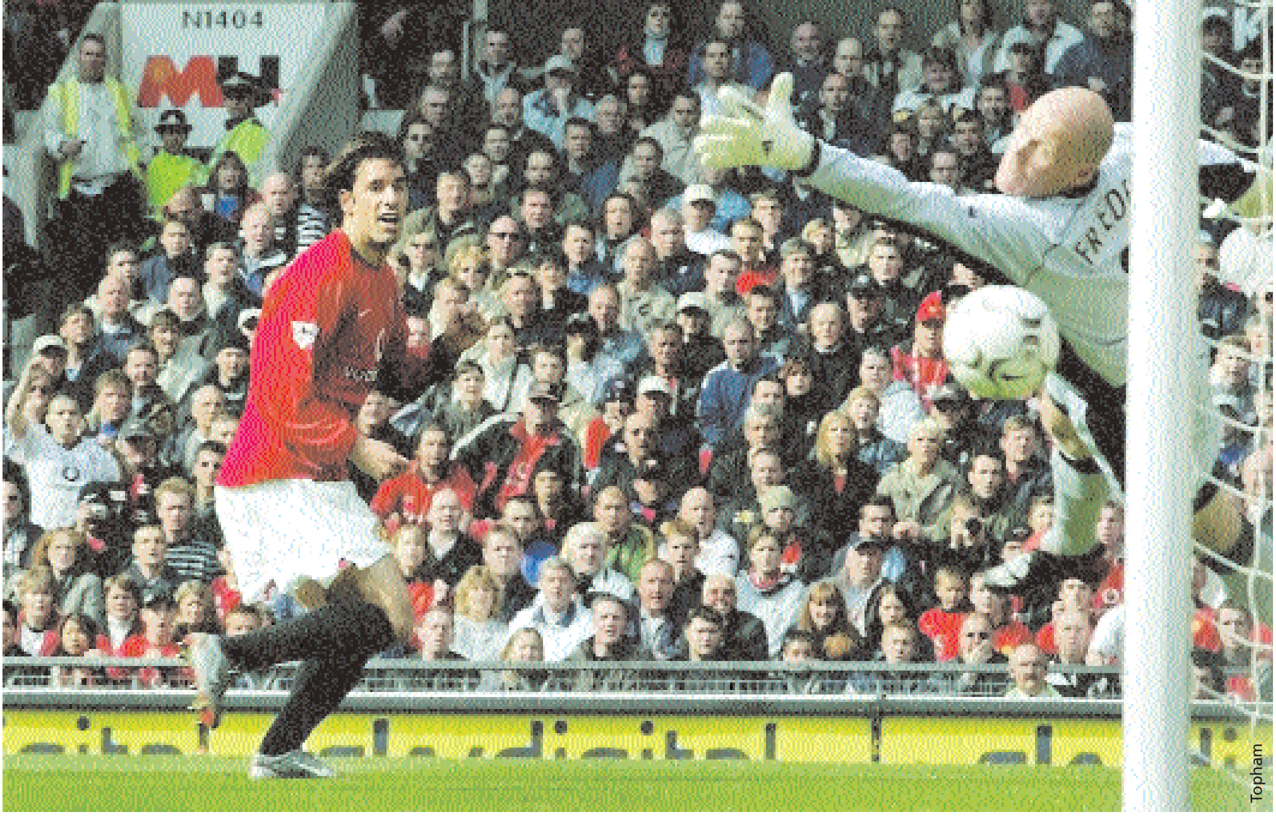
This issue of Catalyst is the last of the four for the school year. It marks the end of a volume. You are also coming up to the end of a school year. This will mean different things to different people. Some of you may be halfway through your GCSE course and looking forward to another year of science before taking your exams. Others of you will be coming to the end of your GCSE course and will have started on your revision. If this is the case, then do make full use of your Catalyst magazines along with your other revision materials, including those *GCSE Science Exam Revision Notes* sent to you with Catalyst in November.

Reading through the magazine is an interesting and informative way of acquiring a wide-ranging knowledge of many of the major topics of your course. If you are not sure exactly what your specification contains, then use Improve your Grade on pages 6–7 to find out. You can then use the GCSE key words at the start of each article to ensure that your revision covers all the different parts of the course. Keep a pencil and paper handy and make notes as you go along. This helps the facts to stay in your memory. Trying some of the puzzles in Catalyst will ensure that you have read the articles carefully, and provide an alternative method of revision.

Whatever stage you are at in your science course do make sure that you try to *enjoy* your science revision. This may sound odd, but you will do better in your exams in the long run if you adopt a positive approach.

With a new volume of Catalyst in preparation, the editors would be interested to hear from you. Tell us what you have liked in the magazine and what you would like to see more of. Address messages to the Catalyst team and send them to the publishers at the address opposite. We wish you success in all your scientific endeavours.

David Moore


Topham

JANE TAYLOR

GCSE key words
Neurone
Reflex
Synapse

***Left:** The striker's (Ruud van Nistelrooy) reactions were quicker than the goal-keeper's (Brad Friedel) in this Premiership goal*

Quick reactions

You take pride in your quick reactions in sports or when you are playing computer games, but how do these speedy responses happen? This article explains how the nervous system works, how nerve impulses pass around your body, and why these responses are so fast.

We are constantly monitoring the world around us. Our ancestors, like animals in the wild today, led a precarious existence, constantly on the look out for predators. The dangers in our lives may have changed, but we still depend on quick reactions.

Sensitivity — the ability to respond to stimulation — is a product of nervous system activity. The nervous system is a network of specialised nerve cells, or **neurones**, which coordinates responses to changes in our environment. Nerves are bundles of neurones that extend through the body. They are connected to the central nervous system, or CNS, which comprises the brain and spinal cord. Information about our environment passes from the sense organs to the CNS. Often, but not always, the brain coordinates and initiates any response.

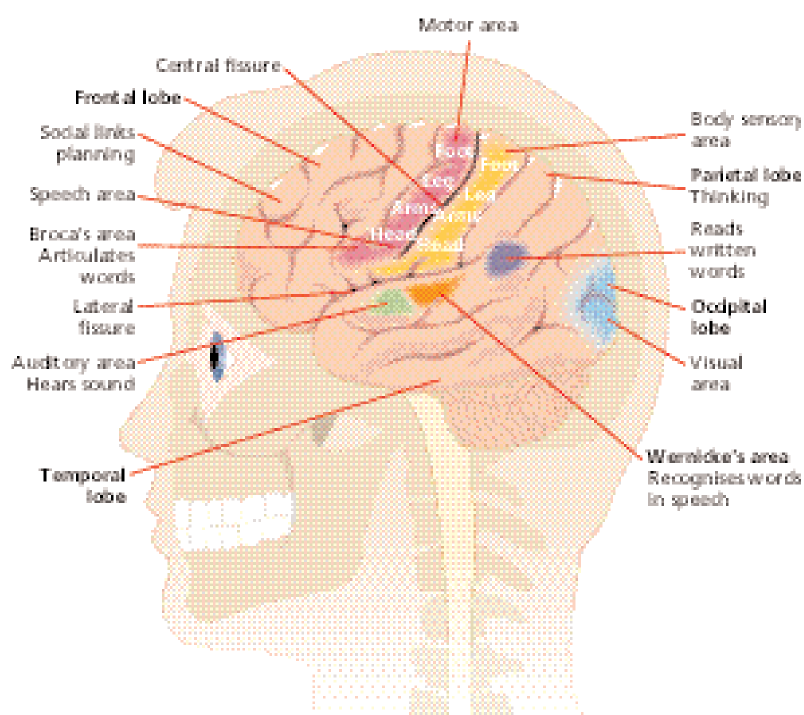


***Figure 1** The cerebral cortex — the largest part of the brain — regulates thinking and feeling. This diagram shows where different functions are located*

WHAT DO WE MONITOR?

We have **receptors** all over our bodies. These are sensory neurones that are specialised to respond to one particular stimulus by generating a nervous impulse which passes along the neurone.

We detect light intensity and, like other organisms that make use of fruits and flowers, we also detect colour using specialised rod and cone cells in the

A human brain contains about 10^{10} interconnecting neurones and about 10^{11} glial cells.

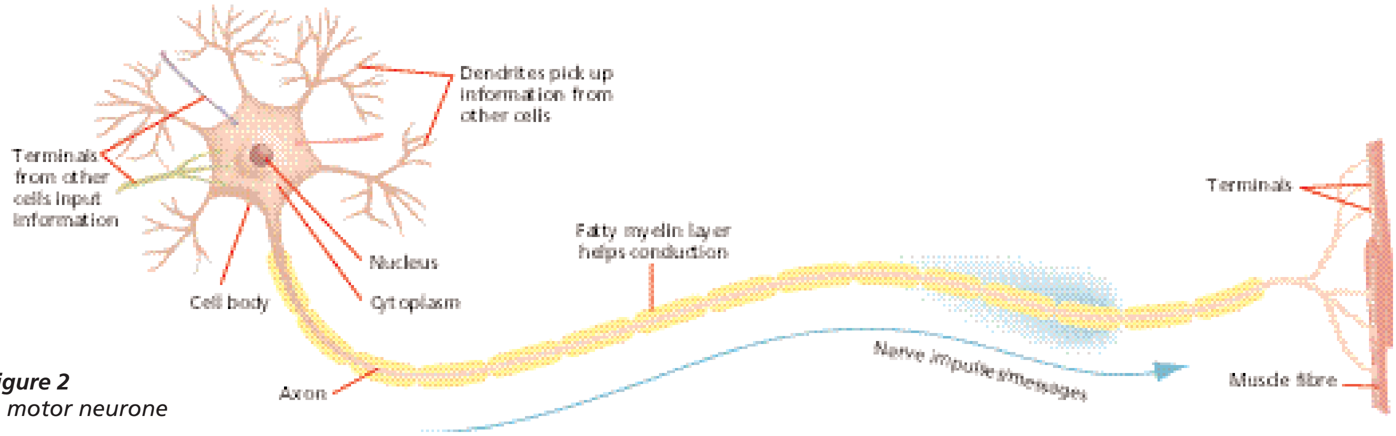


Figure 2
A motor neurone

retina. We detect gravity and sounds using specialised nerve endings in the inner ear. Separate areas of the brain interpret sounds as voices, noises and musical rhythms.

In the skin we have receptors that detect pressure and touch, pain, hot and cold objects, and warmth in our surroundings. These receptors are sensitive. If we touch two warm objects we can distinguish a temperature difference of a fraction of a degree. Receptors in the nose and on the tongue detect chemicals as smells and tastes. Though our sense of smell is not as sensitive as a dog's we can pick up some pungent odours at concentrations as low as one molecule in every 100 000.

As well as information about the outside world we have a constant stream of inputs about the state of our bodies — how much each muscle is contracted, feelings of hunger and thirst, and sensations of pain. Overlying these we have internally generated plans and intentions.

If the myelin layer around a neurone is damaged, as in multiple sclerosis, the impulse does not pass reliably.

An impulse is not like an electrical current. It involves sodium and potassium ions changing places through the axon membrane.

The brain's function is to receive all these inputs, interpret them and integrate them into a mental image of the state of our body and the world around us. Different areas within the brain process this information and initiate a response (Figure 1).

NEURONES

There are several kinds of neurone. **Sensory neurones** detect stimuli and pass an impulse to the central nervous system. **Motor neurones** extend from the CNS to our muscles. An impulse along these makes a muscle contract. Figure 2 shows the structure of a motor neurone. Many glands are controlled in the same way.

In the brain millions of **interneurones** make connections with each other. These carry out our thinking and planning as well as housing our memory and ability to gossip and ride a bike. The nervous system also has **glial cells** that help to support and maintain the highly specialised neurones.

Information passes along our personal information superhighway in the sequence

stimulus ⟶ receptor ⟶ sensory neurone ⟶ coordination ⟶ motor neurone ⟶ effector ⟶ response

e.g. bright light ⟶ retina ⟶ neurones in optic nerve ⟶ brain ⟶ motor nerve ⟶ circular iris muscle ⟶ contracts and narrows pupil

REFLEXES

Nerve impulses speed along neurones at up to 120 m/s so it takes only a fraction of a second for an

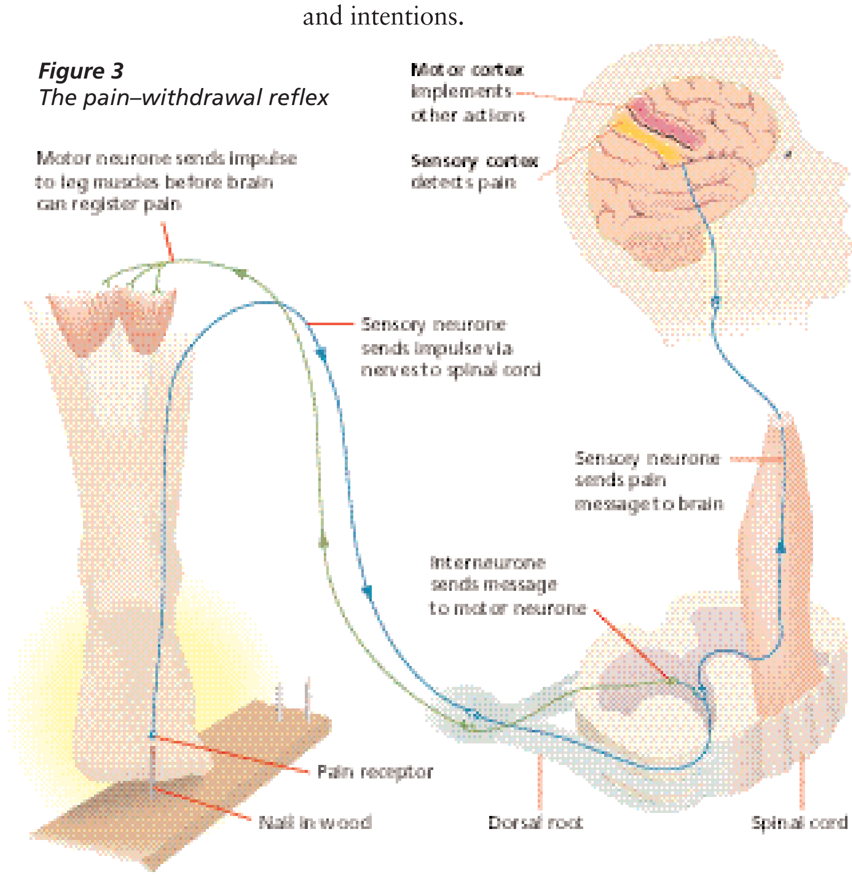


Figure 3
The pain–withdrawal reflex

BOX 1 FRANÇOIS MAGENDIE

François Magendie, a nineteenth-century French physiologist, discovered the role of the two roots of the spinal cord, shown in Figure 3. He made important discoveries about strychnine that led to its use in medicine as well as poisoning. Magendie is also known for his efforts to find out about the nutrients we need in our diet.

John Greim/SPL

Prozac is an anti-depressant that inhibits uptake of serotonin, a neuro-transmitter, and keeps it in synapses for longer

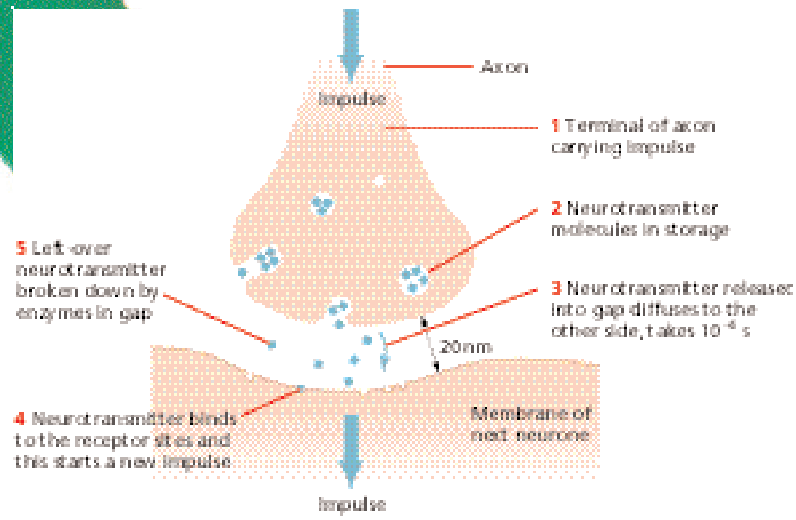


Figure 4 *A synapse. Each neurone makes neurotransmitter molecules. These are stored in small sacs at the end of the neurone. When an impulse reaches the end of the neurone the neurotransmitter molecules are emptied into the synapse. They diffuse across the gap and bind to receptors on the next neurone where they start an impulse. The neurotransmitter molecules are then either broken down or reabsorbed to clear the gap ready for the next impulse. Some painkillers bind to receptors in the postsynaptic membrane and so block the passage of pain impulses*

impulse to complete the circuit through the brain. Even so there are occasions when this is too slow. We have some fast protective **reflexes** that do not involve the thinking part of the brain directly. These are routed through the spine or other parts of the brain. They let us act first and think later.

The pathway in the example above involving the eye is really a reflex. It does not need thought to work. The withdrawal reflex shown in Figure 3 is a protective reaction that operates through the spinal cord. If you encounter a painful stimulus in, say, the skin of a finger, you quickly pull your hand away from the stimulus — and from danger. However, you know you have been hurt because information is also passed up the spinal cord to the brain. The brain coordinates other actions — pulling the shoulders back, bringing your head round towards the stimulus, focusing your eyes on the stimulus and making you yell 'ouch' while you consider the bigger picture of what has caused the pain.

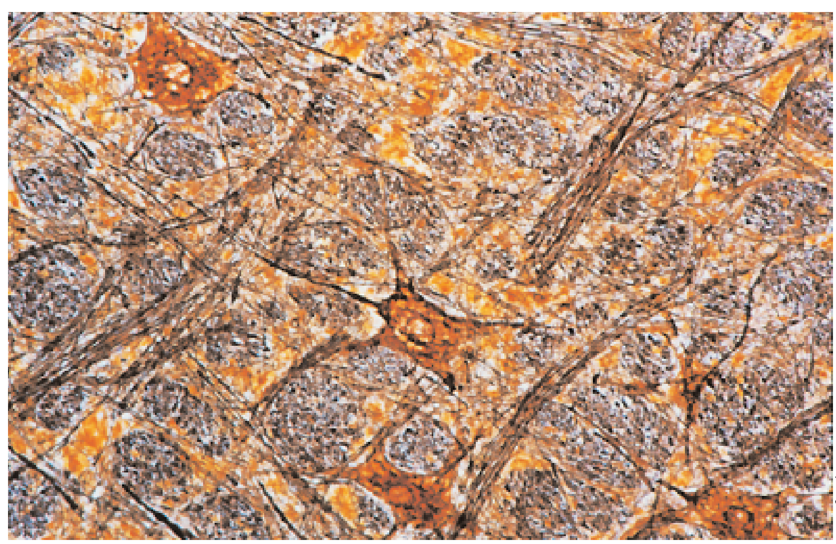
SYNAPSES

At the junction between two neurones there is a small gap called a **synapse**. A chemical called a **neurotransmitter** diffuses across the gap and triggers an impulse in the next neurone. You can see how this works in Figure 4.

Different pathways through the nervous system use different neurotransmitter molecules. The nerves serving the muscles we use to move around and those which slow our heart rate use acetylcholine. The nerves that calm us down after adrenalin has wound us up use noradrenalin. The neurones that smooth out the actions of our arm and leg muscles use dopamine. People with Parkinson's Disease lack dopamine. They cannot control the fine movements of their muscles, which may tremble and make it hard to balance, speak fluently or hold a cup of tea.

The nerve pathways in the brain that are linked to our moods use serotonin as a neurotransmitter. We know that one of the commonest mental disorders, depression, is linked to low levels of serotonin in the brain. Medicines that keep serotonin molecules in synapses for longer help to lift a low mood. Ecstasy makes neurones in the brain release large amounts of this neurotransmitter. This accounts for the warm emotional feelings it creates. However it depletes the stores of serotonin and, because it takes a while for normal stores to build up again, users feel low afterwards. Research is being done to see if the repeated depletion of this important neurotransmitter may have permanent effects — perhaps the prospect of longer-term depression for Ecstasy users.

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

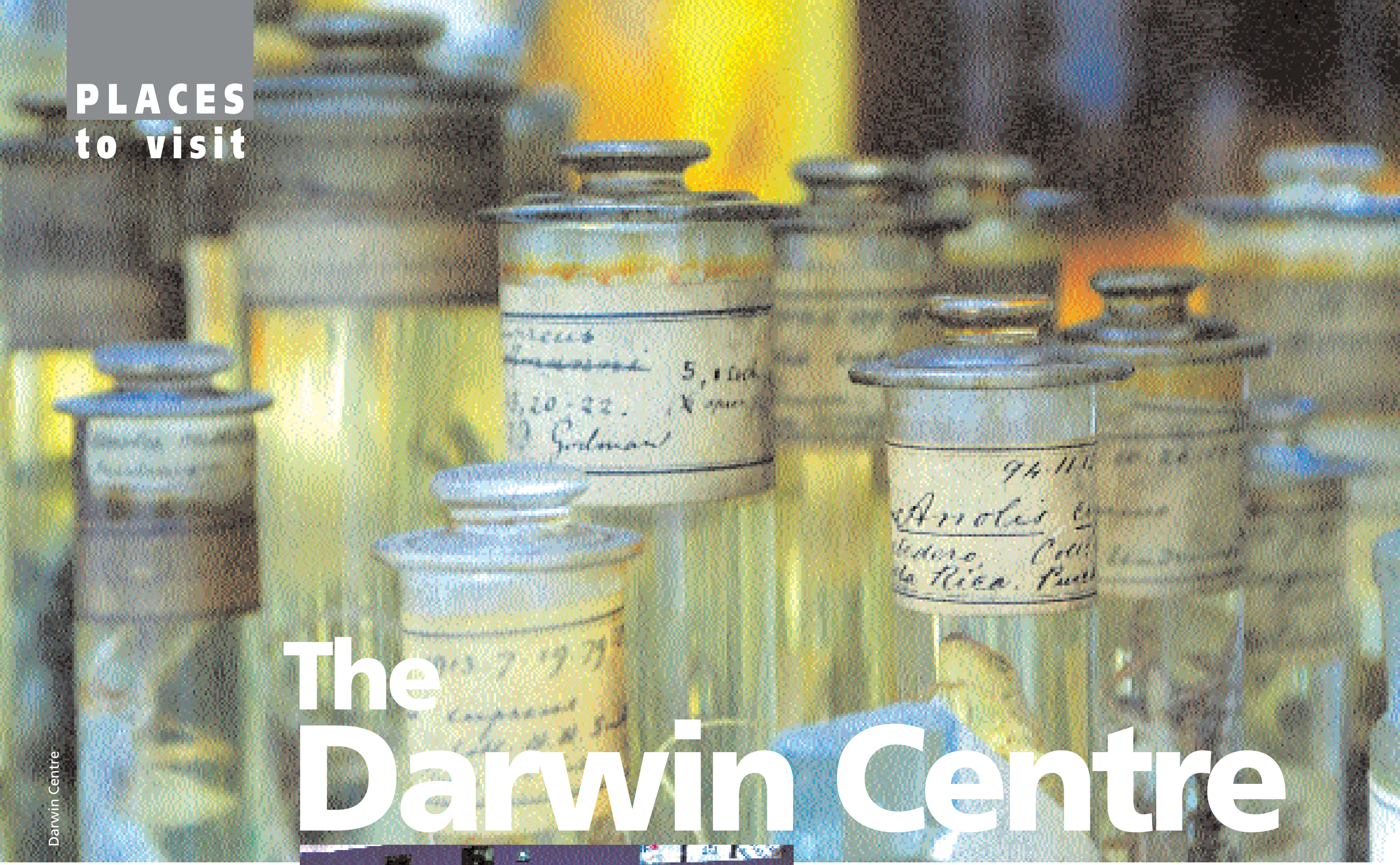


Manfred Kage/SPL

Above: *Neurones in the brain*

You will learn about other effects of drugs such as Ecstasy in PSHE.

In Alzheimer's syndrome the normal mechanism involved in releasing neurotransmitter stays open, flooding the neurone with calcium ions and killing it.



Darwin Centre

The Darwin Centre Phase One

Darwin Centre

***Above:** The collection includes 22 million 'pickled' specimens*

***Right:** Darwin Centre Live allows you to learn more about science at work*

Many of you may have had the chance to visit the Natural History Museum in London. Sue Hordijenko describes the work of the museum, and in particular the new Darwin Centre, where she is Education Manager.

Did you know that more than 350 scientists work at London's Natural History Museum? They research and care for a collection of more than 70 million specimens ranging in size and scale from a grain of pollen to a 70-tonne whale skeleton. Museum scientists are working to further our knowledge of the natural world and help tackle some of the big problems that face our planet today, such as pollution and climate change.

In September 2002 the Natural History Museum opened the first phase of its Darwin Centre. This is the biggest project the museum has undertaken since it opened in 1881. The Darwin Centre is home to 22 million zoological specimens preserved or 'pickled' in spirit. This vast and important index of the natural world includes 200 000 reptiles and amphibians, 2 million fish, 2 million molluscs and 3 million crustaceans.

The collection spans three centuries of scientific discovery and includes specimens collected by Captain Cook in Australia on his 1768 voyage on the *Endeavour* and by Charles Darwin during his *Beagle* expedition. The Darwin Centre also provides state-of-the-art laboratories and research facilities for nearly 100 scientists.

DARWIN CENTRE LIVE

Darwin Centre Live is a varied daily programme of free events at which visitors can meet museum scientists to find out more about their work and the critical role they play worldwide in taxonomy and systematics (see Boxes 1 and 2). From research areas as diverse as life on Mars and the parasites that live on lions and hyenas, Darwin Centre Live allows you to learn more about science at work.

You can discover what is involved in activities such as fieldwork and identification and you don't even need to be in the museum to join in! State-of-the art video-conferencing means you can participate in our

Darwin Centre

BOX 1 WHAT IS TAXONOMY?

Taxonomy is the science of naming and classifying living and fossil organisms. A classification system provides a way of organising knowledge about the natural world. It helps to make sense of the enormous diversity of life.

live webcasts from home or school. You can e-mail us your questions or opinions and we will do our best to respond to you live during the event.

We can also link up to locations all over the world. We have joined scientists doing fieldwork in remote locations such as the rainforests of Belize and chatted to rhino experts at the San Diego zoo. We record as many Darwin Centre Live events as possible and archive them on our website **http://www.nhm.ac.uk/darwincentre/live** so you can have free access to them at any time.

Preserving a flying fish specimen

Darwin Centre

BOX 2 WHAT IS SYSTEMATICS?

Systematic biology includes taxonomy. It is the science in which we discover, describe, name and classify living and fossil organisms, and work out their evolutionary relationships.

'Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological science is a meaningless jumble,' according to Sir Robert May, President of the Royal Society.

DARWIN CENTRE EXPLORE

Darwin Centre Explore takes you on a guided tour behind the scenes of the centre. See the rich array of the museum's collections spread out over seven floors of the building. On your tour you can visit the 'tank room', in the bowels of the building. This houses 51 giant stainless steel tanks, containing 17 000 litres of alcohol, specially designed to preserve the museum's largest specimens including sharks, komodo dragons, giant sting rays and loggerhead turtles.

Explore tours last 30 minutes and take place every day. Places are free, and you can book on arrival.

DARWIN CENTRE PHASE TWO

Planning for Phase Two of the Darwin Centre is already underway. Twice the size of Phase One, it will house millions of insect and plant specimens, as well as the scientists who research them. Phase Two is scheduled to open to the public in 2008.

It took a team of 20 curators and ten trolley pushers 7 months to move 22 million specimens into the Darwin Centre. During this time it is estimated they walked over 1000 km, filled 25 km of shelving and moved 450 000 glass jars.

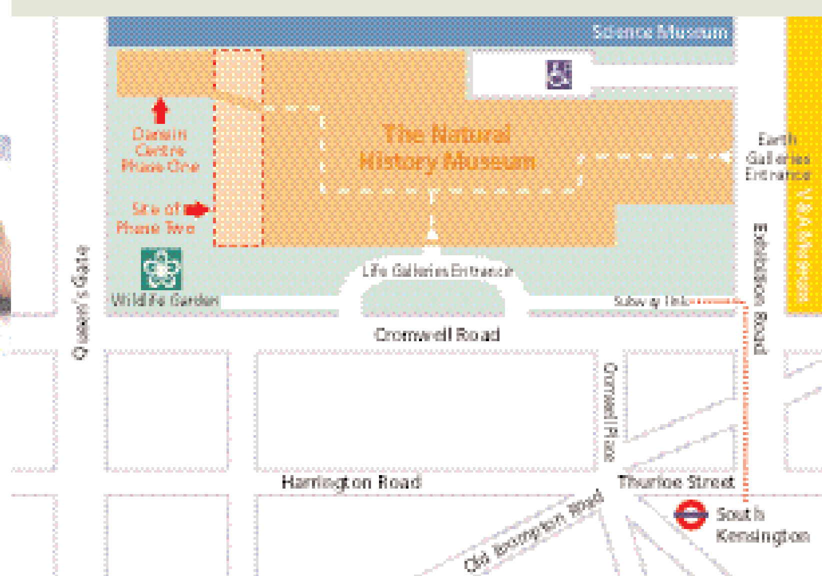
BOX 3 VISITING INFORMATION

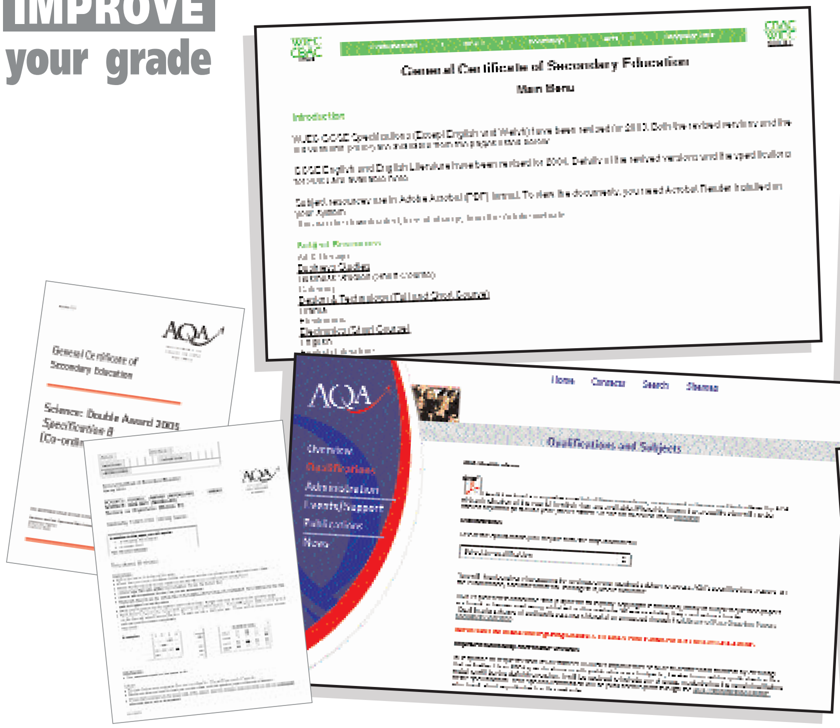
Admission is free, including tours and live events.

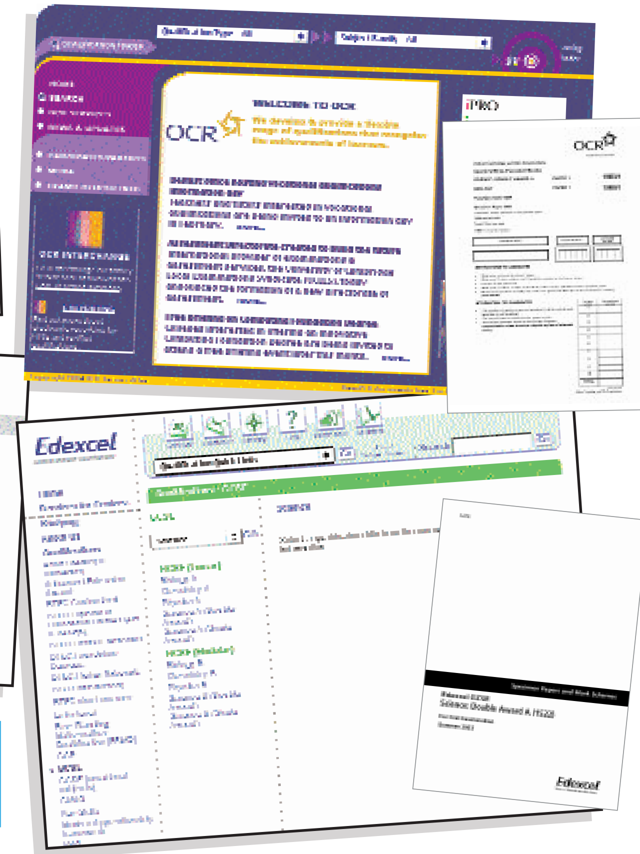
Opening hours: Monday–Saturday 10.00–17.50, Sunday 11.00–17.50.

Entrance via the main museum (see map). The Natural History Museum, Cromwell Road, London, SW7 5BD.

http://www.nhm.ac.uk/darwincentre







Exam board websites

Your teachers will use all sorts of strategies to support you on the way to success at GCSE. They will set you past examination questions and probably provide you with copies of relevant sections of your examination board's specification. The boards have websites which can be well worth visiting. What will you find there to help you achieve success in your GCSE science examinations?

Make sure you know the *precise* title of your course. Many of you might be doing a course you call 'Suffolk Science'. Its exact title is Science Syllabus B (Suffolk) Double Award.

Readers following Scottish syllabuses should look at http://www.sqa.org.uk; Northern Ireland's specifications are at http://www.ccea.org.uk

You should know which examination board your school will be entering you for — if you don't know, ask! Be clear about whether yours is a modular course or a course with the examinations at the end of year 11. Are you doing Double Award Science or Single Award Science? Before visiting the website, make sure that you have the correct title and number for the science course you are following.

Table 1 gives the web addresses for the English and Welsh GCSE examination boards, and tells you how to get to their science sections. What is there on an exam board's website that can help you to improve your grade? First, there is the full **specification** for the course. There are also likely to be some **assessment materials** — specimen or actual examination papers — together with mark schemes. Explore the website for your board and find out what you are going to be examined on.

SPECIFICATIONS

Specifications — or syllabuses as they were once known — used to stand for many years and were relatively short documents. They are now much longer and provide a lot of detail about what you are expected to know, understand and be able to do.

The information in your specification is incredibly useful. You have all sorts of things to learn about and understand in science but a good rule of thumb is to check that you understand *and can remember* what is listed in the specification for your particular course. There can be an amazingly close match between what is in the specifications and the words used in the mark schemes linked with examination papers.

Your teacher may well provide you with a copy of the appropriate section of the specification when you are working on it. If this does not happen, log on to the website for your particular examination board (web addresses in Table 1) and follow the steps which usually allow you to download the specification as a pdf file. You need to be clear in your mind about when you are taking the examination, because this affects which specification applies to you.

When you open the specification (you will need Adobe Acrobat Reader for this, but you can download it free from the internet) do not be distracted by all the information about administrative matters — head for the sections describing the content of the course. This is where you will find the meat of what you need to know, understand and do.

Board	Specification	Sample or specimen papers and mark schemes	Actual past papers and mark schemes
AQA	**http://www.aqa.org.uk/qual/index.html** Click on *Select by qualification* and choose *GCSE* — then select your particular course. Download the pdf file for the specification for your year of final examination — the end of year 11. When you open this scroll to subject content. It may be best to copy and paste just this part into your document	These were available in printed form but are not on the AQA website	These are available only for modular courses at present — go to: **http://www.aqa.org.uk/admin/qp-ms_gcse.html** AQA plans to publish Science: Coordinated examination papers and mark schemes on the internet, after a 6-month delay. The papers from summer 2003 should be available when you read this, though you will have met them already probably, as part of your mock examinations
Edexcel	**http://www.edexcel.org.uk/qualifications/QualificationSubject.aspx?id=50190** This lists all GCSE science courses — click on yours. Then download the specification pdf file (see AQA)	Use the address located by following the steps on the left for your particular course	Not available
OCR	**http://www.ocr.org.uk** Click on *GCSE* in *Qualification type* and *Sciences* in *Subject family*, then click on *Go*. Scroll to the bottom of the page for materials *but* beware — OCR publishes the original specification, rather than the current one, but lists all changes. The actual subject content has probably not changed much	Use the address located by following the steps on the left for your particular course	Not available, although website is designed to allow this
WJEC	**http://www.wjec.co.uk/gcse.html** provides access to specifications for all courses — click on the appropriate science course	Not available	Not available

Table 1 *Web addresses for the English and Welsh examination boards and useful things you can access on them*

ASSESSMENT MATERIALS

Practising with past examination papers is an important part of ensuring that you are getting to grips with a subject. Your teachers will offer you opportunities to go through your paces with past examination questions. Schools build up or buy copies of past papers. When specifications change and examination papers change with them, teachers use their experience to set you appropriate questions from earlier versions of the examination. Past examination questions for current science course specifications are starting to be publicly available on the internet, so what can you gain access to yourself?

Thus far only AQA has published past examination papers and mark schemes on its website. It will be interesting to see whether the other examination boards follow suit. To find out what AQA has to offer, follow these steps:

Log on to **http://www.aqa.org.uk/qual/index.html** and click on *Select by qualification*. Select *GCSE*. Then select the particular science course that you are following and click on *Assessment material*. If you do this for AQA Science: Co-ordinated or the Separate Sciences courses you do not (at the time this was written) reach past examination papers and mark schemes. AQA is publishing them after about a 6-month delay from the first examination in summer 2003. However, a number of modular science examinations (e.g. Science: Double Award (Modular)) have been sat already. You will find all modular science examination papers and mark schemes (as well as those some for other subjects) at **http://www.aqa.org.uk/admin/qp-ms_gcse.html**

The two other English examination boards are apparently not planning to follow AQA in publishing examination papers on the web but they do provide specimen papers for each examination. It is highly likely that you will have met these questions in school already but website addresses that lead you to them are provided in Table 1. The OCR website does seem to have a built-in facility to publish past papers — keep an eye on it!

Nigel Collins teaches biology and is an editor of CATALYST.

BOX 1 CAUTION!

Do not imagine that learning the specification parrot-fashion will lead to success — you need to develop understanding and there are other parts to your science course too, not least coursework.

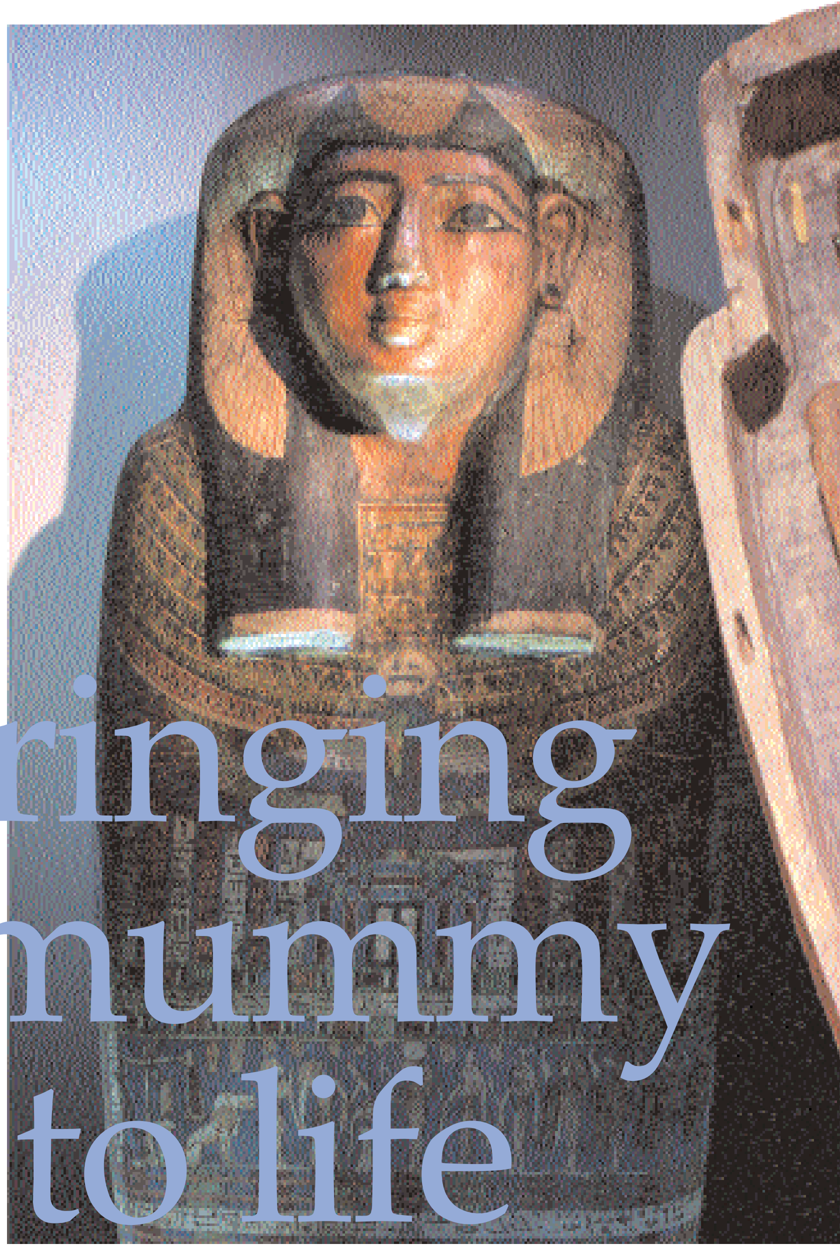
By all means visit the websites of other examination boards and look at past papers — but remember that each examination board has its own styles of questioning and there is slight variation in content between them.

You can also buy past papers and mark schemes from examination boards.

Exam board websites also offer help and guidance on *coursework* and information about scientific *ideas and evidence*.

LOUISE SUTHERLAND

Bringing a mummy to life



Right: *The outer sarcophagus*

Asru was a temple singer over 2000 years ago in ancient Egypt. She was preserved as a mummy, and now lies snug inside her double coffin in The Manchester Museum's Egyptology section. Thanks to developments in medical science, researchers in Manchester are revealing the secrets of her life and piecing together the diseases she suffered from.

GCSE key words
X-ray
Tissue
Microscope

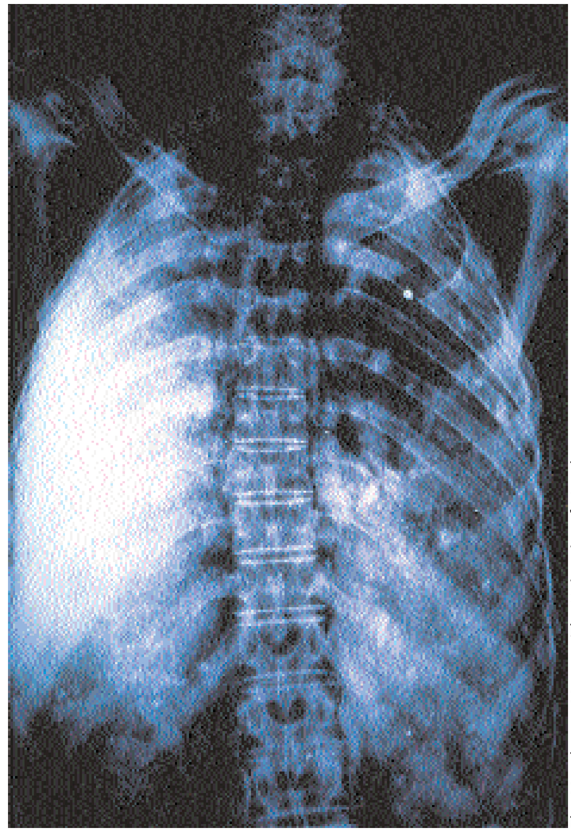
Mummy studies are nothing new in Manchester. One of the first scientific investigations of mummies was carried out by Dr Margaret Murray in 1907. Before this mummies had been treated as curiosities and unravelled with little care. Dr Murray gathered together many scientists for her investigation — experts in anatomy, chemistry, textiles and of course Egyptology.

Seventy years later a similar project was devised by the Keeper of Egyptology, Professor Rosalie David. The project aims remained the same — to use the most modern of scientific techniques to investigate one of the mummies in the museum collection. Professor David put together a team of specialists to create an interdisciplinary team that worked towards two main aims:

- To discover as much information as possible about religious or funerary customs, living conditions, physical and dental health and the actual process of mummification.

The hieroglyphs on Asru's coffin read, 'Asru, Singer of Amun. You are in Temple of Karnak'.

The Manchester Museum/The University of Manchester



The Manchester Museum/The University of Manchester

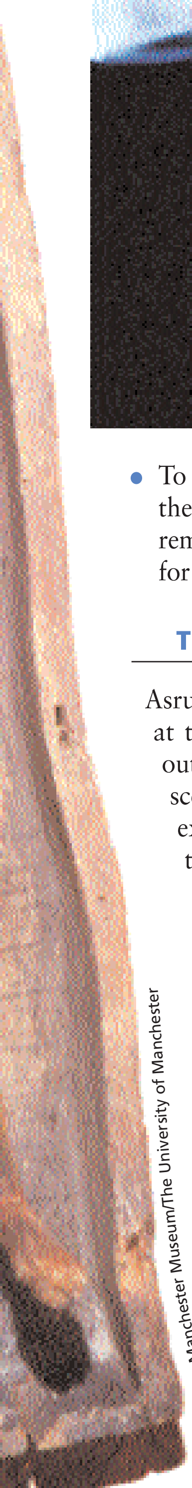
Left: *X-rays of Asru's skull and chest*

- To establish a methodology — a way of using these techniques for the study of human remains which other institutions could adopt for their own investigations.

THE ART OF MUMMIFICATION

Asru was already unwrapped when she arrived at the museum in the 1800s. Her inner and outer coffins are works of art, painted with scenes and inscriptions. The mummy itself is exceptionally well preserved and dates from the XXV Dynasty of Egyptian chronology (*c.* 780–656 BCE). Asru has fine facial features, with her arms outstretched and extended over her thighs. A package of mummified viscera (her internal organs) was placed upon her thighs.

Mummification is a complicated procedure. New information is constantly being uncovered as no two mummies were treated exactly the same. Unusually, the Egyptians seem to have kept no written records or instruction manuals, which makes us think that this was a secretive profession. The brain was removed through the nasal passages in the skull. All the internal organs except the heart were extracted through an incision, and dried using a salt mixture before being placed into Canopic jars. The body was dried using the same salt mixture, then washed and anointed with oils and spices. Finally the body cavity was packed and bandaged with linen and placed in the coffin for burial.



The Manchester Museum/The University of Manchester

Left: *Asru inside the inner coffin*

INVESTIGATING ASRU

The Mummy Team in Manchester has used a variety of techniques, such as X-rays, CT scans, endoscopy, tissue biopsy, histology, DNA studies and chemical analysis to find out about the quality of life Asru may have had in Pharaonic Egypt.

X-rays

Asru's X-rays show that her teeth were worn down, probably from eating food contaminated with sand and that she lost some teeth after her death. She seems to have had arthritis in her arms. Her legs show signs of arrested development, perhaps as the result of a poor diet at times during her childhood. We can also see that her kidneys were removed. Some of the vertebral discs in her spine are damaged. A skull can provide other information, such as the gender of its owner and his or her dental health. From all this information we can conclude that Asru was an elderly female who had calcification — hardening — of her main arteries, as well as slipped discs and arthritis.

A polystyrene copy of Asru's skull was made using information from X-rays of her head. Specialist

BCE = before common era.

Canopic jars were urns with lids in the form of animal heads of the gods. They were used to hold the internal organs of a mummy. The stomach, intestines, lungs and liver were placed in separate jars. Egyptians regarded the heart as the seat of learning and left it in the body cavity.

In endoscopy a narrow tube is pushed through a small incision in the body cavity, a joint, or along the gut. Tiny television cameras or surgical tools can be moved through the tube to allow internal examination, sampling or even microsurgery.

Above: Asru undergoing endoscopy

Professor Rosalie David with Asru

medical artists were able to use this skull to reconstruct how Asru's face might have looked before she died. The size and shape of your skull determine your facial features and this is one of the principles behind facial reconstruction, as seen in television history programmes such as *Meet the Ancestors*.

Histology is the study of tissues. **Cytology** is the study of cells.

Tissue biopsy

Sectioning and staining pieces of tissue allows scientists to see the different tissue types that make up the organs of the body. Tissues from a mummy, unlike those from a living person, are dry, hard and brittle and this makes them difficult to cut. Scientists get around this by rehydrating the tissue, soaking it in a saline solution before embedding it in wax and then slicing it into very thin sections that will transmit light. The thin slices are stained with coloured dye to make the cellular structure visible under a microscope.

Asru's tissues tell us that she was infested with parasitic worms. She had a worm infection in both the lining and the muscular wall of the intestine. There is also evidence that she had a cyst in her lungs caused by a tapeworm. This would have resulted in chest pains and breathlessness. Asru also had schistosomiasis, a disease caused by yet another worm (see Box 1).

BOX 1 SCHISTOSOMIASIS

This water-borne parasite affects millions of people today in the developing world. The eggs of the parasite hatch inside the bodies of water snails and release larvae into the water. The larvae enter the human body through hair follicles and immediately become worms. The worms move through the body and enter the liver, where they breed and lay eggs. If enough eggs hatch the sufferer develops internal bleeding. The cycle continues when the parasite re-enters the water via sewage. Researchers are still investigating schistosomiasis; by studying its ancient patterns they hope to find ways of reducing the infections suffered today.

BOX 2 FURTHER INFORMATION

Find out more about research on mummies, as well as what else can be seen at The Manchester Museum at **http://www.museum.man.ac.uk/home/index.htm**

Log on to **http://www.pbs.org/wnet/pharaohs** and hit *Secrets and Science*.

There are video clips of CT scans of mummies at **http://www.gustavianum.uu.se/ums/**

Borrow *Conversations with Mummies: New Light on the Ancient Egyptians*, by Rosalie David and Rick Archibold, from the library. This richly illustrated book shows how modern biomedical technology has been used to explore the lives of ancient people from every walk of life — from pharaohs to labourers.

LIFE AND DEATH

It is hard to say whether her heavy load of parasitic worms was responsible for Asru's death, but there is no doubt that it would have been uncomfortable and debilitating. The blood loss caused by the infestations might have made Asru anaemic, and her intestine may sometimes have been severely inflamed, causing pain and diarrhoea. This infection could have spread to other parts of her body resulting in her death.

This is just speculation — despite all we know about Asru and her life, we do not know why she died. She obviously had a good quality of life as a temple singer and she would have had access to medical treatment and good food. Her hands and feet show little wear, which tells us that she did not have to do much manual labour.

Asru's body tells us the story of her life, but we should also remember that once she was like us, living and breathing, with thoughts and emotions. Her help in the study of ancient diseases may one day prove invaluable.

***Louise Sutherland** works at The Manchester Museum. She studied anatomy for her first degree. She then moved on to a master's degree in forensic anthropology and is now working on her PhD. She was a Catalyst reader at school — our first reader to graduate to author.*

DAVID MOORE

Carbon dioxide

In recent issues of CATALYST *we have seen how carbon dioxide can be used as a solvent in industry, or as a regulator of blood pH. This article looks at some other uses of carbon dioxide and considers its importance in global warming.*

Left: *Fizzy drinks are 'carbonated' with carbon dioxide*

GCSE key words
- Atmosphere
- Global warming
- Respiration
- Fermentation

Carbon dioxide has always been part of the Earth's atmosphere. It was spewed from volcanoes when the Earth was formed. Today the atmosphere contains only about 0.04% carbon dioxide. This is kept fairly constant by the carbon cycle (Figure 1).

Carbon dioxide is removed from the atmosphere by photosynthesis, by dissolving in oceans and by the locking away of carbon in fossil fuels. It is released into the atmosphere in the processes of respiration, fermentation and combustion of organic compounds. Fermentation occurs when yeast, a fungus, uses sugar as an energy source, breaking the sugar down into ethanol and carbon dioxide:

glucose ⟶ ethanol + carbon dioxide

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

Bread-making also involves yeast. In this case the bubbles of carbon dioxide gas in the dough make it rise. The heat of the oven kills the yeast and drives off the ethanol.

THE GREENHOUSE EFFECT AND GLOBAL WARMING

It is important to understand that the greenhouse effect is a natural part of the operation of the Earth's atmosphere. Without it the average temperature over the surface of the Earth would be about –15°C rather than the +15°C that it is now.

Radiation from the Sun reaches the Earth in the form of visible, ultraviolet and infrared rays. Most of this radiation passes through the atmosphere, and is absorbed or reflected by the Earth's surface. The Earth is warmed by this radiation and, because it is warm, it emits infrared radiation. This low-energy, long-wavelength radiation tends to be absorbed by carbon dioxide in the atmosphere. The carbon dioxide molecules thus gain energy, and so the molecules vibrate more. The carbon dioxide molecules

In CATALYST **Vol. 14, No. 3 we discussed how carbon dioxide regulates blood pH, and in Vol. 14, No. 1 we looked at how carbon dioxide could be used as a solvent for large organic molecules.**

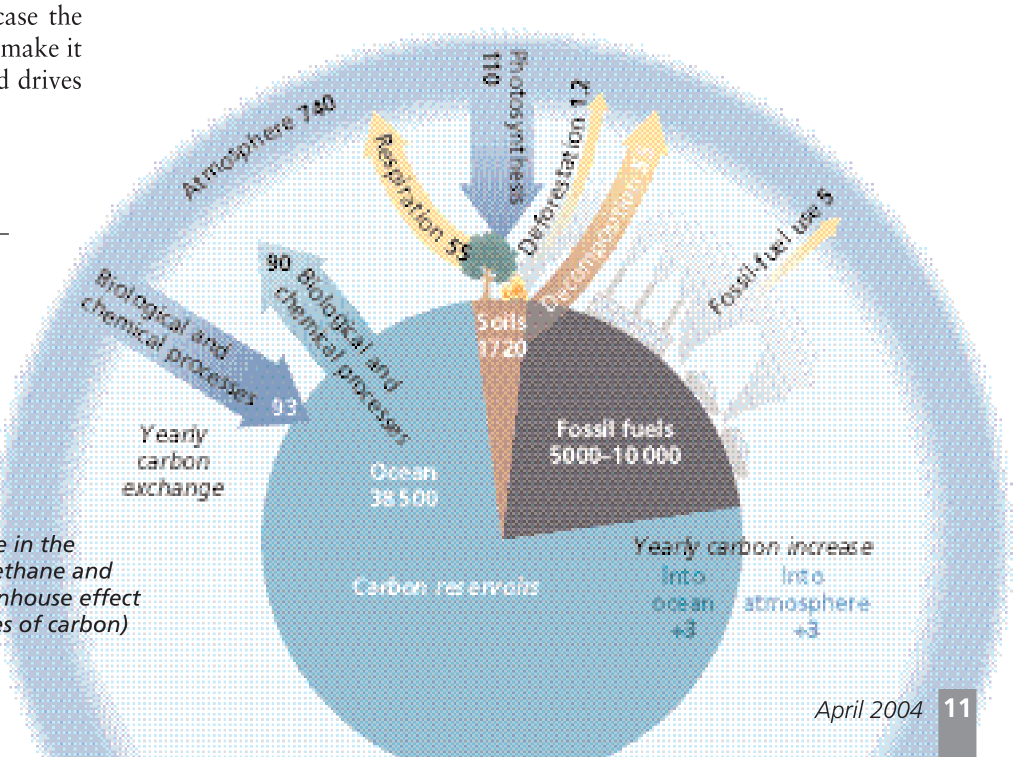
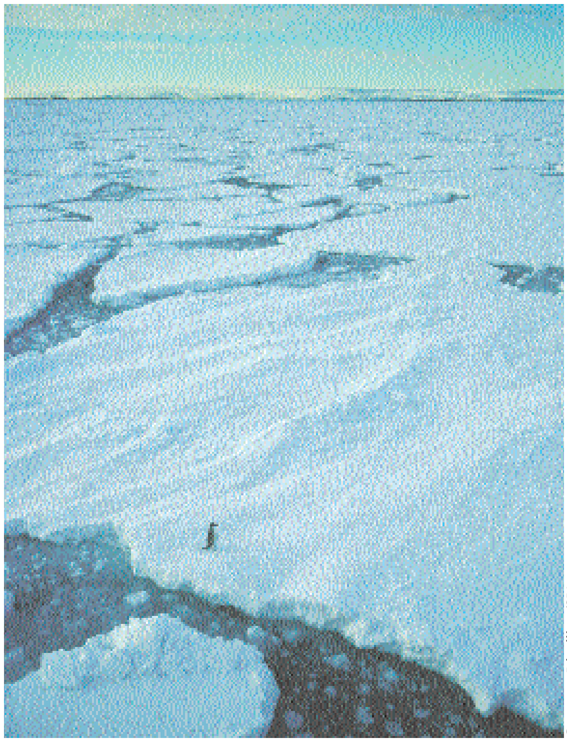


Figure 1 *The carbon cycle. The carbon dioxide in the atmosphere (together with water vapour, methane and some other gases) is responsible for the greenhouse effect and global warming. (Figures in billion tonnes of carbon)*

Right: *Antarctic pack ice could melt if global temperatures increase*



Gregory Dimijian/SPL

Carbon dioxide dissolved in water forms a weak acid called carbonic acid.

- **Can you write the equation for the reaction of calcium carbonate with hydrochloric acid?**

- **Find out the freezing point of carbon dioxide.**

re-radiate infrared radiation in all directions. The effect is that the Earth's infrared radiation finds it hard to escape, and warms up the atmosphere (Figure 2).

The burning of fossil fuels in power stations and vehicles is gradually increasing the amount of carbon dioxide in the atmosphere (see Try This, p.13). This is having an effect on its temperature. The consequences could be dire if levels of carbon dioxide get out of hand. It is probable that sea levels will rise because the increased temperature will cause the water in the oceans to expand in volume and will melt land and sea ice. There may be more clouds in the sky as the oceans warm up, which will also trap more heat in the atmosphere, changing the climate.

There are problems involved in modelling this process. No-one knows just how much carbon dioxide the oceans can hold, or how much they can remove from the atmosphere. It is an example of a reversible reaction:

$$CO_2(g) + H_2O(l) \longleftrightarrow H_2CO_3(aq)$$

An increase in global temperature will push the equilibrium to the left. More carbon dioxide will be released because gases become less soluble in water as temperature increases.

HOW IS CARBON DIOXIDE MADE?

Carbon dioxide can be made in a lab by reacting an acid with a carbonate, usually calcium carbonate in the form of chalk or marble.

Making carbon dioxide like this is not feasible on an industrial scale. Most carbon dioxide used in industry is a by-product of the manufacture of ammonia (see CATALYST Vol. 14, No. 3). It is also a by-product from the manufacture of quicklime (calcium oxide). Calcium carbonate is heated to make quicklime and carbon dioxide is given off.

WHAT DO WE USE IT FOR?

Carbon dioxide is used in many commercial products, most notably drinks. It is pumped into soft drinks, beer and water at about 7 atmospheres pressure to make them fizzy, or **carbonated**. When the bottle top is released the gas, which was under pressure and also partially dissolved, comes out of solution, forming bubbles.

The gas is also used in food packaging. As carbon dioxide does not react with foodstuffs it is used to modify the atmosphere around pre-packed foods to reduce oxidation and stop the food spoiling.

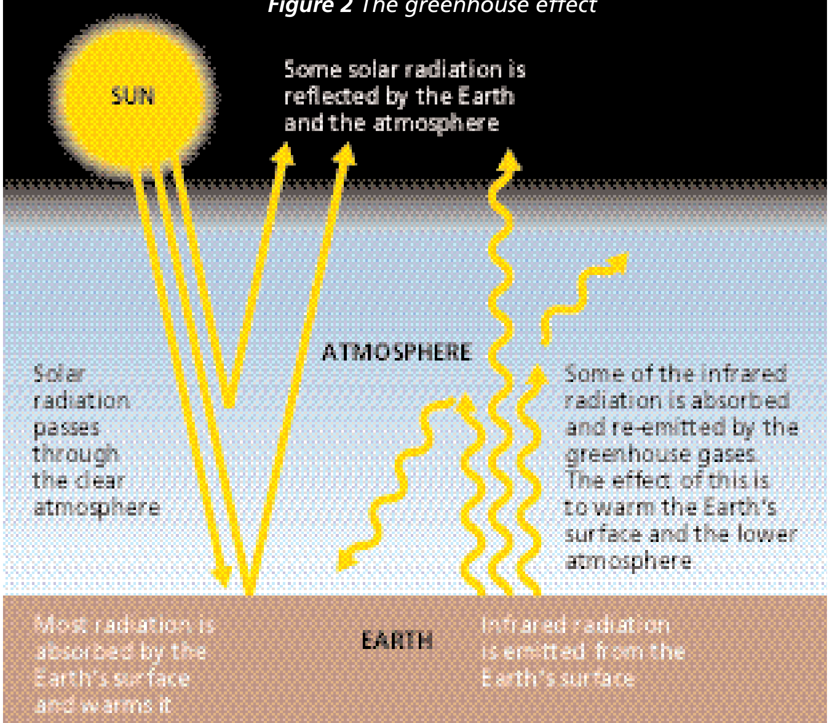
Some fire extinguishers contain carbon dioxide. It is useful on electrical fires as it does not conduct electricity. The dense gas smothers the burning object, shutting out oxygen and extinguishing the fire.

Carbon dioxide gas is also used as a coolant in nuclear reactors. The gas is blown in through the core of the reactor to transfer heat away. This prevents the reactor (which operates at about 600ºC) from catching fire, and the heat is used to generate electricity.

Some carbon dioxide is combined with ammonia to make urea ($CO(NH_2)_2$), a water-soluble nitrogenous fertiliser.

Carbon dioxide is easily solidified — in this form it is known as dry ice. Highly compressed carbon dioxide is allowed to expand rapidly. As it does so it

Figure 2 *The greenhouse effect*



cools and solidifies. Solid carbon dioxide **sublimes** readily (at −78°C). When this happens, water droplets in the air may condense in the cold gas, giving rise to the familiar clouds of white 'smoke' used in stage effects.

Solid carbon dioxide is also used as a coolant, for example aboard aeroplanes. Food can be kept cool by packing it in dry ice which, unlike frozen water, does not release liquid as it warms up.

TESTING FOR CARBON DIOXIDE

Carbon dioxide forms a precipitate when it is bubbled through limewater, which is a solution of calcium hydroxide in water. Calcium hydroxide is not very soluble in water so the actual amount present in the solution is quite small. Carbon dioxide reacts with the calcium hydroxide to form a white suspension of calcium carbonate.

If an excess of carbon dioxide is passed through this solution the precipitate disappears as soluble calcium hydrogencarbonate is formed. It is however only stable in solution — if the mixture is evaporated the precipitate of calcium carbonate reappears. These reactions are responsible for the formation of underground caves, stalagmites and stalactites in limestone areas.

Richard Folwell/SPL

***Left:** Dry ice is often used to create dramatic effects*

● What is sublimation?

The equations for the reactions are:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

***David Moore** teaches at St Edward's School and is an editor of* CATALYST.

See http://www.darvill.clara.net/altenerg/nuclear.htm for more details about the use of carbon dioxide in nuclear reactors.

Carbon dioxide graph

TRY this

This activity is designed to test your ICT skills and also to get you to make predictions.

The observatory at Mauna Loa in the South Pacific is situated well away from sources of pollution and so is an ideal site at which to measure carbon dioxide levels.

Go to the following website: **http://www.atmos.washington.edu/~klarson/ta211/co2.html**

Here you will find a list of carbon dioxide concentrations from 1976 to 1997. Cut and paste the two columns headed TIME (years) and [CO2] into Excel (or a similar spreadsheet package). Use the graph-plotting abilities of this program to print out a graph of year (on the horizontal axis) against concentration in parts per million (on the vertical axis). You should end up with a graph similar to that shown in Figure 1. If you have problems in your graph plotting ask your teacher for help.

Print out your graph and add your predicted curve continuing the trend from 1997 to the present day.

Now look up on **http://cdiac.esd.ornl.gov/pns/current_ghg.html** the current carbon dioxide concentration. How close was your predicted point to that given on this website? Do you think your predicted curve could be reliably used in the future? Why do you think the curve wiggles up and down? And why does it show a steadily rising trend?

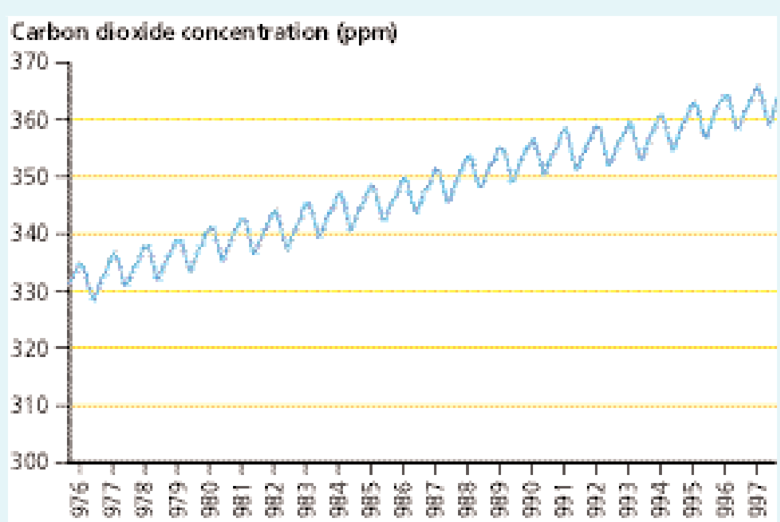
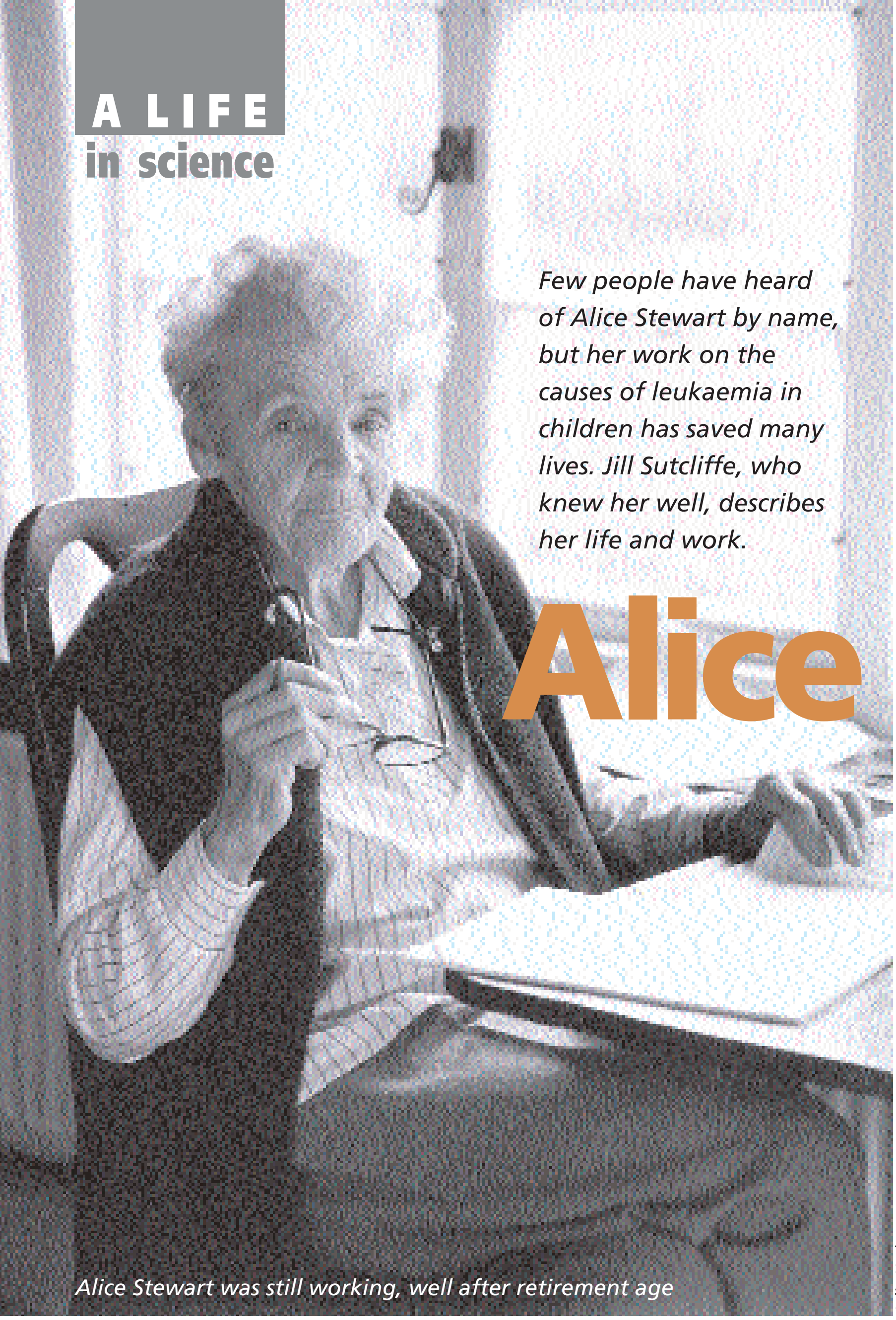


***Figure 1** Carbon dioxide variations at Mauna Loa*



A LIFE
in science

Few people have heard of Alice Stewart by name, but her work on the causes of leukaemia in children has saved many lives. Jill Sutcliffe, who knew her well, describes her life and work.

Alice Stewart was still working, well after retirement age

Julia Hedgecoe

Alice Stewart 1906–2002

In the 1950s, it was known that the number of young children who contracted leukaemia had doubled in 20 years (Figure 1). Alice Stewart and her colleagues set out to discover the cause. They drew up a questionnaire which covered a range of things: diet, socioeconomic background, and other possible factors. The crucial factor that emerged was that the children's mothers had been X-rayed during pregnancy. Following this discovery the practice of X-raying pregnant women was stopped, and this has saved hundreds of lives each year ever since. This sort of work, which opens up a new field, usually brings honours and recognition. Yet Alice received little.

CONTROVERSY

Initially Alice's findings were disputed. They did not fit with the then conventional wisdom that only large doses of radiation were harmful to humans and that low levels were safe. Alice Stewart believed her findings showed that there is no safe level (Figure 2). Later a similar study in the USA came to the same conclusion.

NEW APPROACHES

Alice Stewart was the first woman under 40 to be elected Fellow of the Royal College of Physicians. What appealed to her was problem-solving and this led her into the new field of epidemiology. During the Second World War, before her research on leukaemia, she looked at whether people exposed to TNT and making gas-proof clothing were becoming ill or not. Nobody had been studying 'social' or 'industrial' medicine and she had to devise many of her own methods. These were to stand her in good stead later. After the war, Dr John Ryle invited her to join him in a new research centre in Oxford to study child cancer. This was where she carried out her famous work on leukaemia.

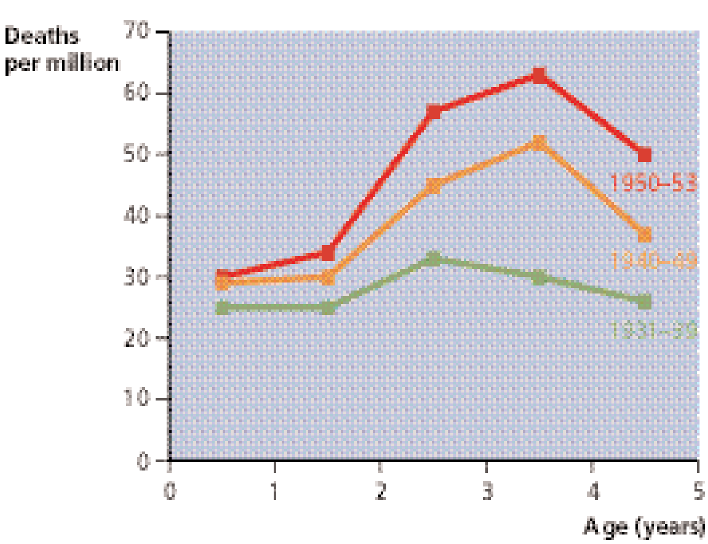


Figure 1 *Rates of mortality from childhood leukaemia rose rapidly during the first half of the twentieth century*

HEALTH STUDIES ON NUCLEAR WORKERS

In 1974 — when Alice was working beyond normal retirement age — Thomas Mancuso contacted her and her statistician George Kneale. Mancuso worked for the US Atomic Energy Commission and had been

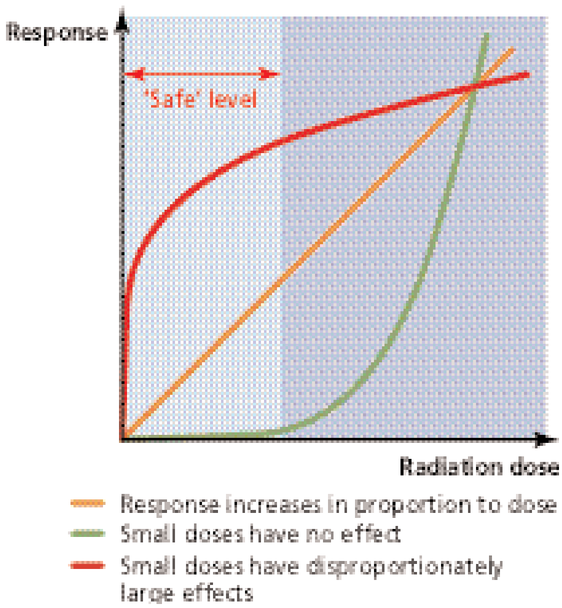


Figure 2 The greater the dose of radiation, the more serious its effects. The conventional view is that low levels have no significant effects — Alice Stewart believed her findings showed this to be wrong

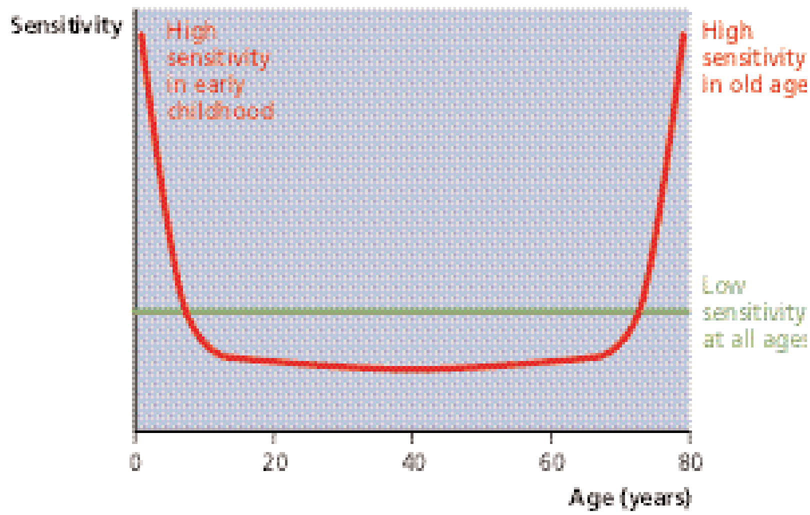


Figure 3 No-one knows for sure which of these graphs is correct — Alice Stewart believed that the young and the elderly are more sensitive to the effects of radiation

asked to evaluate the risk of workers in a nuclear power station developing cancer. His preliminary results seemed to indicate that there wasn't a problem. However, with Stewart and Kneale's help, he found that the cancer rate was noticeably higher among older workers. So what was the reaction to these findings? His funds were cut and he lost his job.

Alice Stewart was concerned about the risks posed by radiation. Estimates of these risks are based on studies of the people who survived the dropping of atomic bombs on Hiroshima and Nagasaki in 1945. In order to establish the risks you need a cross-section of all types of people. Stewart and Kneale realised that the first people to die had been those who were most sensitive to the effects of radiation — the young and the old. So by looking at the survivors decades later, scientists were using a biased sample. The implication of Stewart and Kneale's study is that the current risk estimates are flawed and exposure to radiation is more dangerous than we thought (Figure 3).

PUBLIC UNDERSTANDING OF SCIENCE

Alice was always prepared to talk about her results, and this made the issues she investigated more accessible. She won the 1986 Right Livelihood Award, the so-called 'alternative Nobel prize' awarded by the Swedish parliament the day before the real Nobel, and the 1991 Italian Ramazzini Award. But in the UK she achieved almost no recognition for her work. An annual conference convened by members of the public — the Low Level Radiation and Health Conference — named its opening lecture in her honour in 1994. After this Bristol University gave her an honorary professorship in recognition of her life's work.

Alice 'retired' from Birmingham University aged 92 and took home a computer so that she could learn to e-mail her grandson Charles in America. She died in 2002 aged 95. Her work on low-level radiation led her to believe that its effects were more dangerous than we thought but despite the controversy her research created she firmly believed that 'the truth will out'.

Dr Jill Sutcliffe works for English Nature. She has a particular interest in the effects of radiation from radioactive substances in the environment.

BOX 1 EARLY EXPERIENCES

Alice Stewart was born in 1906. Her parents were doctors in Sheffield, and they believed education was important for girls as well as boys. Yet Alice felt she never really bloomed at school. That happened later. She decided to study medicine and went to Girton College, Cambridge, just when women had been granted entry but were not allowed to sit the exams. Here she describes her first lecture:

It was a large room. I slipped in, hoping to take a seat as close to the back as possible. As I took my first step into that room, bang! came the sound of 200 students, all male, stomping their feet in unison. I took my second step and the stomp was repeated. Every step I took, there was this stomp, stomp, stomp. My first instinct was to duck into a seat and disappear, but no — every row was blocked by the men. I was forced down to the front row, where I found three other girls and a Nigerian. These medical students had managed to segregate us out — they weren't going to have anything to do with women or minority populations.

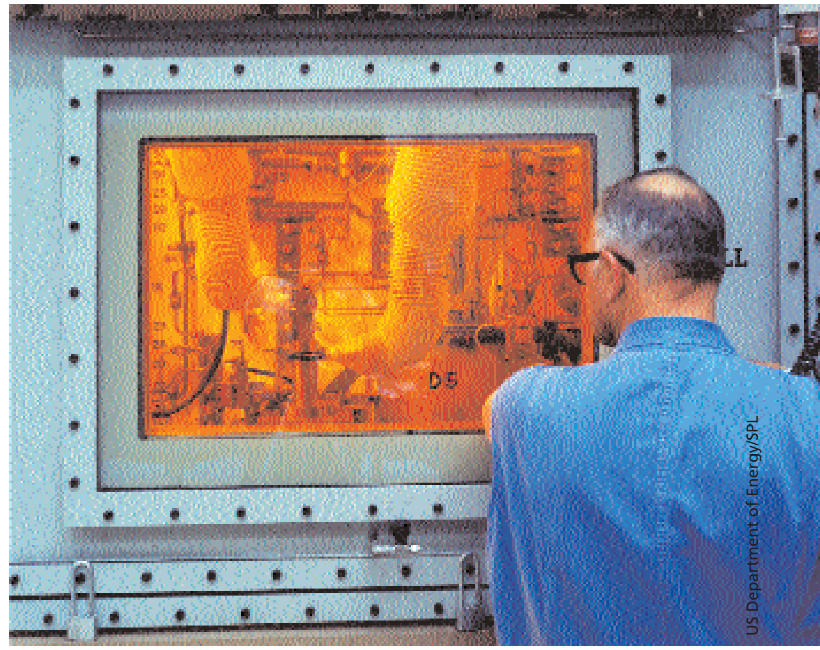
Leukaemia is cancer of the tissues which form blood cells.

Epidemiology is the study of patterns of disease in populations.

DAVID SANG

Hot, corrosive, a source of intense radiation — that's high-level nuclear waste. The nuclear industry is seeking safe ways to deal with such waste, and wants the public to help shape the decisions that are made. This article presents some information, and suggests ways to join in the decision-making process.

Hot problems



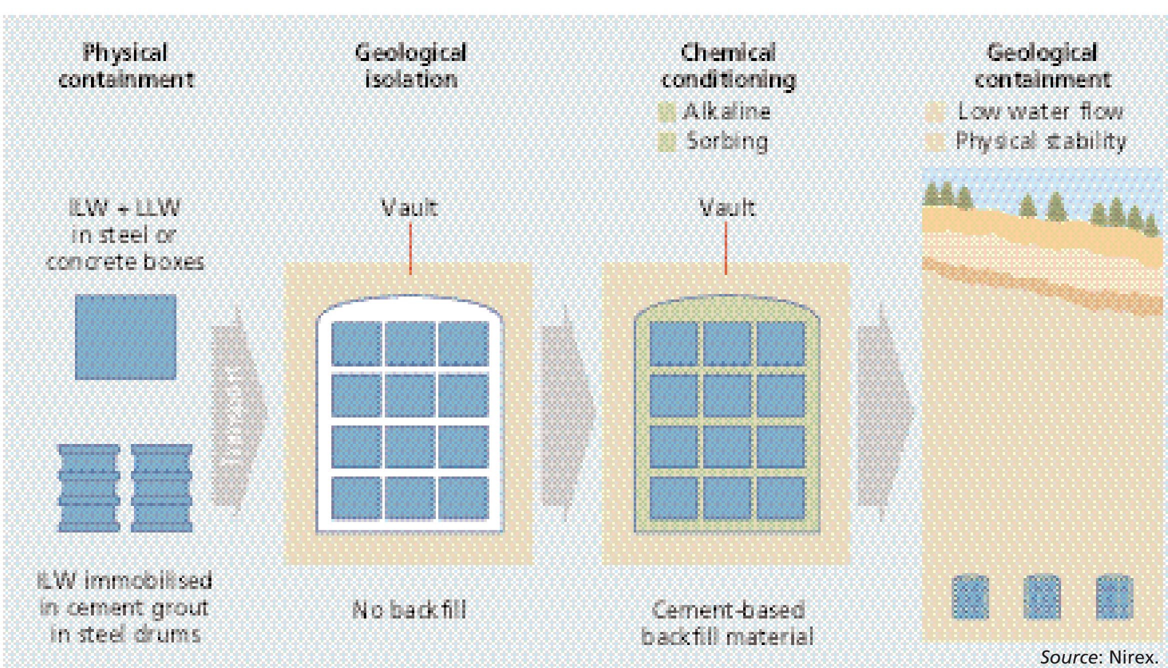
A technician in the USA using remote welding arms to seal radioactive waste in double-walled metal containers. He is shielded from the waste by metre-thick leaded glass. The containers will be stored under 4 metres of water

GCSE key words
Radioactive decay
Half-life

A small amount of radioactive waste comes from medical (2%) and military (1%) sources, but the bulk of it is produced by the nuclear power industry. In the UK, about 20% of our electricity is generated in nuclear power stations which use uranium as their fuel (see CATALYST Vol. 13, No. 4). Energy is released from the nuclei of uranium atoms by the process of fission. The waste left when the fuel is used up ('spent') contains many fission products — atoms of a variety of elements which are often highly radioactive. These hazardous substances make up a large proportion of nuclear waste. More radioactive waste is produced when power stations are decommissioned at the ends of their lives (see CATALYST Vol. 14, No. 2).

Large volumes of radioactive waste have been

Figure 1 The stages of containment in the long-term management of low and intermediate-level waste



Source: Nirex.

accumulating for decades. Many of the radioactive materials involved have long half-lives, so they will have to be stored safely for centuries before their activity falls to a safe level. The time has come to make decisions about how to do this.

GRADES OF WASTE

Most radioactive waste is classed as **low-level waste** (LLW). This includes things like discarded protective clothing, paper towels and wrapping materials. It is not safe to dispose of alongside household waste, so it is compacted into drums and dumped in a landfill site. The main UK dump is at Drigg, near Sellafield, in Cumbria.

Intermediate-level waste (ILW) is more radioactive. It includes materials which have been inside reactors, such as the cladding from fuel rods. This waste is cut up and packed in cement inside 500-litre stainless steel drums (Figure 1). ILW remains radioactive for centuries, so there is a problem knowing how best to deal with it.

High-level waste (HLW) is the most radioactive (and the most difficult to deal with). This material, which has been extracted from spent fuel rods, is dissolved in nitric acid and then concentrated by evaporation. It is stored in stainless steel tanks inside thick concrete walls.

HLW is so intensely radioactive that it becomes hot, and so the storage containers must be water-cooled. Attempts have been made to turn HLW into glass blocks by the process of vitrification, but this has proved tricky. The advantage of this would be that glass doesn't corrode. Ninety per cent of the UK's HLW is stored at Sellafield. Government policy is that HLW must be stored for at least 50 years to allow it to cool down; long-term management should then be easier.

Much HLW is now in a dangerous condition. It corrodes the containers which are meant to keep it

A Greenpeace protest against a nuclear shipment from Japan, bound for Sellafield for reprocessing

safe, and these then have to be placed inside further containers. There is a constant danger of leakage into the environment. We can't go on like this!

CONTAINING WASTE

High-level nuclear waste is going to be with us for a long time. Even if all nuclear power stations were shut down tomorrow, we would still have to cope with existing stocks of HLW, and more would come from decommissioning work (Figure 2). In addition, there will continue to be a steady trickle from medical and industrial uses. Ideally, we would like to be able to dump all nuclear waste in some safe way and forget about it, but we can't wish this problem away.

What are the difficulties? The problem is partly one of timescale. Some fission products have long half-lives, and will have to be contained for thousands of years (Figure 3). The industrial age is just a few centuries old, and we don't have the experience of dealing with dangerous materials over longer periods of time.

So predicting the future is important. How far ahead can we look? And would it be fair to leave future generations with a problem created by our own use of energy?

The nuclear industry predicts that it will need thousands of graduates in physics, chemistry, geology, materials and environmental science over the next few years to develop safe ways of storing the radioactive waste produced by the operation and decommissioning of nuclear power stations.

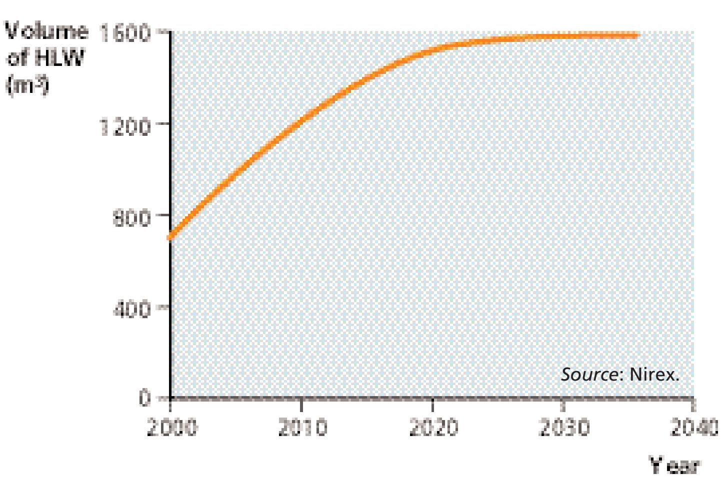


Figure 2 *Volumes of HLW will continue to rise over the next 10 years. If any new nuclear power stations are built, the graph will rise beyond 2020*

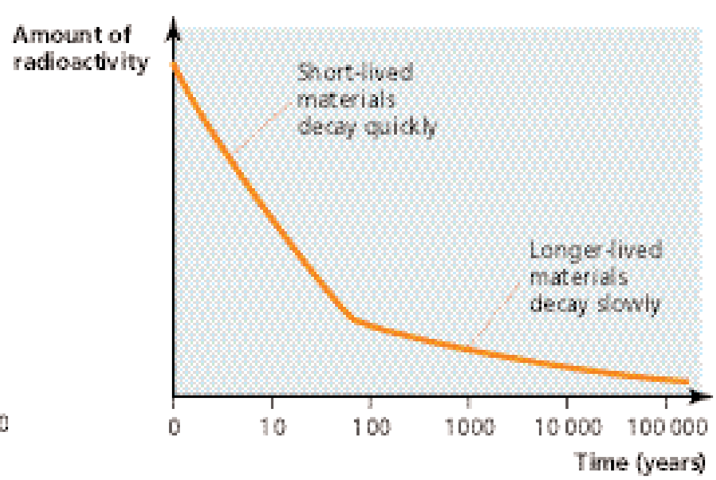


Figure 3 *While some components of HLW decay quickly, others are much longer lived and will go on being a hazard for thousands of years*

BOX 1 OPTIONS FOR STORAGE OF RADIOACTIVE WASTE

Interim surface or underground storage in appropriate conditions	Temporary storage, either at ground level, or underground; containers of waste would be monitored to check for overheating and leaks of radiation or chemicals
Long-term surface storage	Storage at ground level throughout the hazardous life of the waste. Would require constant management
Sea disposal, sub-seabed disposal	Containers of waste dumped at sea, or disposed of in a repository excavated under the seabed. Currently banned by international treaty
Disposal in subduction zones	Containers of waste buried where they will be carried further underground by the movement of tectonic plates. Currently banned by international treaty
Underground disposal	Containers of waste deposited in a space excavated below ground level, or in a borehole drilled deep into the ground. Favoured by most scientists; such repositories are now being built in Sweden, Finland and USA
Deep underground disposal	Waste deposited deep underground; containers may need further packaging to avoid chemical corrosion by surrounding clays, salts etc. The ground must be stable, without water flow, for perhaps 100 000 years
Disposal in space	Waste carried by rockets into space. Could be considered for the relatively small volumes of HLW, but rocket launches are not considered reliable enough at present

Below: *A tunnel for the storage of nuclear waste 650 metres below the ground in salt beds, New Mexico, USA*


US Department of Energy/SPL

MAKING DECISIONS

The question of what to do with radioactive waste raises many issues — social and ethical as well as scientific and technological. The UK government is encouraging a review process which will allow citizens to have a say in waste disposal. The aim is to achieve public confidence in whatever decisions are made.

Security is vital. If radioactive waste fell into the wrong hands, it could be used in a so-called ‘dirty bomb’ or ‘radiological weapon’, in which conventional explosives are used to shower radioactive materials over a large area.

Sustainability is vital, too. The burden on future generations should be minimised. Environmental damage should be no greater than is acceptable today, and we shouldn’t rely on the stability of future governments. That’s a lot to ask.

Nirex Ltd, the body that researches ways of dealing with waste, is coordinating the national debate on these issues. Box 1 details some of the options it is considering. You can find out more from Nirex (**http://www.nirex.co.uk**), and you can contribute to the debate by attending public meetings and exhibitions, and through the internet (Box 2).

LONG-TERM MANAGEMENT

It is proposed that radioactive waste and materials would be packaged securely, and then stored in one or more of the ways shown in Box 1.

Several disposal methods have already been ruled out. These include:

- Allowing hot containers of highly-active waste to melt their way down into rocks, or into polar ice-sheets — it’s too uncertain where the material would end up.
- Transmutation, a process in which waste is irradiated with beams of fast neutrons, converting unstable isotopes into stable ones — the technology has not yet been developed.

BOX 2 JOIN THE DEBATE

Find out more and join in the debate about handling nuclear waste at
http://www.schoolscience.co.uk/content/4/physics/nirex/index.html

David Sang writes textbooks and is an editor of CATALYST.

Bask in the Sun or stay in the shade?

Corel

SUN SAFETY ADVICE

- Stay in the shade between 11 a.m. and 4 p.m.
- Make sure you never burn.
- Always cover up with a T-shirt, wide-brimmed hat and sunglasses.
- Use factor 15+ sunscreen.
- Take extra care to protect children from burning.
- Report any mole changes or unusual skin growths promptly to your GP.

Summer is on its way. For many people, an ideal holiday includes spending hours on the beach, soaking up the Sun's rays. They like a 'healthy tan'.

But there's a growing awareness that the Sun's rays can be harmful. Ultraviolet (UV) radiation from the Sun is a form of ionising radiation. It is absorbed by the cells of your skin and its energy can ionise and damage the molecules within your cells. This is dangerous. Cells may be killed, which is bad. If the DNA in a cell is damaged, it's worse. The mechanisms that control cell division may fail, and cells may divide out of control, starting a cancerous tumour.

There are now more cases of skin cancer in the UK each year than in Australia, despite the fact that Australia is much sunnier. People in Australia have learned to avoid excessive exposure to UV. People with fair skin are most at risk. They don't have the dark pigment melanin which protects the skin by absorbing UV radiation.

ON THE OTHER HAND...

But exposure to UV isn't all bad — in fact, it's essential. Sunlight is needed for our bodies to make vitamin D, which is found in few foods. There is evidence that vitamin D protects us from cancer of the breast, colon and other organs. Latest evidence from Australia suggests that there is a danger that these cancers are becoming more common, because a significant proportion of the population has become very good at avoiding all exposure to direct sunlight, and suffers from vitamin D deficiency.

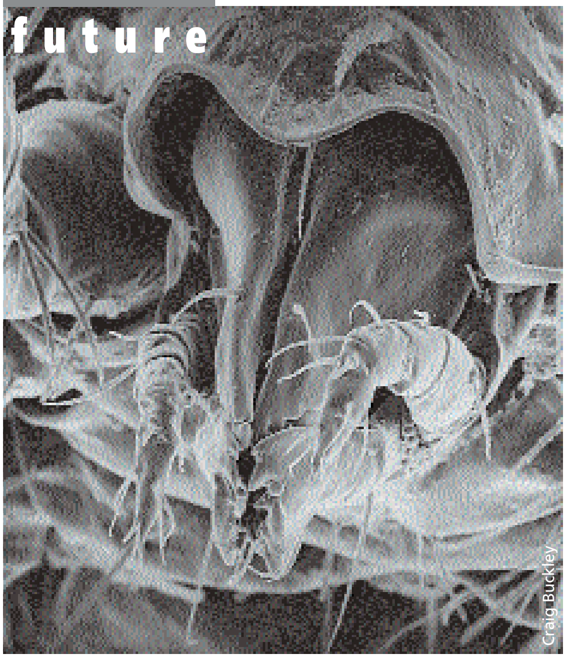
In addition, many people claim that sunshine lifts their spirits and helps them avoid depression.

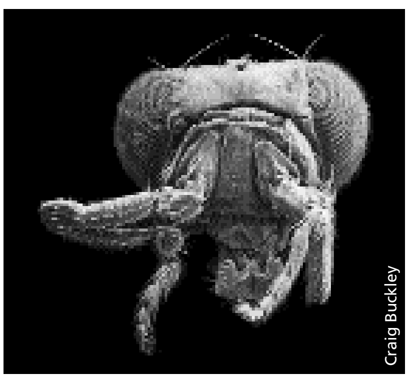
THE DEBATE

What advice would you give to the public? What are the costs and benefits of exposure to the Sun's rays, and how can we decide the balance between them?

David Sang writes textbooks and is an editor of CATALYST.

The ultraviolet spectrum is divided into three zones: UVA (least energetic, closest to visible light), UVB and UVC (most energetic, most harmful).





How are groups of living things related? Are organisms that share similar body shapes necessarily related? Craig Buckley is a research biologist studying the processes of embryonic development and what they can tell us about the relationships between different groups of organisms. Here he describes his work.

Molecular

Top left: *A close up of the head of an adult soil mite. The head is less than 0.2 mm across*

Top right: *Craig in the lab setting up an electrophoresis gel*

Bottom left: *An antp mutant fly has legs growing where its antennae should be*

Curiosity is the most important requirement for a scientist. I used to find school a bit restrictive. Don't get me wrong, I loved learning, but I was impatient to go out and try answering questions for myself. I read a vast amount, but I also used to go wandering in the park near my house, or by the river looking for frogs or insects or just about anything that caught my attention.

I was good at science in school and I discovered a real love of animals (even the many-legged ones) and a desire to understand nature better. When I went to university I chose a degree course — biology, psychology and philosophy — that I hoped would reflect my interests.

A CHOICE OF PATHS

There are many ways of studying the natural world and I could have taken a number of different paths. I've crouched in a hide watching social behaviour in mandrills, surveyed mushroom species in Scottish woodlands and gone snorkelling to measure biodiversity in marine environments.

- **Find out what a mandrill is.**

In the end I decided to specialise in molecular biology and systematics, working with DNA, RNA and proteins. More specifically, I am an evolutionary developmental geneticist. I study the genes responsible for organising the development of embryos from fertilised eggs to fully formed adults. The 'evolutionary' bit means that I study how those genetic mechanisms and the resulting body-plans have changed over time and what that can tell us about the relationships between different species.

I'm looking at how head parts and brains grow in soil mites (members of the Arthropoda, a phylum which includes insects, crustaceans, spiders, millipedes and centipedes). Mites are closely related to spiders and scorpions and we want to compare their development to that of insects. Most work in developmental genetics has been done with insects, especially fruit-flies, so it is important to make sure that the pattern we see in the flies corresponds to that in other animals.

When people ask me why I work with soil mites I tell them it's because human beings struggle too much! In fact, as far as the genes determining head

Figure 1 Working out species relationships using DNA data. We are given short DNA sequences from five species (a–e) and a sequence for the same stretch of DNA from an unrelated organism (O). This provides a baseline to compare the others to. The alignment at the top shows that the sequences differ (they have mutated) at four sites (highlighted in colour). The diagram at the bottom is a phylogenetic tree, created using these differences, and it shows the possible relationship between species a–e. Similarities in the DNA sequences are taken to show a relationship, and the more shared sequence there is between individuals, the closer their relationship is assumed to be. Note that this diagram is not the only possible solution for arranging the tree, but it is the most likely

biologist

development are concerned, there's almost no difference between humans and soil mites. An organism with a mutation in one of these genes might end up with legs growing out of its head, or without a head at all, and the genes are almost exactly the same in flies, mites, mice and human beings. The puzzle is to work out how the little differences in the DNA lead to such big differences in body shape.

MY WORKING DAY

The first of my daily tasks is deciding how to divide my time between 'wet work' and 'dry work'. Wet work is done in the laboratory and might involve a DNA extraction, or some gene sequencing. I work in a busy, hi-tech laboratory, which means I have to be able to plan and negotiate with other people.

The dry work is stuff I can do in my office. It might be aligning a collection of protein or nucleotide sequences from different organisms, working with databases to look for new genes or just having meetings with the rest of my research group to check that everyone knows what's going on in the group. You have to be motivated and able to work by yourself to be a scientist, but you also must be ready to work as part of a team. Sharing information is important, whether it involves writing papers for journals, talking to the media, giving talks at conferences or teaching.

Today I'm setting up some cloning reactions and finishing up some sequencing, so I'd better get going….

Craig Buckley

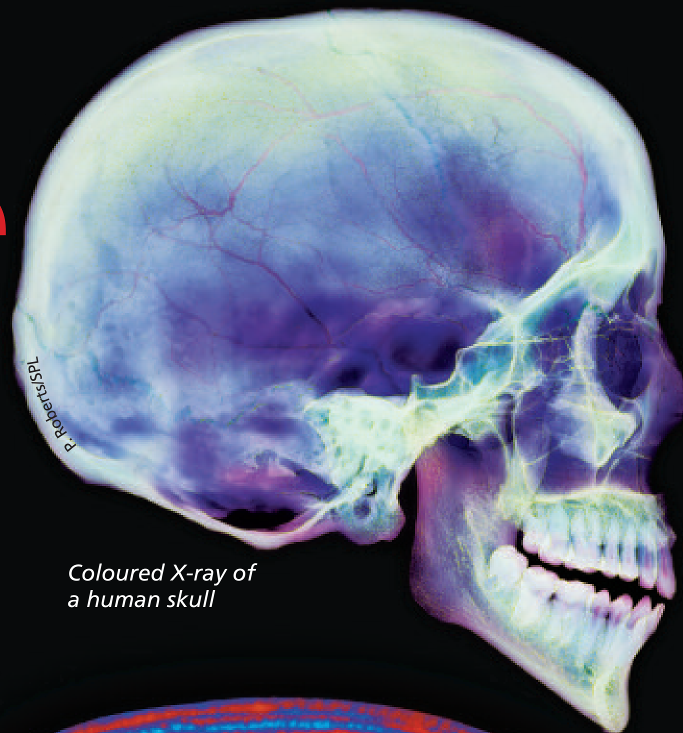
WEB ACTIVITIES

The Palaeontology Museum at Berkeley provides a good overview of arthropods and is pretty approachable: **http://www.ucmp.berkeley.edu/arthropoda/arthropoda.html**

There is a really user-friendly beginner's guide to molecular biology at **http://www.rothamsted.bbsrc.ac.uk/notebook/courses/guide**

The tree of life project homepage is at **http://www.tolweb.org/tree** There are some interesting pictures and text, but the site has a steep learning curve and might be a bit difficult. It does reinforce the whole idea of phylogenetic relationships.

Magnetic resonance imaging

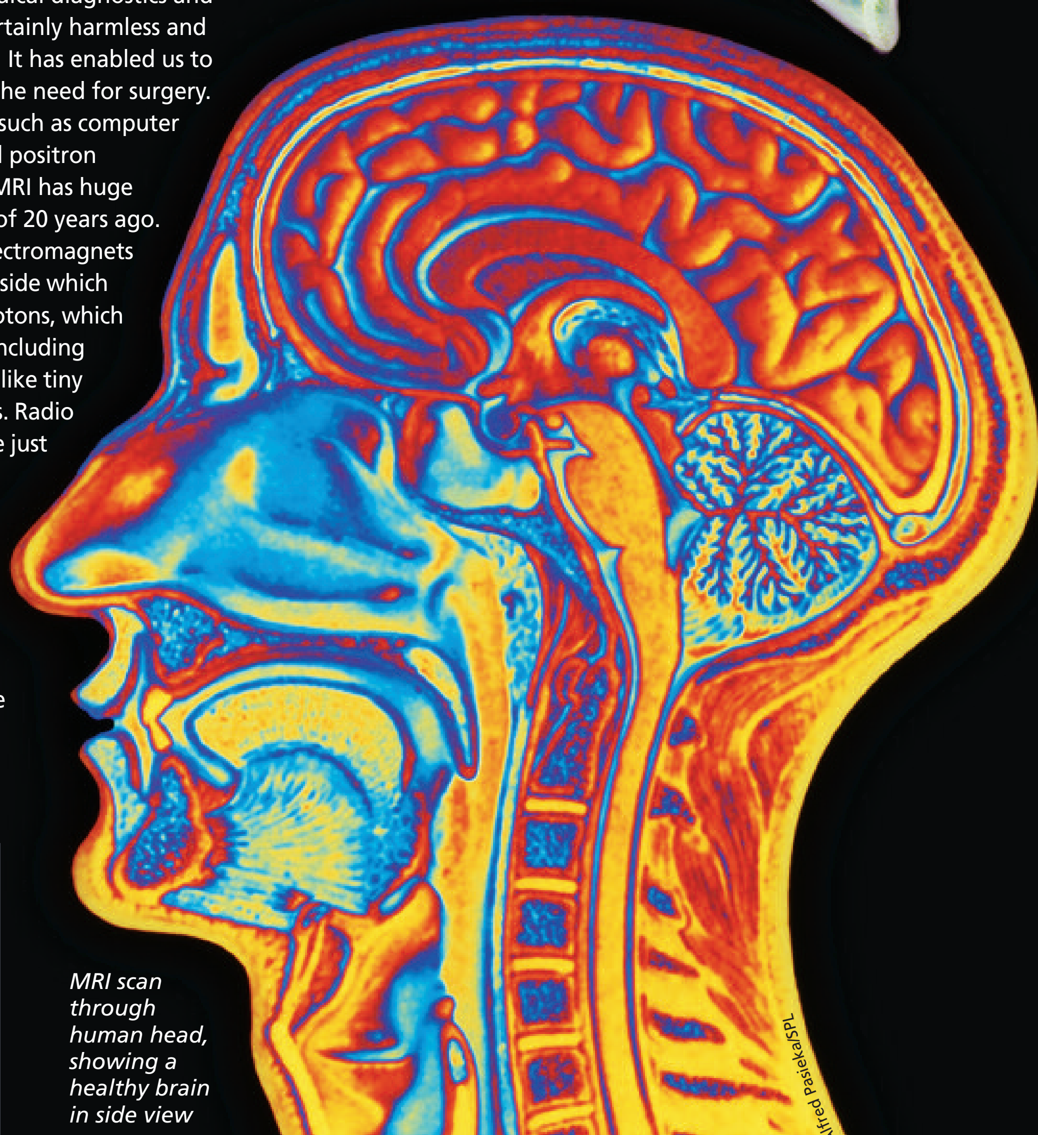


P. Roberts/SPL

Coloured X-ray of a human skull

The 2003 Nobel prize for medicine was awarded to the British scientist Sir Peter Mansfield and to Paul Lauterbur from the USA for the development of magnetic resonance imaging (MRI). In its citation, the Nobel Assembly said that the development of MRI represented a breakthrough in medical diagnostics and research. MRI is painless, almost certainly harmless and produces the most brilliant images. It has enabled us to see our insides without danger or the need for surgery. Along with other new techniques, such as computer assisted tomography (CT) scans and positron emission tomography (PET) scans, MRI has huge advantages over the X-ray images of 20 years ago.

An MRI scanner uses powerful electromagnets to set up a strong magnetic field, inside which the patient's head is placed. The protons, which are the nuclei of hydrogen atoms, including those in the patient's head, behave like tiny magnets and line up like iron filings. Radio waves are then turned on, and have just the right energy to tip the protons over, which also affect the nuclei. When the radio waves are switched off the protons gradually line up again with the field, giving off radio waves as they do so. These can be detected, processed and turned into an image like the one shown here.



Alfred Pasieka/SPL

MRI scan through human head, showing a healthy brain in side view

ACTIVITIES

- Find out more about Sir Peter Mansfield's life and work by putting his name into an internet search engine.
- Use the internet to find out which of PET and CT scanning uses X-rays.