# Catalyst

GCSE Science Review

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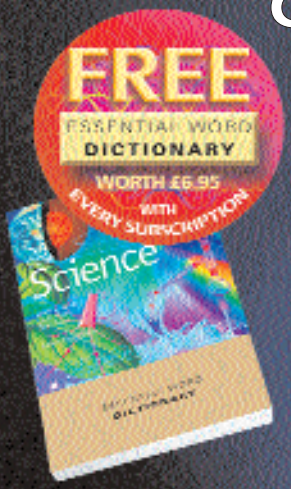


## Cyborgs
### The next step in evolution?

philip allan
UPDATES
www.philipallan.co.uk

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# Catalyst



*The front cover shows Arnold Schwarzenegger as the Terminator (Hemdale Film Corp/RGA). See pages 10–11.*



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# Editorial

## Welcome to issue 1!

Welcome to the first issue in a new volume of CATALYST. Some of you will be starting out on your GCSE science course; for others, your second year is beginning and the end of the course is just coming into view. Whichever applies to you, we hope that CATALYST will be an interesting and useful companion along the way.

Each issue of CATALYST includes several articles on aspects of science which are relevant to your course — look for the GCSE key words box near the start of the article. These articles should help to reinforce the ideas you are studying. At the same time, they will help you to learn about the frontiers of science — many are written by practising scientists describing the research they are involved with at present.

What else will you find in CATALYST?

- In each issue Improve Your Grade suggests ways in which you can improve your revision techniques, make effective notes or write better exam answers.
- Your Future describes an area of scientific work which might be a possible career for you.
- Scientists do experiments, so most issues include one to try.
- A Life in Science looks at the work of a particular scientist — useful in understanding how ideas in science have developed.

Lastly, we try to include a puzzle in each issue. These are just for fun, but if you enjoy getting to grips with a good puzzle, that could mean you would make a good scientist. Scientists spend a lot of their time struggling with quite tricky puzzles — and there are no answers at the back to help them on their way.

Enjoy your CATALYST!

**David Sang**

# Plastics
## An insoluble problem

DAVID MOORE

Emmanuel Viale/Still Pictures

**GCSE key words**
Polymer
Polyethene

*As part of your GCSE course you will be looking at plastics and their uses — but have you wondered what happens to them once they are discarded?*

Imagine the *Time Team* excavating a site at some time in the future. What will they make of large holes in the ground which have been filled with tonnes of plastic before being covered with soil? Unlike discarded metal washing machines, waste paper and cardboard, plastic does not decompose once it has been thrown away. What can be done to change this, how can we recycle plastics, and can we make plastics that dissolve?

### PLASTICS WHICH WASH AWAY

To start at the end, yes, plastics which will dissolve in water have been known for quite some years. They are used in hospitals to make laundry bags. Panels within the bag are made of dissolving plastic. Soiled sheets and clothes can be put in the bag and the whole bag placed in a washing machine without handling the dirty laundry again. Once the hot water is in the machine the plastic dissolves and simply washes away, leaving the clothes and sheets free to be washed. How does this happen?

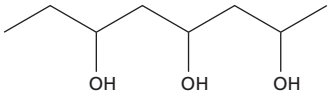



***Figure 1*** *The structure of poly(ethenol).*

Peter Frischmuth/Still Pictures

***Top:*** *Plastic bags cause a serious litter problem because they blow about and do not decompose.*

***Above:*** *Plastic bottles for recycling.*

| OH groups (%) | Solubility in water |
|---|---|
| Below 90 | Soluble in cold water |
| 90–96 | Soluble in warm water |
| 97–98 | Soluble in hot water |
| 99–100 | Insoluble |

***Table 1*** *Relationship between percentage of OH groups on alternate carbons of the polymer chain, and solubility of the plastic*

The plastic is made from chains of polymer called poly(ethenol) which has OH groups on every other carbon of the polymer chain (Figure 1). These can form a special type of bond, called a **hydrogen bond**, with water, and so dissolve. Table 1 shows how the percentage of OH groups affects the dissolving properties of this type of plastic. Some shops now offer these ecologically-friendly plastic bags in an attempt to reduce the litter problem caused by waste plastics.

## BOX 1

Polymers (or plastics) are long molecules made up of chains of carbon atoms. These polymers are made by joining many thousands of small molecules — called monomers — together:

$$A + A + A + A + A\ldots \longrightarrow A\text{–}A\text{–}A\text{–}A\text{–}A\ldots$$

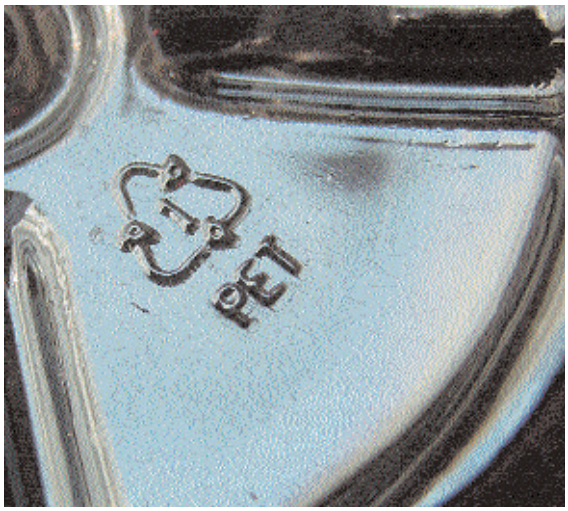
Polymers which are soft and springy and will regain their original shape after being stretched are called **elastomers**. Polymers which remain deformed after being stretched are called **plastics** while those which can be made into strong thin threads are called **fibres**.

High-density polyethene is made up of long chains of carbon atoms. These chains are not branched, so they can lie close to each other. This allows strong interactions to occur between the chains and the polymer becomes strong and tough. Low-density polyethene is made up of branched chains which cannot lie close to each other. The forces between chains are therefore weaker and the polymer is more flexible and not tough.

**A normal household can use more than 1000 carrier bags a year. Britain's annual plastic bag mountain weighs over 145 000 tonnes.**

## WHERE DID PLASTICS FIRST COME FROM?

Polyethene — the main material from which plastic bags are made — was first invented in 1933 by Eric Fawcett and Reginald Gibbon who worked for ICI in Cheshire. Polyethene was discovered accidentally. Both men were trying to make a totally different compound, but kept obtaining a white waxy solid. At first they couldn't find anything to do with it and so it remained a curiosity. However it was found to be both chemically and electrically inert and so was used in the Second World War to shield the circuitry in radar apparatus from stray electrical fields. It was also used as a protective sheath to prevent water attacking undersea cables.




*The triangle on the bottom of a plastic bottle tells you what it is made of (see Table 2).*

The first polyethene produced melted just above the boiling point of water. It wasn't until 1953 that a German chemist, Karl Ziegler, refined the manufacturing process to produce high-density polyethene (see Box 1), which was far more stable to heat and very durable.

Nowadays the starting materials for plastics manufacture come from the petrochemical industry. The ethene is obtained from distillation and cracking in oil refineries. Most plastics can be readily moulded, are chemically inert, have good strength properties and, weight for weight, are both more flexible and stronger than steel.

## CAN WE RECYCLE PLASTICS?

To a limited extent, yes, we can. If you look at the bottom of a plastic drinks bottle you will find an embossed triangle with a number in it. The number, which varies between 1 and 7, tells you what plastic the item is made from (see Table 2).

**● The Irish government has introduced a tax on plastic carrier bags (about 9p a bag). How much would your family spend a year on bags if we had such a tax here?**

**● See how many of the different types of plastic in Table 2 you can find around the home. Sort them and work out whether there are any relationships between their code number and the use to which they are put.**

***Table 2*** *Recycling numbers*

| Number | Plastic | Uses |
|---|---|---|
| 1 PETE | Polyethylene terephthalate | Drinks bottles, water bottles, vinegar bottles, medicine containers, backing for photography film |
| 2 HDPE | High-density polyethene | Containers for laundry/dishwashing detergent, fabric softeners, bleach, milk, shampoo, conditioner, motor oil. Newer bullet-proof vests, various toys |
| 3 V | Polychloroethene (PVC) | Pipes, shower curtains, meat wraps, cooking oil bottles, shrink wrap, clear medical tubing, coffee containers |
| 4 LDPE | Low-density polyethene | Wrapping films, grocery bags, sandwich bags |
| 5 PP | Polypropene | Tupperware®, syrup bottles, yogurt tubs, outdoor carpet |
| 6 PS | Polystyrene | Coffee cups, disposable cutlery and cups (clear and coloured), bakery shells, meat trays, 'cheap' hubcaps, packing peanuts, insulation |
| 7 OTHER | Other | Products labelled 'other' are made of any combination of 1–6 or another, less commonly used, plastic |


*Above: How many of the different types of plastic in Table 2 can you spot here?*

The main problem with recycling is that in a batch of household waste there may be plastics with many different numbers. A bottle top may be made from a different plastic to the bottle itself. An article of clothing may be made from mixtures of many types of polymer fibre, each with its own properties to enable the clothing to function properly. The difficulty comes with separating all the plastics into their different types before or after they are collected — some plastics may not even have a recycling number on them.

Councils that do separate plastics from other household waste often leave them mixed — once cleaned and re-melted they produce a low-quality plastic which may be used for packaging purposes. Plastic has to be heated carefully during recycling to stop it decomposing and releasing carbon particles that would contaminate and weaken it.

## ARE THERE ALTERNATIVES TO PLASTICS?

Yes, there are many, but they may not have all the desired properties of a plastic. Extruded cellulose is now commonly used as a packaging material for fragile objects, but if it gets wet the cellulose softens and the structure collapses to a paste. A strong composite of laminated wood and reclaimed plastic has been made using a special chemical called a **graft copolymer** to join the two together. In the past objects made from fusing together wood and plastic have often failed to last. This is because plastics are essentially oily substances while wood consists of water-loving molecules, and the two don't easily coexist.

*A woman in the market in Minsk, Belarus, selling Western carrier bags to shoppers.*


Jane Buckett

## PLASTIC, PLASTIC, EVERYWHERE

Plastic carrier bags were first introduced into shops in 1968 and are now found all over the world — quite literally! In some of the poorest countries they are a status symbol and are re-used many times. But when it comes to litter they are a major problem because they tend to last for ever. They weigh so little that they blow about and are both a visual eyesore and a hazard to wildlife.

Perhaps we should be more like the Swedish, who have large resources of wood and tend to use far more paper bags than plastic ones. Surprisingly this is also true of Americans who tend to use the potentially more fragile paper sack instead of the plastic carrier bag. Even if the paper of the bag is not recycled, at least it will decompose once it is in the ground — unlike plastic.

It is up to all of us to try and cut down on the use of plastic, in particular plastic bags, or in the future we will be submerged in a sea of plastic. The alternatives are out there — it is up to us to use them.

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

**An average carrier bag will hold more than 10 kg of food without breaking.**

**99% of all carrier bags are used twice: once to put shopping in and then to put rubbish in, before being thrown away.**

- **Take a bag with you when you go shopping and try to avoid collecting any more carrier bags. See how difficult it is!**

IMPROVE
your grade

# Revision

We want to help you with your exams. During the year Improve Your Grade will help you improve your revision techniques, show you how to make effective notes and help you write better exam answers. Some of you have mocks coming up, so in this issue we are looking at revision and learning.

**Q** *When should I start revision?*

**A** You might not need help with this, but many people find it difficult to overcome the psychological barrier and actually start revising. They make revision timetables, finish off bits of homework which aren't due for a week, tidy some desk space, sharpen their pencils and so on. Of course these are all good things to do, but they do put off the evil moment. If you find you are brushing your teeth before you open your physics notes **stop procrastinating** and get on with it. Do regular small amounts of revision interspersed with your normal work in the weeks before the exams. It's never too late to do some revision, but it can be too early.

**Q** *What do you mean by 'it's too early to do revision'?*

**A** Make sure you know the difference between **learning** and **revision**. Revision refreshes and reminds you of what you already know — it isn't learning things for the first time. It should be done just before your exams and shouldn't take very long. Learning is what takes the time. Are you waiting to learn your topics until just before the exams? If so you are making your life difficult. You must do your learning well in advance and leave the time in the weeks before exams for true revision and learning the most recent work.

**Q** *When is the best time to learn the topics?*

**A** You learn all the time — obviously you are learning while you are in lessons and when you do your homework. You also need to set aside regular amounts of time during the week to learn the topics you have recently studied. It needn't be a long session, but remember that every activity you do helps you to learn. The more you have to think about and do things the more likely you are to remember them. For example, you tend to remember practical activities that you did yourself better than those you watched your teachers do or read about in books.

Break down the module of work into sub-sections. Figure 1 is a spider diagram showing how a biology module on control and coordination can be broken down into smaller sections. Set aside small amounts of time for learning each sub-section as you go along — ideally shortly after the block of lessons on that topic. By the time you get to the end-of-module test you will already have learnt most of the work and need only learn the last bit and revise the rest.

**Q** *What can I do to help my learning?*

**A** First of all, don't be lazy when doing homework. If, for example, the homework is 'read page 73 and answer questions 1, 3 and 4' don't just read the questions and scan the page for the lines covering the answers. Read the page properly — it gives a context for the information in the answers and that will help them to stick.

When you are learning try the following activities which involve you processing information.
(1) Visit the school library with your exercise book and a note pad. Find a book that isn't your textbook, or a CD-ROM that covers your topic, read about your topic and check that your notes are accurate. Watch any animations. Make crib notes of everything in your note pad. The crib notes themselves aren't important, but writing them down is. The processing of information that you do while making the notes helps you remember them. The fact that the information is presented in a different way from your textbook also helps you remember. Some people find it easier to remember pictorial information than words.
(2) Make a spider diagram of the topic and turn it into a concept map by adding the links between words (see Figure 3, and Improve Your Grade

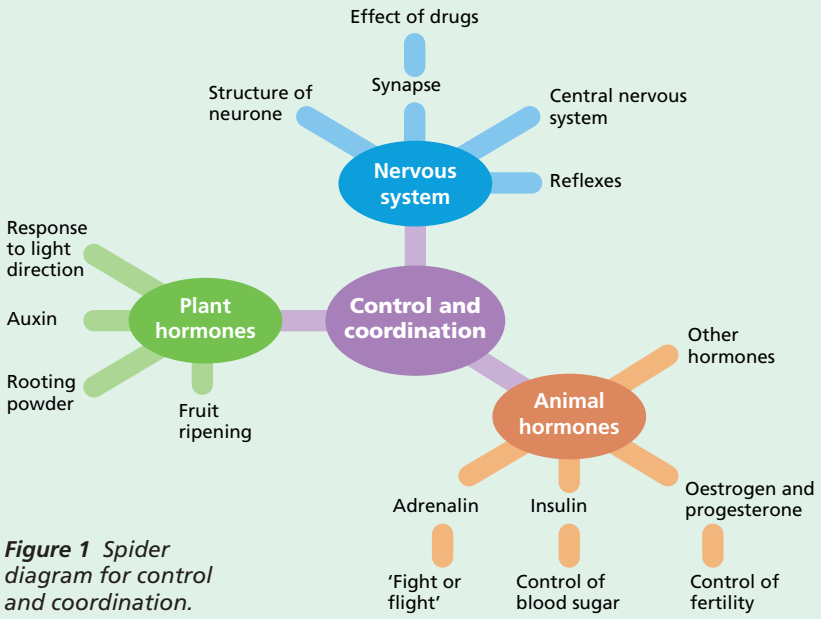
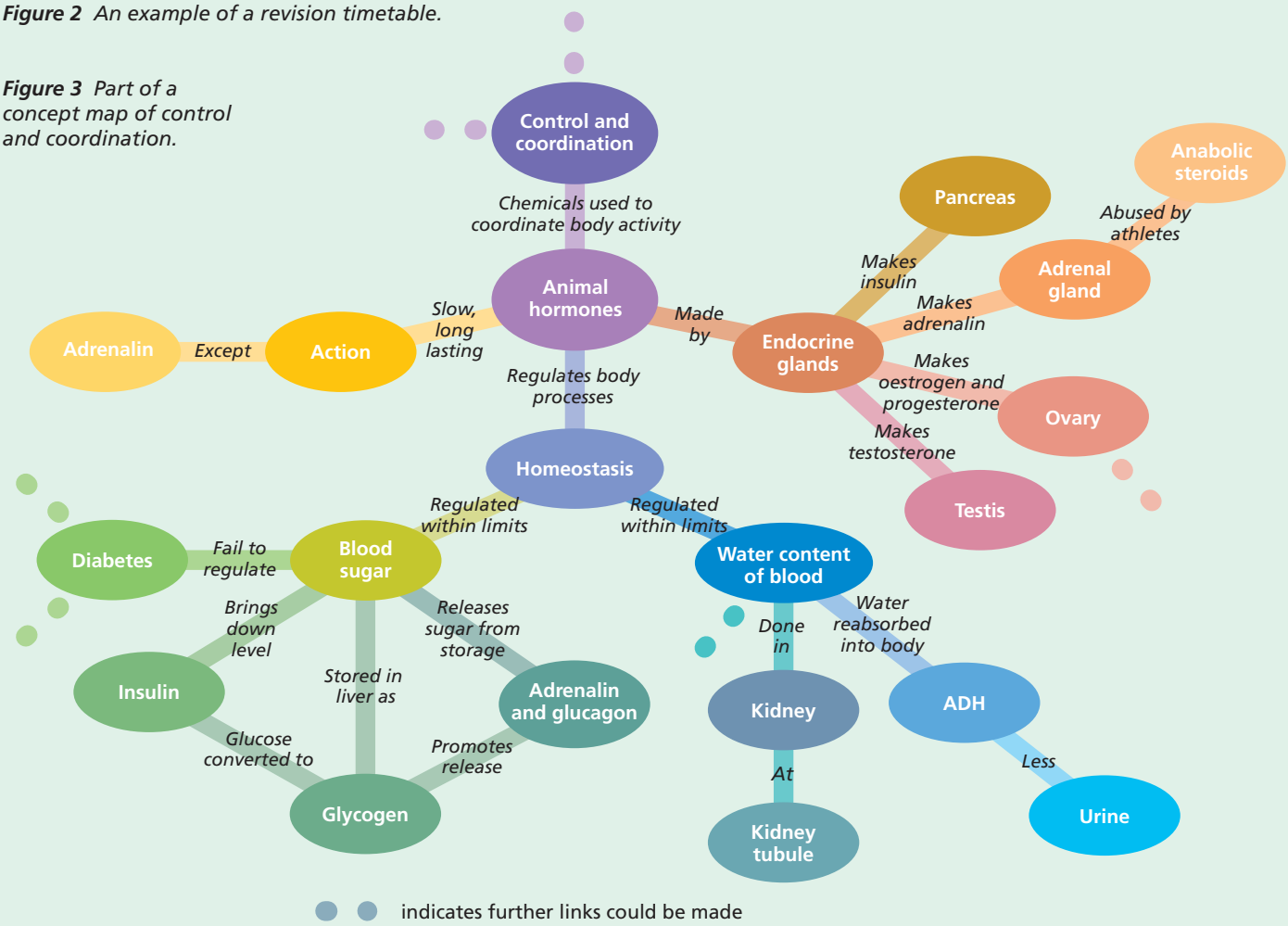



***Figure 1*** *Spider diagram for control and coordination.*

| 14 October | Week 2 If you work a fortnightly timetable | | | | |
|---|---|---|---|---|---|
| | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **Homework** | Maths<br>*questions* | English<br>*essay, due Thur* | RE<br>*plan discussion* | Maths<br>*questions* | English<br>*poetry* |
| | Spanish<br>*vocab,*<br>*test next lesson* | Geog<br>*notes* | DT<br>*coursework* | French<br>*questions* | DT<br>*coursework* |
| | Business studies<br>*coursework* | Science<br>*write expt* | Business studies<br>*coursework* | Science<br>*revise* | Geog<br>*read and plan* |
| **Tests** | | | ***Spanish tomorrow*** | | ***Biology test Mon.*** |
| **Coursework** | Business studies ---------- | ---------- | ---------- | ---------- | ---------- |
| | | | DT ---------- | ---------- | ---------- |
| **Review** | | Review<br>*control of blood sugar, adrenalin* | Revise<br>*Spanish* | Review<br>*Treaty of Versailles* | Revise<br>*control and coordination* |

***Figure 2*** *An example of a revision timetable.*

***Figure 3*** *Part of a concept map of control and coordination.*




about making concept maps in CATALYST Vol. 11, No. 3). You will have to think about the relationships between the topics. Even better, work with a friend. As you argue about a diagram you have to formulate your ideas and turn your thoughts into speech, which helps you remember.

(3) Use study support clubs to straighten out difficulties.

(4) Don't waste time on random internet searches — much of what you find will be rubbish. Instead use guides to useful sites like the one in CATALYST Vol. 12, No. 2, GCSE Bitesize and the National Curriculum website.

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

DAMIAN MURPHY

# Hearing the world

*In your GCSE science course you will learn about how sound waves are affected by their surroundings as they travel. Engineers are using this understanding to develop highly-realistic sound systems for films, music systems and computer games. The same ideas can help people with eyesight and hearing problems. Damian Murphy of York University describes how this is done.*

Stereophonic sound has been around for over 30 years, and multi-speaker techniques are now commonplace in cinema sound systems, home cinema and DVD systems. They give a more 'immersive' feel to the sounds you hear. Your PC may have surround-sound enhancements for games and other entertainment software. This 'three-dimensional audio' can also be produced using standard headphones or stereo speakers together with precise measurements of the detailed physical characteristics of a person's head and ears.

For accurate surround-sound two things need to be taken into account. First, the environment in which it is heard — a room, a corridor, the middle of a field — affects the quality of a sound, and we need to be able to understand and recreate this. Second, our hearing system is designed to give us information about where a sound is coming from. This is a basic survival mechanism enabling us to run away from sounds associated with danger (e.g. a stampeding woolly mammoth, or an approaching fast car). Our sense of direction is very finely tuned, and for convincing surround-sound we need to know more about how our ears give us this directional information.

## IMPULSE RESPONSE OF A ROOM

The size, shape and materials of a room all play a part in the quality of any sound heard within it. Imagine a gun being fired inside a large room or hall. This short, sharp and very loud event causes variations in the air pressure (known as **compressions** and **rarefactions**) that are transmitted through the air itself, spreading out into the room in every direction — a **sound wave**.

Figure 1 shows how a sound wave travels across a room. When it strikes objects in the room, it is

**GCSE key words**
Sound waves
Reflection
Diffraction

Will and Deni McIntyre/SPL

# around us

partially **absorbed** and partially **reflected**. There may also be **diffraction** effects, where the sound bends round an object or passes through a gap (such as an open door), resulting in further spreading of the original sound wave. It is because of diffraction that we can hear through an open door or window. Very quickly (within 100 ms) the sound from our gunshot has spread through the room, having been reflected, absorbed and diffracted, resulting in a very complex and random pattern of sound.

## MEASURING SOUND

The example of a gunshot sound is used because it contains all the audio frequencies in which we are interested at equal amplitudes. We can describe the complex way the room affects this sound using a single measurement called the **impulse response**. We measure the variation in air pressure using a microphone (or just by listening to the sound) at a point in the room. We can examine how each frequency has been changed by its interactions with the room.

The impulse response itself is not very interesting to listen to. It lasts anywhere between 0.1 and 10 seconds depending on the size of the room and how reflective the surfaces are, and sounds like a click with a prolonged and decaying tail. This decaying part of the impulse response is due to the **reverberation** present in the room and is the characteristic 'hanging on' quality of a sound that can be heard once the sound source itself has become silent. Reverberation can, for example, be heard quite clearly in an empty church. It is possible to take this very boring sound and combine it electronically with any other sound — for example, a piece of music. We can make the music sound as though it is coming from inside any particular space, as long as we know the impulse response of that environment.

The impulse response of a room can be measured directly, but for most applications it is more practical to calculate an approximation using an acoustic model. Figure 2 (above) shows how the acoustics of a room can be modelled using a computer simulation.

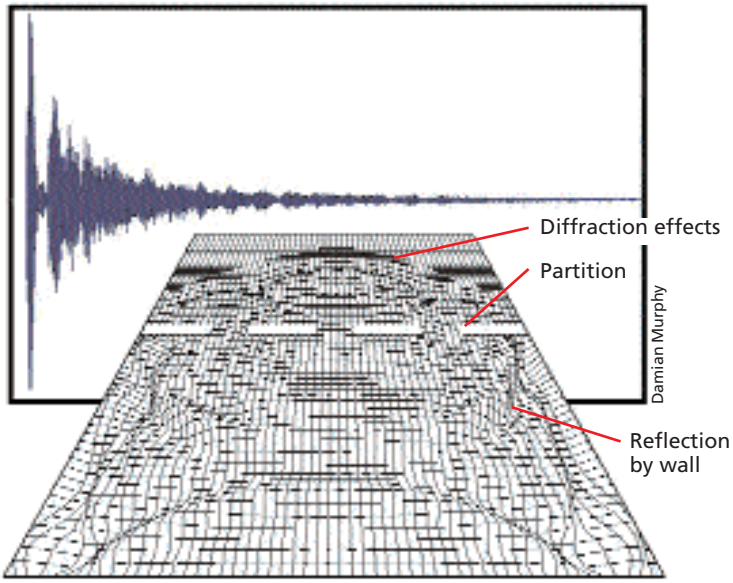



***Figure 2*** *A sound wave caused by the computer equivalent of a gunshot propagating through a mesh structure that is designed to simulate a room. Notice the reflections at the boundaries and the diffraction effects in the partitioned area, caused by gaps in the dividing wall. In the background is a typical room impulse response obtained from such a model.*

**● Most pop music vocal recordings take place in small rooms or booths yet the results we hear on a CD have a very different acoustic characteristic. What do they sound like? Why do you think this is?**

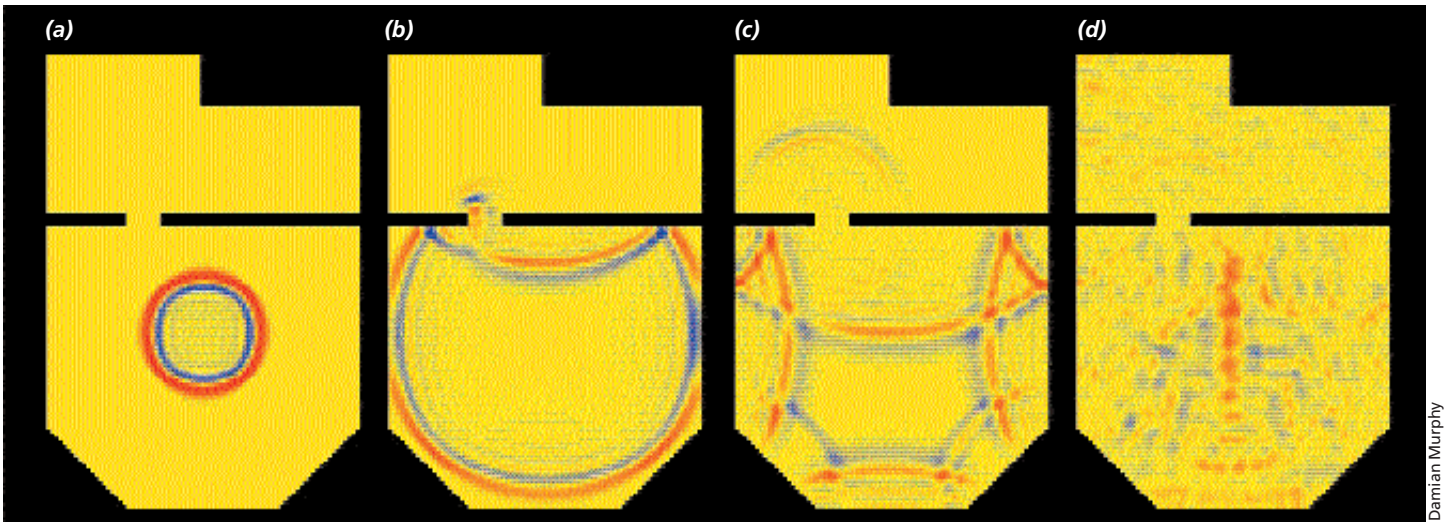
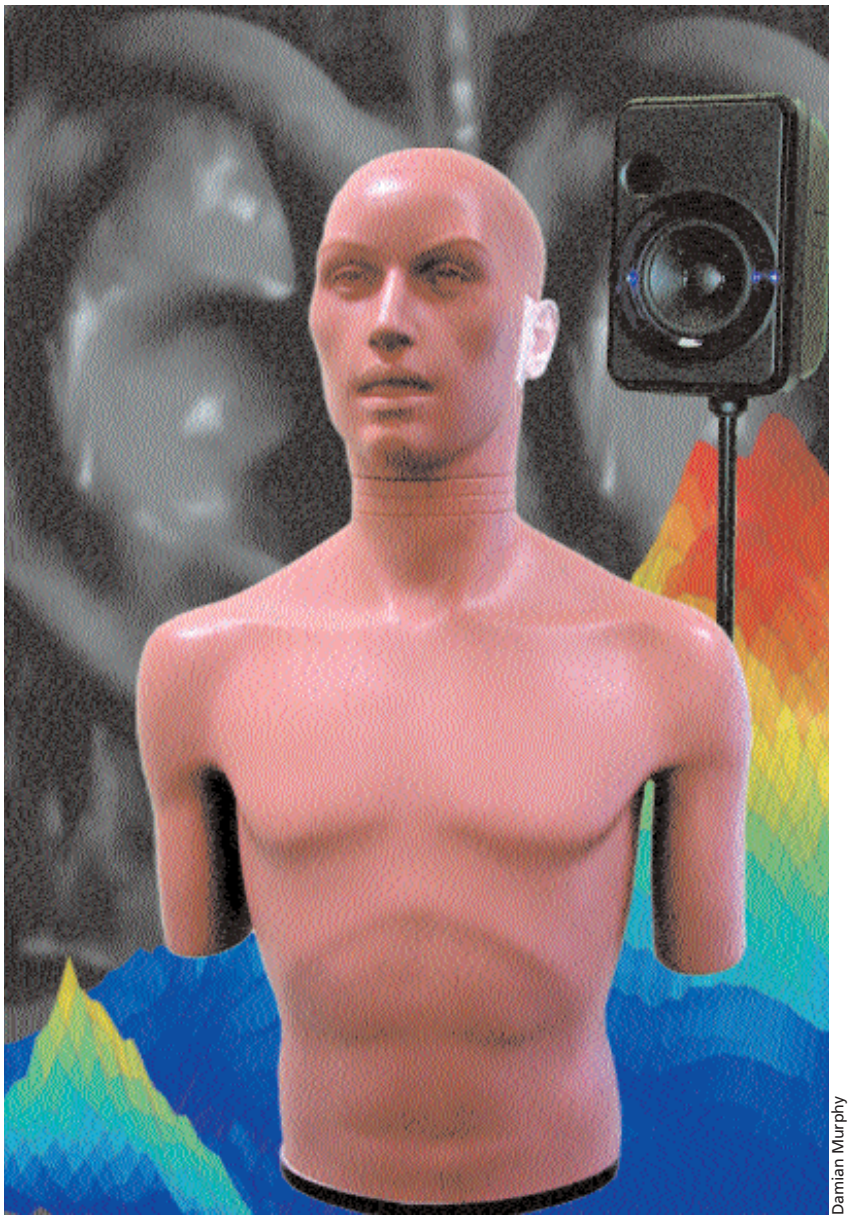



***Figure 1 (a)*** *A sound wave spreads out into the room.* ***(b)*** *It is partly reflected and partly absorbed by the walls.* ***(c)*** *It is diffracted as it passes through a doorway into the room beyond.* ***(d)*** *After a while, both rooms are filled with a random jumble of low-amplitude sound waves.*



Damian Murphy

**Some owls have one ear higher than the other. This is thought to give them a better three-dimensional picture of the sounds around them in a dark wood.**

***Figure 3*** *A mannequin and speaker used in the measurement of the head-related impulse response. A dummy is often used because it stays still when the measurements are being made. In the background is a three-dimensional graph of the measured head-related impulse responses showing how frequencies vary with the direction of the sound, and also a model of the outer ear.*

## IMPULSE RESPONSE OF THE EAR

Just as the room around us affects the sounds we hear, so does the shape and structure of our head, but on a much smaller scale.

A sound coming to us from one side arrives at one ear slightly before the other and its amplitude is different at each ear. Sound waves diffract around the head, and undergo minute reflections in the pinnae (the fleshy parts of the outer ears). This alters the frequency content of the sound that reaches the eardrums and is how we know which direction the sound has come from.

Every person's head affects sounds in its own way because we all have heads and outer ears of different sizes and shapes.

If we measure the room impulse response at the entrance to the listener's ears we can find out how sounds are affected by both the room and the listener's head and ears. It can be electronically combined with any audio source. A sound can then be placed at any position in a three-dimensional virtual space around the listener's head, and reproduced using only headphones (or stereo speakers) (see Figure 3).

Damian Murphy

*Damian Murphy with the mannequin head.*

## THE GOAL

Sound research can be valuable in producing aids for both visually and hearing-impaired people, for example:

- improved hearing-aids;
- audio guides for popular tourist attractions;
- computer interfaces that translate visual information into a virtual surround-sound space by placing 'audio icons' around the listener's head.

The ultimate scientific goal in surround-sound is to electronically generate a complex three-dimensional acoustic world that is indistinguishable from what we normally hear around us. As well as work with the visually impaired, this technology has applications in music composition, sound reproduction, art, architectural design, cinema, telecommunications, user-interface design, television and gaming entertainment. The result is accurate, exciting surround-sound effects.

***Damian Murphy*** *is in the Department of Electronics at the University of York.*

- **Next time you go to the cinema, listen carefully to the sound you hear around you. What can you hear from each set of speakers? How good is the surround-sound effect?**

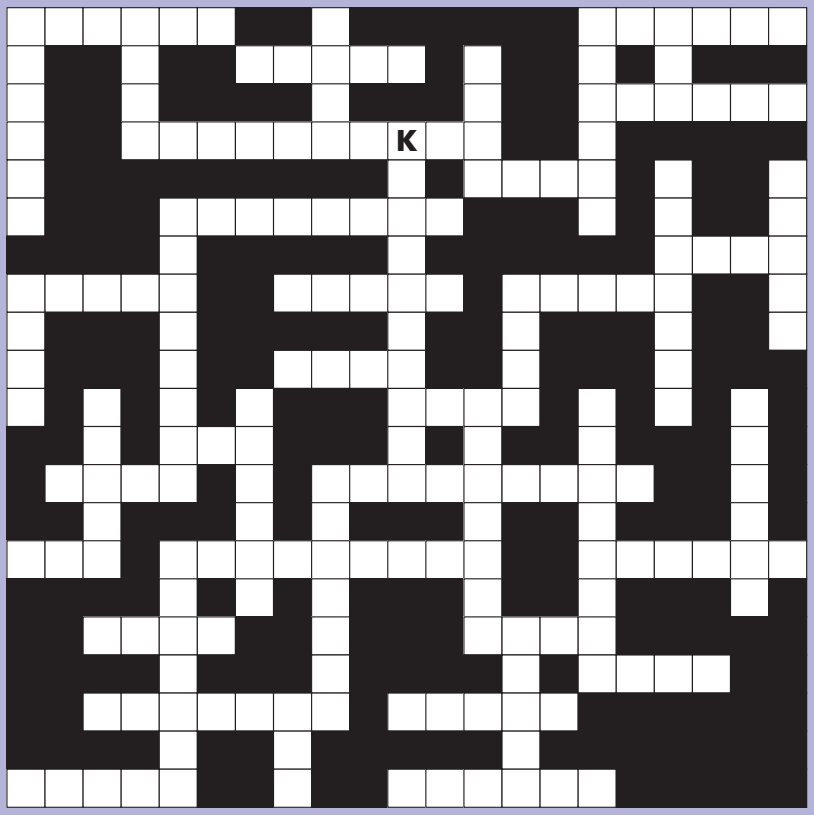
# Investigating sound

Check out some of the ideas in 'Hearing the world around us' (pages 6–8):

- Do your own impulse response test. Clap your hands loudly, once, listen carefully and you will hear the impulse response of the room as your handclap reverberates and quickly dies away.
- You can hear an echo if it arrives at your ears at least 100 ms after the original sound. What is the shortest length of room for us to hear a distinct echo from sound reflecting off the far wall (speed of sound in air = 330 m/s)?
- Why do people like singing in the shower? Think about the physical properties of a typical bathroom compared with those of a living room. What effect will they have on a person's voice?
- We use the differences in timing and amplitude of a sound at each of our ears (together with the position-dependent frequency characteristics) to work out where a sound is coming from. What other physical mechanism (apart from vision) do we use to precisely locate a sound source?
- The fronts and backs of ears have very different shapes. Why do you think this is? Accentuate this difference by cupping a hand round each of your ears. How do the sounds around you change as you move your head around?

# Birds puzzle

Use the words in the list to complete the wordsquare.
Answers on page 15.




**3-LETTER WORDS**
AUK
EMU
JAY
OWL

**4-LETTER WORDS**
COOT
CROW
DOVE
DUCK
HAWK
IBIS
KIWI
LARK
RAIL
RHEA
SWAN
TERN
WREN

**5-LETTER WORDS**
BOOBY
DIVER
FINCH
GOOSE
HERON
MACAW
STORK
SWIFT
WADER

**6-LETTER WORDS**
CUCKOO
FALCON
GANNET
GROUSE
PLOVER
PUFFIN
THRUSH
TOUCAN
TURKEY

**7-LETTER WORDS**
OSTRICH
PELICAN
PENGUIN
SWALLOW
WARBLER

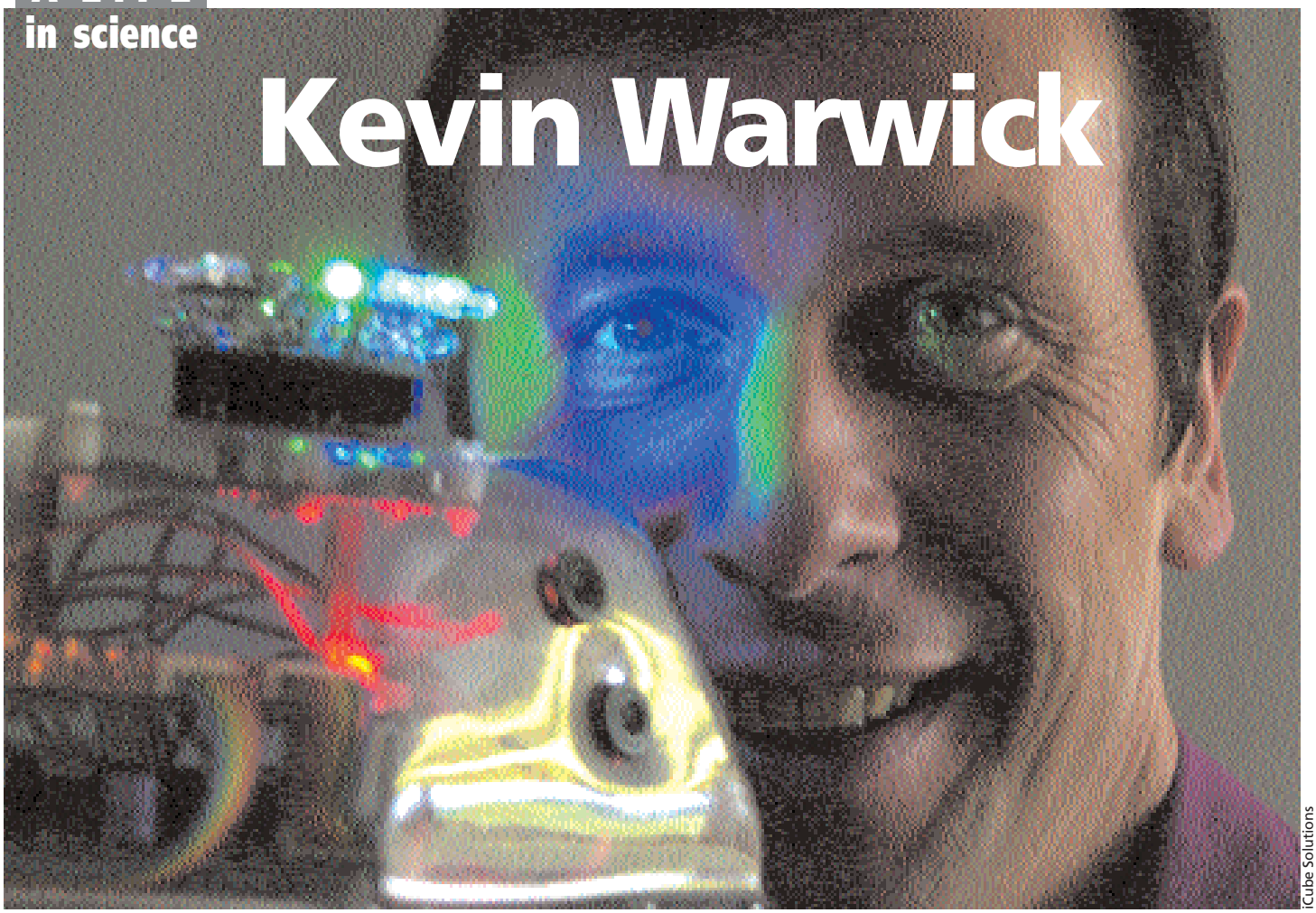
**8-LETTER WORDS**
NIGHTJAR
PARAKEET
PHEASANT

**9-LETTER WORDS**
PARTRIDGE
SPOONBILL

**10-LETTER WORDS**
KINGFISHER
WOODPECKER

A LIFE in science

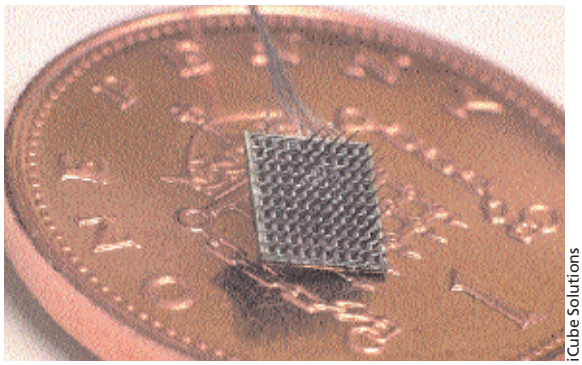
# Kevin Warwick



iCube Solutions

**Norbert Weiner founded the field of cybernetics in the 1940s in the USA. He believed that one day 'nervous prostheses' would be developed which would allow people with spinal injuries to control their paralysed limbs using signals detected in their brain.**

*On 14 March 2002, at 8.30 a.m., an operation was carried out at the Radcliffe Infirmary, Oxford to implant a microelectrode array onto the median nerve in the arm of Professor Kevin Warwick. The surgery, which lasted just over 2 hours, went very well and was declared a success. It was the world's first operation of this type. But what of Kevin's life before this? How did he become the first* ***cyborg*** *— a human and machine joined together?*



iCube Solutions

*The array which was implanted in Kevin's wrist.*

The array which was implanted in Kevin's wrist contains 100 spikes with sensitive tips, each of which make direct connections with nerve fibres. This sophisticated implant allows a two-way connection to the nervous system. In one direction the natural activity of nerves is detected, and in the other direction nerves can be activated by applied electrical pulses. Wires linked to the array have been tunneled up Kevin's arm, and emerge through a skin puncture 15 cm away from the array. These are joined to a novel radio transmitter/receiver device which links Kevin's median nerve to a computer by means of a radio signal.

Such neural connections may lead to medical benefits for a large number of people. In particular they might be used to assist movement in people who have suffered spinal cord injury or limb amputation.

**You may have watched The Royal Institution Christmas Lectures on television. Kevin presented them in the year 2000, with the title 'Rise of the Robots'.**

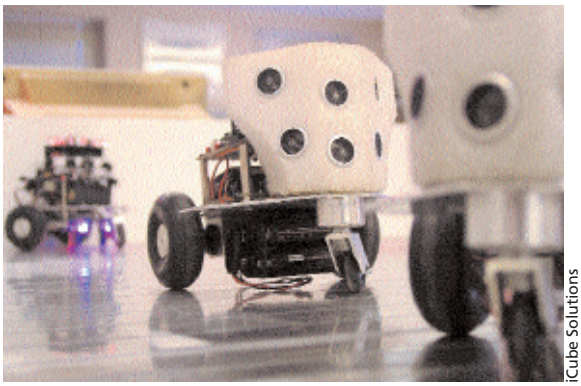
## PUSHING BACK THE FRONTIERS

Dr Kevin Warwick is Professor of Cybernetics at the University of Reading where he carries out research in artificial intelligence, control and robotics. His favourite topic is pushing back the frontiers of machine intelligence.

## BOX 1 A MULTIDISCIPLINARY TEAM

The team working with Kevin has come together from different branches of cybernetics and neurosurgery. Kevin Warwick specialises in artificial intelligence and robotics and Brian Andrews in biomedical engineering, neural prostheses and spinal injuries in the Department of Cybernetics at the University of Reading. Peter Teddy has a long involvement with neural implants and is the Head of Neurosurgery at the Radcliffe Infirmary in Oxford.

These three principal investigators lead a large team of surgeons and researchers including Brian Gardner, Ali Jamous, Amjad Shad and Mark Gasson of the world famous National Spinal Injuries Centre (NSIC)-Stoke Mandeville Hospital.



iCube Solutions

*Three of the Seven Dwarfs, a group of small robots designed by Kevin and his team. Their electronics mimic aspects of the human nervous system.*

*The implant surgery in progress.*

iCube Solutions

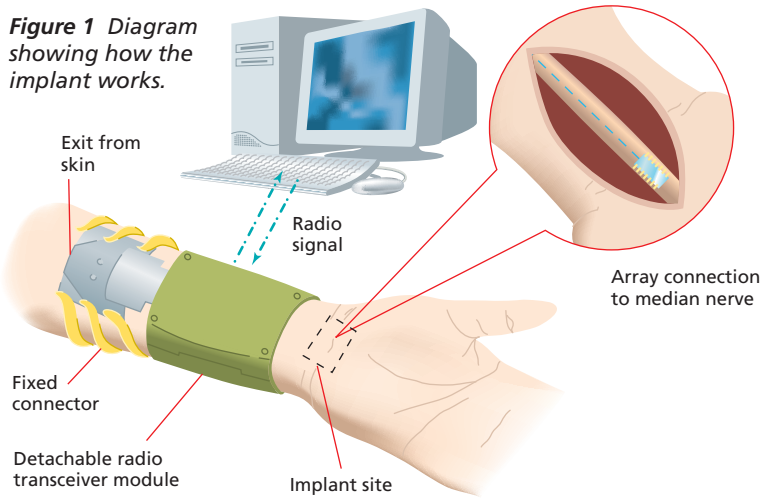



***Figure 1*** *Diagram showing how the implant works.*

Kevin was inspired to start thinking objectively about the human brain when he was a child and his father had a successful neural operation. Reading H. G. Wells and watching *Dr Who* led him to think about what might be possible using machines and science.

Kevin began his career by joining British Telecom, where he worked for 6 years, the first 3 years as an apprentice. He learnt a lot of science by taking motorcycles apart and trying to make them go faster than they should.

At 22 he took his first degree, a BSc in electrical and electronic engineering, at Aston University. This was followed by a PhD and a research post at Imperial College, London. He subsequently held positions at Oxford, Newcastle and Warwick universities before taking up the professorship at Reading in 1988, at the age of 32. He is married and has two children.

## THE FIRST CYBORG

In 1998 Kevin shocked the international scientific community when he had his first implant — a silicon chip transponder in his left arm. The implanted chip emitted a unique identifying signal which allowed a computer to monitor him as he moved through the halls and offices of the Department of Cybernetics. He could operate doors and switch on lights, heaters and other computers without lifting a finger.

This article was written soon after the second operation. You can find updates about what happened on Kevin's website **http://www.kevinwarwick.com**. There is more in Kevin's latest book *I, Cyborg*, which was published in August by Century. This gives more details of his life and the events following on from the implant last March.

Kevin has published over 350 research papers and his paperback *In the Mind of the Machine* (published by Arrow in 1998) warns of a future in which machines will be more intelligent than humans. He has been awarded higher doctorates by both Imperial College and the Czech Academy of Sciences, Prague and has been described by Gillian Anderson of the *X-Files* as Britain's leading prophet of the robot age.

- **Apart from Kevin's own site, you can find out more about cybernetics and the Seven Dwarfs at his department's site: http://www.cyber.rdg.ac.uk/**

- **Longer articles he has written recently are at: http://www.wired.com/wired/archive/8.02/warwick.html and http://www.guardian.co.uk/Archive/Article/0,4273,3954989,00.html**

CHRIS MEAD



# Where have all the skylarks gone?

*Living things can act as biological indicators of problems in the way we are managing our environment. Skylarks and other birds are disappearing from our farmland. How do we know that this has happened, why have they declined and what can we do to encourage them back? Chris Mead from the British Trust for Ornithology has some of the answers, which will be useful when you look at human impacts on the environment in your GCSE science course.*

**GCSE key words**
- Population
- Pesticides
- Human impact on the environment
- Data collection and analysis

If you eat a packet of M&Ms you see the number left in the packet declining — and if you like particular colours best those are likely to disappear quicker! Measuring populations of birds in Britain is a bit more complicated. Birds move around during the year — some spend the winter in Africa — and losses through death may be completely offset by new birds hatching and growing up.

To get up-to-date figures, large numbers of volunteer birdwatchers go out in the summer every year and count the birds on over 2000 randomly-selected plots in all sorts of habitats throughout the country. Each plot is 1 $km^2$ of the National Grid.

## COUNTING BIRDS

Every year the counts are made by the *same* people using the *same* method at the *same* sites. They walk 2 km in a straight line recording everything they see or hear, once during the first half of the breeding season and again during the second half. The results are compiled by the British Trust for Ornithology (BTO) and compared with those from the same site the previous year, to give an overall percentage change from year to year (Box 1). If the change from year to year is small or there are small numbers of records it may not be statistically significant — in other words it could have happened by chance — but many are significant.

This Breeding Bird Survey (BBS) has been operating since 1994 and has shown that, of 96 different species with records from at least 30 plots, more (35 species) had *increased* significantly than had decreased (23 species).

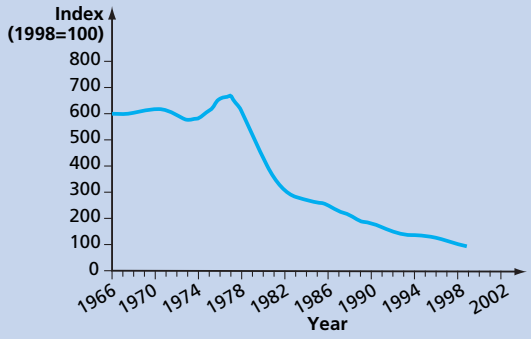
The BBS replaced an earlier survey (Common Birds Census or CBC) that was more limited, covering

### BOX 1 COMPARING YEARS

The BTO surveys are designed to compare populations from different years. One year is chosen as the benchmark and given an index value of 100; all other years are **indexed** on that year. If 1998 was the index year, with 500 birds and, in the same plots, there were 450 birds the next year (1999), the index value for 1999 would be 90. If the number recorded in 1968 was 1000, the index value for that year would be 200, giving a percentage decrease from 1968 to 1999 of 90/200 × 100 = 45%. Table 1 shows these percentage changes.

## GREY PARTRIDGE

The chicks must be able to find insects, like sawfly larvae, if they are to survive their first fortnight. These insects have become much rarer in the last 40 years. Chicks may also be killed by chilling in wet summers, of which we have had many.




Chris Knights/Ardea

***Left:*** *The grey partridge is found on farmland and moorland.*

fewer sample sites and species from fewer habitats. However, it had data across more than 35 years.

## RESULTS

Table 1 shows all species where the population halved between 1968 and 1998. The percentage change in the index is shown for this period for the CBC and for the BBS for the whole of the UK for 1994–2000.

You can see detailed results for other species on the British Trust for Ornithology website at **http://www.bto.org/birdtrends/** Other species are also giving great cause for concern. For instance the lapwing population (also known as peewit, green plover and a host of dialect names) in England fell by 49% between 1987 and 1998.

There are several species where the reasons for decline seem to be clear (see the boxes on this page and overleaf), but detailed research needs to be done to find out exactly why this has happened.

**The government now includes bird populations in the 'Feelgood Factor' indices published each year.**

## HOW AND WHY HAVE BIRDS DISAPPEARED?

Finding out that bird numbers have declined is only the first part of the detective work. Why has it happened? What can we do to get them back?

***Table 1*** *Change in CBC index for selected species*

| Species | Habitat* | CBC change 1968–1998 (%) | BBS change 1994–2000 (%) |
|---|---|---|---|
| Tree sparrow | F, W | –95 | +25 |
| Lesser redpoll | S | –90 | +8** |
| Grey partridge | F | –83 | –22 |
| Corn bunting | F | –83 | –35 |
| Spotted flycatcher[S] | W, F | –79 | –21 |
| Tree pipit[S] | W | –77 | +12** |
| Woodcock | W | –70 | Not calculated |
| Starling | F | –70 | –5** |
| Turtle dove[S] | F | –69 | –24 |
| Willow tit | S, W, F | –66 | –54 |
| Marsh tit | S, W, F | –66 | +45 |
| Song thrush | F, W, S | –60 | +12 |
| Linnet | S, F | –59 | –6** |
| Whitethroat[S] | S, F | –57 | +26 |
| Yellowhammer | F, S | –54 | –12 |
| Skylark | F | –53 | –8 |
| Bullfinch | F, S | –50 | –25 |

[S] Summer migrants.

* Major habitats are F = farmland, W = woodland and S = scrub.

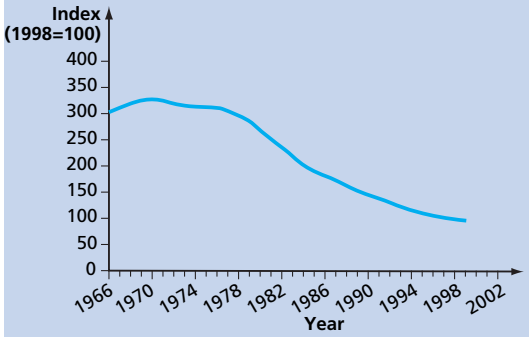
** These figures are not statistically significant.

Peter Laub/Ardea

***Above:*** *A nesting song thrush.*

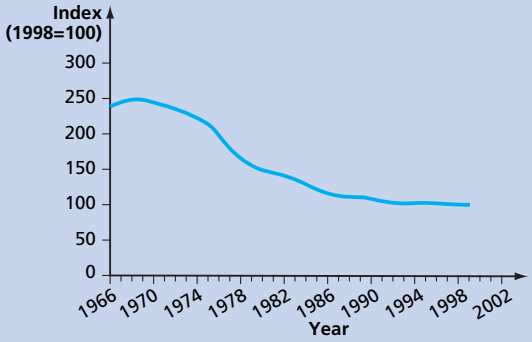
## TURTLE DOVE

Many pairs are breeding better now than they used to (average 0.8 chicks rather than 0.6 per attempt). However they are breeding once a year instead of twice so each pair only rears 0.8 of a chick rather than 1.2.



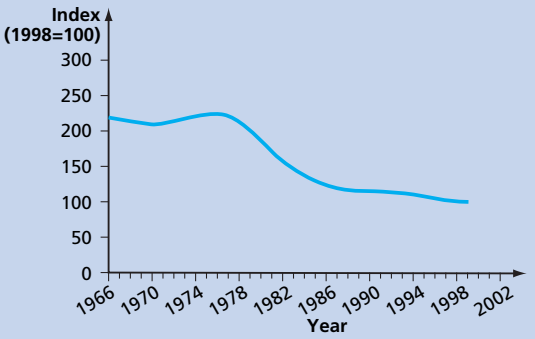

## SONG THRUSH

Survival studies show that the young birds are more likely to die, some time between fledging and the next breeding season. Breeding season research shows that there are fewer breeding attempts than there used to be, possibly because summers are drier. In the last few years damp summers have led to a slight recovery.




## SKYLARK

Skylarks nest on the ground. Many crops are now sown in the autumn for harvesting early the following summer. Such crops are too thick for birds to breed in during the spring. Skylarks feed on seeds which they obtain from the soil in bare winter fields. The seed 'bank' in the soil has been much reduced by use of herbicides and so their winter survival has fallen. Setting land aside from cultivation and planting crops in spring will help them recover.




**Pasture** is grazing land. Some permanent pasture may have been grazed for centuries and has great biodiversity, with wild flowers amongst the grass, and many insects.

In the long term questions like this can only be answered by tackling far-reaching problems to do with the countryside and the working of agriculture.

Many of the species listed in Table 1 live in farmland — some (like grey partridge and skylark) in the open fields, but most of them in and around hedges. Changes in agriculture over the past 40 years have meant that fields have been drained, hedges removed, crops planted in autumn rather than spring and new pesticides introduced to control insects, weeds and diseases. This reduces the number of animal species in the area. Pasture land is mown more frequently and is treated with much greater quantities of fertiliser, reducing the variety of plants growing in it. Crop yields have been increased by these measures but little attention has been given to the needs of wildlife.

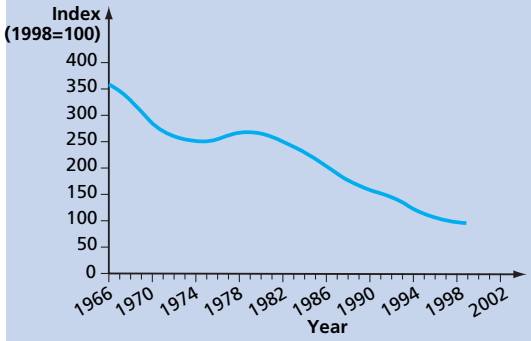
## FARMERS PROTECTING BIRDS

The European Union's Common Agricultural Policy has recently been changed and farmers will now be paid to adopt practices that help wildlife and the environment. These include:

- reducing the amounts of fertilisers and pesticides used;
- leaving 6-metre uncultivated strips round the edges of fields for wildlife;

## STARLING

Adults and young birds seem to be able to survive as well as ever but the nestlings are at risk because they are fed on soil invertebrates, like leatherjackets, whose numbers have been reduced by pesticides.




## BOX 2 HOW BIRD POPULATIONS MIGHT DECLINE

Think about a pair of birds which normally has three broods of young each year with an average of two chicks each. On average, one of the adults and one of the chicks survives to breed the next year. Try out the maths of the following scenarios:

(1) Adult mortality increases and, on average, only 0.9 adults survive.

(2) Juvenile mortality increases and, on average, only 0.8 chicks survive.

(3) Nest survival decreases and only one chick per nest survives to breed.

(4) The breeding season shortens and only two nesting attempts can be made.

See how long it takes for the species to decline by 50%.

These are the kind of changes that we suspect are happening to some species or other: try seeing what happens with other scenarios.

Answer: not very long

(1) 14 years (2) 7 years

(3) 3 years (4) 4 years

- providing uncultivated areas across big fields, to act as beetle banks;
- 'setting-aside' areas, usually whole fields, which are left uncultivated for a season or longer.

All this will take several years to come into effect.

Farmers can also join schemes run by DEFRA (Department of the Environment, Farming and Rural Affairs) which are trying to preserve the special feel of an area like the Yorkshire Dales or the East Anglian Brecklands, or simply helping wildlife in ordinary farmland. They include things like careful management of hedges, planting of farm woodlands and conservation of small wetlands.

Ian Bearnes/Ardea

***Left:*** *Starlings are often found in gardens and urban areas but their numbers are declining.*

**● Species by species accounts for all of Britain's breeding birds from Chris Mead's book can be found at http://birdcare.com/bin/searchsonb**

**Many beetles are useful on farms, preying on crop pests. Beetle banks provide a space for them to reproduce.**

BTO surveys will be worth watching over the next few years to see whether the decline in some of the farmland bird populations described in this article is reversed by more wildlife-friendly farming.

***Chris Mead*** *worked for the British Trust for Ornithology for over 33 years. He was mainly concerned with bird-ringing and has marked over 300 000 birds in Britain, Spain, Portugal, Italy, Senegal, Zimbabwe, Malaysia and Belize. He still carries on bird-ringing and writes and broadcasts about birds.*

## Answers to Birds puzzle, page 9

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FOR debate

Royal Pigeon Racing Association

*Right: A champion racing pigeon. The lighter-coloured birds seem to be more vulnerable to attack.*

*Below: A peregrine falcon. These birds were on the edge of extinction before they were protected. Are they now too much of a threat?*

One winter day in the garden I noticed a flattened spot in the snow circled by a puff of grey pigeon feathers. There were no paw prints in the snow to give a clue about the predator. I was mystified, but my father-in-law was not. 'Hawk strike!' he muttered. He should know — sparrowhawks and other **raptors** are regular visitors to his South Yorkshire pigeon loft, and from time to time they **stoop** on his birds on exercise flights.

Raptors such as peregrine falcons and sparrowhawks feed on garden songbirds, other wild birds, grouse and pigeons. Though many bird species are declining through loss of habitat (see 'Where have all the skylarks gone?' on pages 12–15), bird of prey numbers are increasing as a result of conservation. Flocks of racing pigeons could be a good food source for raptors facing increased competition for sustenance. Racing-pigeon owners are angry about the large number of pigeons they believe are lost to raptors and would like to introduce controls on raptor numbers.

# Pigeons or peregrines?

## Should predators be preserved?

**GCSE key words**
Conservation
Human impact on the environment
Accumulation
Predator

Piers Cavendish/Ardea

**A gamekeeper is someone who looks after young birds bred for shooting in field sports. Preventing predation is part of the job.**

**A raptor is a term to describe birds of prey which pounce on their prey.**

**Stooping describes the way a falcon dives on its prey from above.**

### CONSERVATION VIEW

Some birds of prey became very rare in the 1960s as changes in agricultural practice reduced their numbers. Increasing field size and changes in crops and cultivation techniques reduced the numbers of the small birds and mammals they predated. Pesticides accumulating through the predator food chain eventually reached concentrations that affected their reproduction. Gamekeepers shot or trapped birds believed to take pheasants and grouse reared for shooting. It seemed possible that a significant section of our wildlife would completely disappear.

Legislation was introduced to protect particular birds of prey — it became illegal to shoot them, damage the nests, take them from the wild for falconry, or to collect and trade in birds' eggs. Pesticides such as DDT that had harmful effects in the food chain were restricted. Bird conservation bodies protected breeding pairs and raised public awareness for the cause. Captive-bred birds like the red kite were reintroduced to areas where they had died out. As a result birds on the edge of extinction, such as peregrine falcons, have increased to secure numbers.

Richard Howey

**One study estimated that 50 breeding pairs of peregrines in the South Wales valleys will kill almost 12 000 racing pigeons each year. How could an estimate like this be checked?**

*A racing pigeon killed by a raptor.*

## PIGEON-FANCIER'S VIEW

Numbers of many garden birds are declining dramatically and increasing numbers of racing pigeons are going missing during races and training flights, including experienced birds which are less likely to get lost. Pigeon owners blame raptors. When a peregrine falcon stoops on a flock of pigeons the birds disperse in all directions to escape. The falcon may take one bird but others are lost as they fly off in different directions for some time, go to ground or take refuge in trees, perhaps staying overnight, short of food. Scared pigeons may take up with wild flocks of pigeons.

Racing pigeons are ringed with an identification number, and pigeon fanciers claim that hundreds of rings have been found in areas where raptors are established. Races passing through areas where raptors have been successfully conserved are at high risk. Where predators live near traditional race release points they are attracted by the circling flocks of pigeons seeking direction. Pigeons struggle home with bloody feathers and torn flesh having survived raptor attacks, and pigeon owners are as fond of their pigeons as you are of your pets. There is an economic loss too. Pigeons can be very valuable, changing hands for thousands of pounds, apart from the prize money.

What can the fancier do? Some are experimenting by using dark-coloured birds for better camouflage. Some argue they should stop racing for two seasons — if raptor numbers fall it suggests that they need pigeons to survive. There may be other reasons for reduced pigeon numbers — perhaps pigeon breeders selecting for speed and homing ability have accidentally been breeding more stupid pigeons over the last few years, or maybe the increase in electrical appliances and power cables is upsetting the birds' magnetic navigation system.

Royal Pigeon Racing Association

*Birds of prey living in places where races start are a particular threat.*

## THE ISSUE

All over Europe projects are underway to encourage diversity and return species to the wild in regions where they have died out. In the Jura region of France, captive-bred lynx are being released, while elsewhere bears and wolves are protected. Returning wolves to the wild in Scotland has even been discussed. But is this automatically 'a good thing'? A valid argument against the reintroduction of beavers in Scotland is that ecosystems have found a new balance since they died out 300 years ago. This balance would be disrupted if beavers were returned.

What about the balance in your locality: foxes, kestrels and grey squirrels thrive in our urban environments? Would you want to see it changed? Far more species have died out and been replaced during the Earth's history than are alive now: what is the evolutionary view? How would you feel if a predator were introduced to your area and your pets couldn't go out without the risk of being eaten? Farmers are also not keen to see the return of predators and would require compensation for losses.

What do you think?

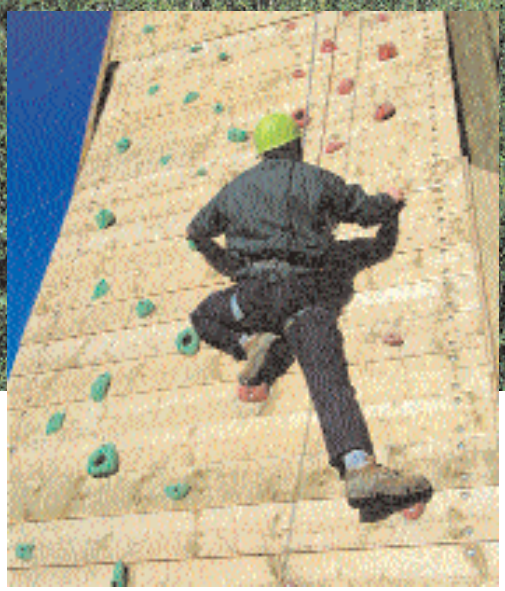
*Jane Taylor teaches biology and is an editor of* CATALYST.

- **If you find a pigeon with a ring, or just the ring, contact the Royal Pigeon Racing Association at http://www.rpra.org**

- **Visit the RSPB website http://www.rspb.org and search for 'pigeons'; or SongBird Survival at http://www.songbird-survival.org.uk for differing views on protection of birds of prey.**

# Earth Centre

*Many of the topics you study as part of your GCSE science course, for example, global warming, acid rain or resource depletion, tend to be presented as huge problems we as individuals are powerless to do anything about. The Earth Centre near Doncaster is a unique and imaginative hands-on visitor attraction which demonstrates that we can do something.*



***Above:*** *Our energy-efficient conference centre.* ***Right:*** *Climbing is one of the activities available at the centre.*

The Earth Centre opened in 1999, its construction transforming the badly scarred and polluted land that had been the site of two coal mines. Its unusual buildings, exhibitions, demonstrations and lovely gardens invite visitors of all ages to discover the idea and reality of enjoying a better quality of life without harming other people or the environment.

Over the last 3 years the Earth Centre has welcomed educational groups from all parts of the UK, as well as overseas parties from mainland Europe and North America. A science day here might see you doing any of the following:

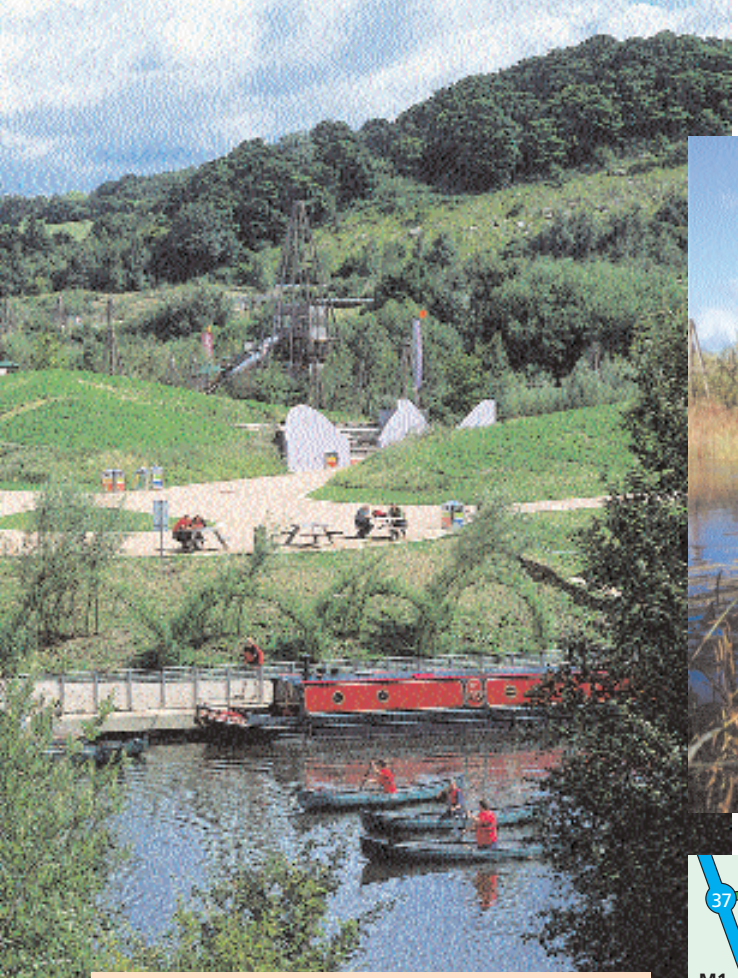
- investigating energy with a journey from fossil fuels to renewable energy possibilities;
- building and experimenting with our 'solar buggies';
- expending some energy with your friends riding on our seven-seater circular bike;
- investigating our energy-efficient buildings and devices;
- looking at food chains and webs by actually building your own live food chain in a jar;
- becoming a drop of water and experiencing the water cycle in our 'white knuckle' simulator ride;
- watching sewage being digested in our tropical greenhouse and seeing how we reduce the problem of eutrophication with our 'bio-fence'.

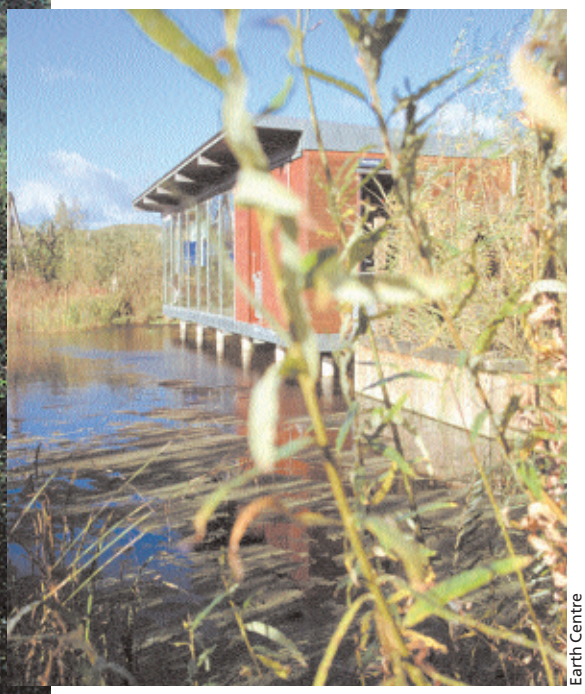
## VISITING THE CENTRE

The Earth Centre is in South Yorkshire, between Sheffield and Doncaster, at Conisbrough (see Figure 1). It is signposted from the motorways if you are travelling by car, or you can take on board the Earth Centre's sustainability message and travel by local bus from Sheffield, Rotherham or Doncaster.

If you are walking or cycling the Trans-Pennine trail you will pass right by the centre, and if you are on a narrowboat holiday you can tie up at the Earth Centre's wharf for a visit — although you must ring first for a mooring. The wharf is also used for trips down the River Don from the centre.

The centre holds cycle events from time to time, with some weird and wonderful bikes. Cycles are important in managing the centre — they are used by the staff to get about and do things like emptying the bins.





Earth Centre

***Far left:*** *The Earth Centre with the River Don in the foreground.* ***Left:*** *Natureworks.*

## BOX 1

**Sustainability** is the main focus at the Earth Centre — at the heart of its construction as well as its activities. This region of South Yorkshire was once famous for its steel industry, coal mining and metal smelting so restoring the site involved land remediation and reclamation. Soil was made using a mixture of organic materials: sewage sludge, farm manure, mushroom farming waste and other sorts of green manures. Recycled wood and steel were used to build the structures.

Visitor wastes are recycled or composted. The landscape was designed to recreate natural habitats that encourage repopulation by native species of animals, such as the grey partridge (see page 13), and plants. The woodland is managed for sustainability.

## A DAY VISIT...

The centre is open between 10 a.m. and 4 p.m., longer in the summer, with short tours available during the middle part of the day for an extra payment. Tokens are needed to pay for some activities and rides and these can be bought separately or as a package with the entrance fee. Activities include canoeing, climbing, abseiling, zip-wiring, archery, team-building and mountain biking.

Admission charges are:
Adults: £4.50
Under 16s: £3.50
Under 5s: free
Family tickets are also available

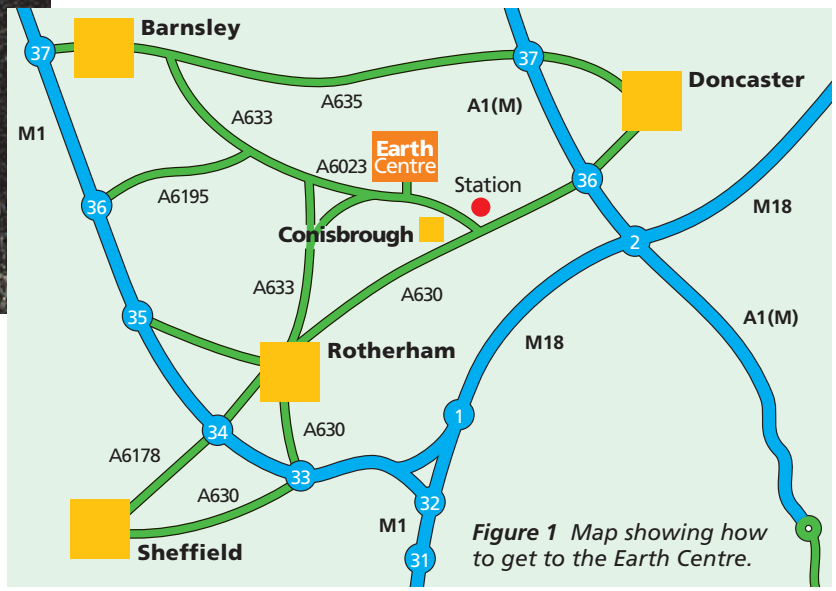



***Figure 1*** *Map showing how to get to the Earth Centre.*

## ...OR COME AND STAY

Because there is so much to do in one day, last year the centre introduced a residential package with a difference. Students stay in luxurious en-suite accommodation, and experience workshops and the wide range of adventure activities listed above to create a truly dynamic experience. There is a well-equipped computer suite, and digital cameras are provided to document your discoveries.

If you would like to find out more about the wide range of activities available at the Earth Centre, visit **http://www.earthcentre.org.uk**

***Steve Bowles*** *is Education Manager at the Earth Centre. Before taking up this post he was Head of Science at a secondary school.*

**Teachers can request a schools' pack by telephoning the bookings team on 01709 513944.**

# Chemical engineering

*Do you have a mobile phone? Do you wear trainers? Do you use hair wax or gel? All these products depend on chemical engineering. And here is something else that may surprise you — chemical engineers also save lives.*

Chemical engineers help in the manufacture of products and components of products that have an impact on all our lives. They develop the processes that create fuels to power our industry, homes and cars. They develop dyes and specialist fabrics for the clothes and shoes we wear.

They even developed the process by which microchips are made for mobile phones. These start life as grains of sand, and chemicals, gas and gold have to be added under the right conditions and at the right time in the process to make the chip. The products of chemical engineering are all around you.

## SAVING LIVES

Usually we think of doctors, paramedics and nurses as the people who save lives, but chemical and biochemical engineers are also involved in developing the drugs and treatments that modern medicine depends upon. For example, they are currently working on ways of growing replacement body parts for transplant, including healthy bone marrow for treating conditions such as non-Hodgkin's lymphoma and leukaemia, as well as advancing radiography treatments for cancer.

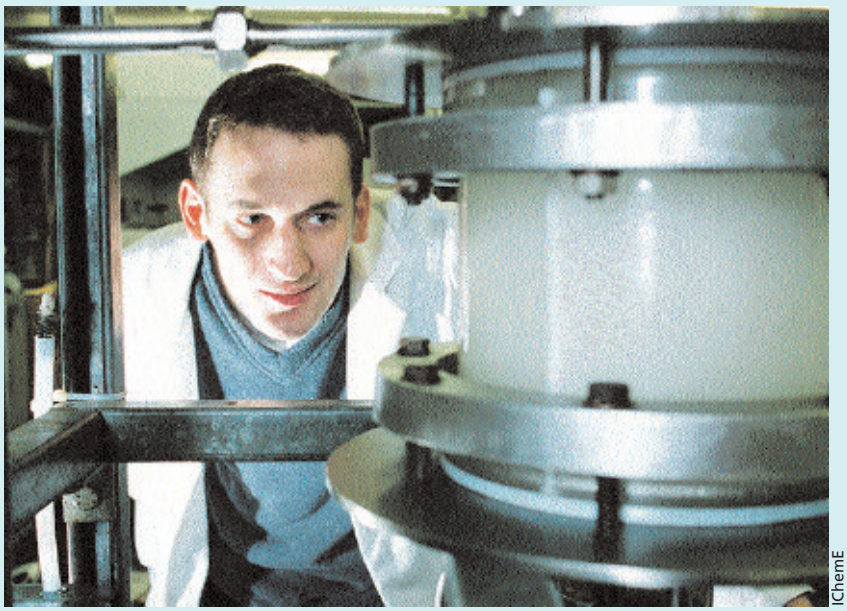
The case studies in Boxes 1 and 2 give an insight into what a career in chemical engineering is like.

## SKILLS AND INTERESTS

Chemical engineers often work as part of a team, and are required to have good social skills. They face stiff challenges that demand excellent problem-solving and analytical skills, plus a dose of imagination. Chemical engineers are also highly IT-literate, as much of their work uses computers.

## REWARDS

Chemical engineers earn, on average, more than similarly qualified accountants, chemists, software engineers and architects. In addition to the high financial rewards, chemical engineers are regarded as



IChemE

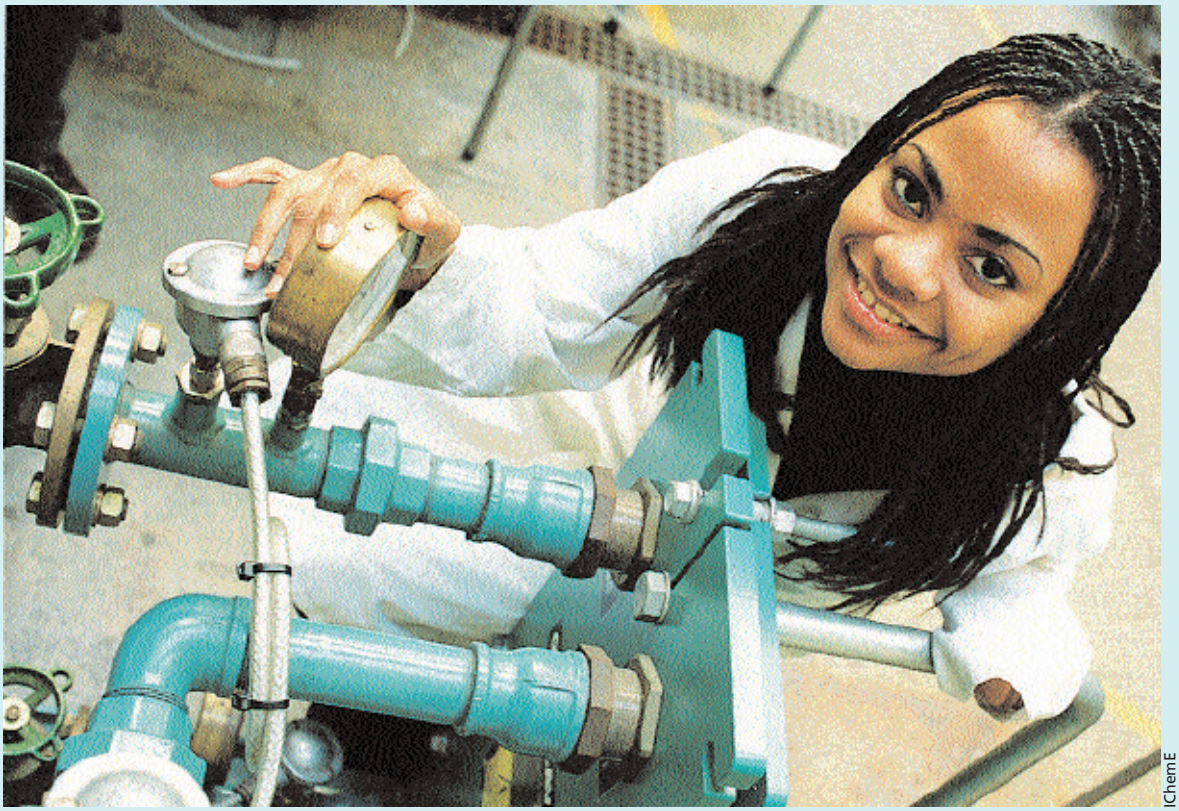
### BOX 1 SUSHIL ABRAHAM, LONZA BIOLOGICS, NEW HAMPSHIRE, USA

Biotechnology is a really fast-growing sector that is making huge developments all the time. Choosing to study biochemical engineering was one of the best decisions I ever made — it's extremely dynamic and the job prospects are fantastic.

At the moment I'm working in the States for Lonza Biologics. I develop processes that happen in the laboratory into large-scale manufacturing. This means working out what the processes are, and what machinery will be needed to achieve the finished pharmaceutical product.

I deal with lots of people on a daily basis— everyone from scientists to suppliers, which keeps me up-to-date with the latest developments. I really enjoy being able to work in a team, which is just as important as being able to manage and supervise other staff.

My job is challenging and the rewards are excellent. I know that I'm contributing to society by providing badly-needed drugs and treatment. How many other people get to see their project through from start to finish?



IChemE

*The photographs show students on chemical engineering courses getting hands-on experience of monitoring processes.*

professional 'high flyers', and have the potential to gain Chartered Chemical Engineer status.

## HOW TO QUALIFY

The preferred route to becoming a chemical engineer is to gain a degree accredited by the Institution of Chemical Engineers. Ideally, you need to consider MEng chemical engineering degree programmes.

To be accepted on an accredited degree course, you will need good GCSE results and A-levels in mathematics and chemistry, with physics if you want to study chemical engineering, or with biology to study biochemical engineering. There are some alternative routes and you should approach universities for further information.

## BOX 2 PHIL SOUTHERDEN, BP CHEMICALS, LONDON, UK

When I was at school I had no firm idea about what I wanted to do as a career so I chose chemical engineering to keep my options open.

I have worked both in the UK and abroad and have constantly been faced with new development opportunities and challenges as I moved from project to project.

The highlight, so far, has been working as the main process engineer on a BP site in Indonesia to fit the first large-scale operation of the next generation of catalyst to their existing plant, which was a great success.

My job involves travel, meeting people and gives me a huge amount of independence and responsibility.

## ONE DEGREE, MANY CAREERS

Chemical engineering is a well-respected degree that opens many career paths. Many graduates are attracted by highly-paid jobs in the City and the bank HSBC is the biggest employer of chemical engineers. Employers appreciate that graduates of chemical engineering have analytical and problem-solving skills that are second to none. Careers within chemical engineering are equally diverse — industries you could work in include: food and drink, oil and gas, pharmaceuticals and tissue engineering.

## FURTHER INFORMATION

**http://www.whynotchemeng.com** carries more information about chemical engineering and case studies of real-life chemical engineers. It also links to the websites of all UK universities offering accredited chemical engineering degree courses, and a sample of major industrial employers.

Information packs are available from: The Institution of Chemical Engineers, Davis Building, 165–189 Railway Terrace, Rugby, CV21 3HQ, tel. 01788 578214.

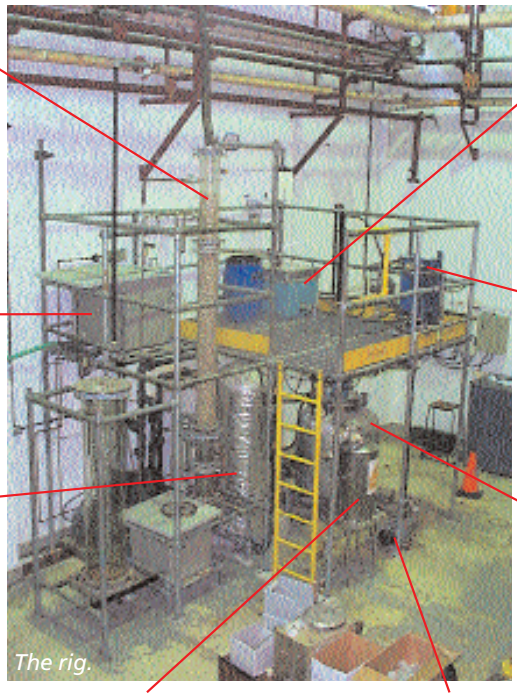
***Louise Robinson*** *works for the Institute of Chemical Engineers where she is Marketing Executive and Project Leader for* **whynotchemeng** *website.*

**An aspect of chemical engineering is featured on the back page — a rig which was designed and built purely for teaching purposes. If you were to take the chemical engineering course at Surrey University you would learn by experience on this rig.**

# Chemical plant

*The reactor vessel.*

This rig includes many features of a larger-scale chemical works, such as control of feed materials to reactions, a reactor vessel and all sorts of monitoring and control systems. It is used to train people at many different levels, including prospective chemical weapons inspectors for the United Nations.



*The rig.*

Carbon dioxide is removed from the gas stream by the **carbon dioxide scrubber** so it is not released to the atmosphere

The finished product collects in the **product tank**

The **heating vessel** contains two electric heaters which heat the water circulated around the reactor vessel to control its temperature

The solid calcium carbonate that precipitates out is removed by the **main process filter**

The **solid feed hopper** has a screw feeder which can be turned at different speeds to control the rate of solid feed to the process

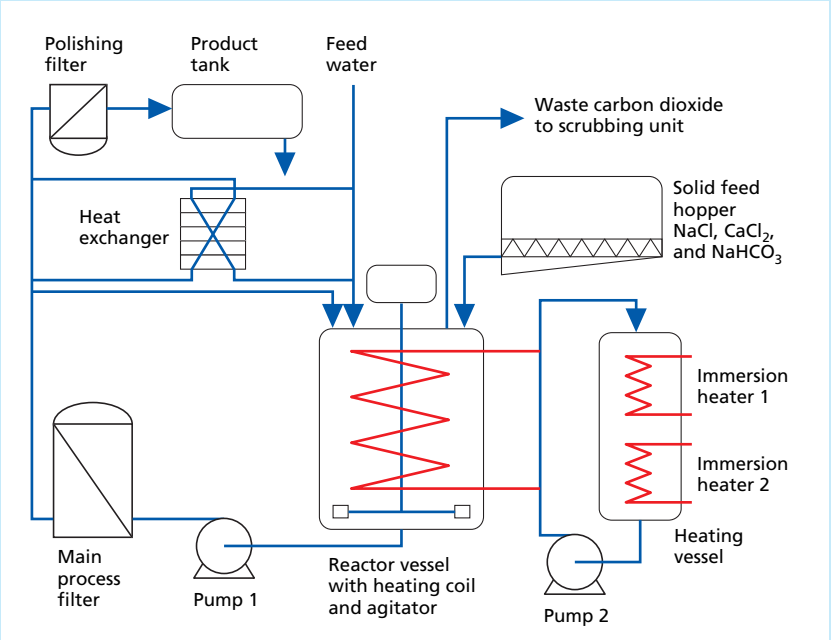
In the **heat exchanger** the feed water is preheated using heat from the product stream

All the reactions take place in this heated **reactor vessel**. It has an agitator (stirrer) to aid mixing

The **pump** circulates the liquid exiting the reactor vessel

The rig itself produces a highly pure sodium ion solution which could have applications in the electronics and pharmaceuticals industries, among others.

The feedstocks to the process are rock salt (solid sodium chloride with a small percentage of calcium chloride contaminant), sodium bicarbonate and water. These feedstocks react together in the reactor vessel, according to the process chemistry below, and the precipitated contaminant is removed from the solution by filters. A high-quality sodium and chloride ion solution is produced.




## PROCESS CHEMISTRY

The sodium bicarbonate thermally decomposes:

$$2NaHCO_3(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l) + CO_2(g)$$

The sodium carbonate then reacts with the calcium chloride contamination in the feed:

$$Na_2CO_3(aq) + CaCl_2(aq) \longrightarrow 2NaCl(aq) + CaCO_3(s)$$

The solid calcium carbonate can then be removed from the system by the filter, leaving a pure salt water solution as required.

- **Match the components in the diagram with the photograph of the rig.**