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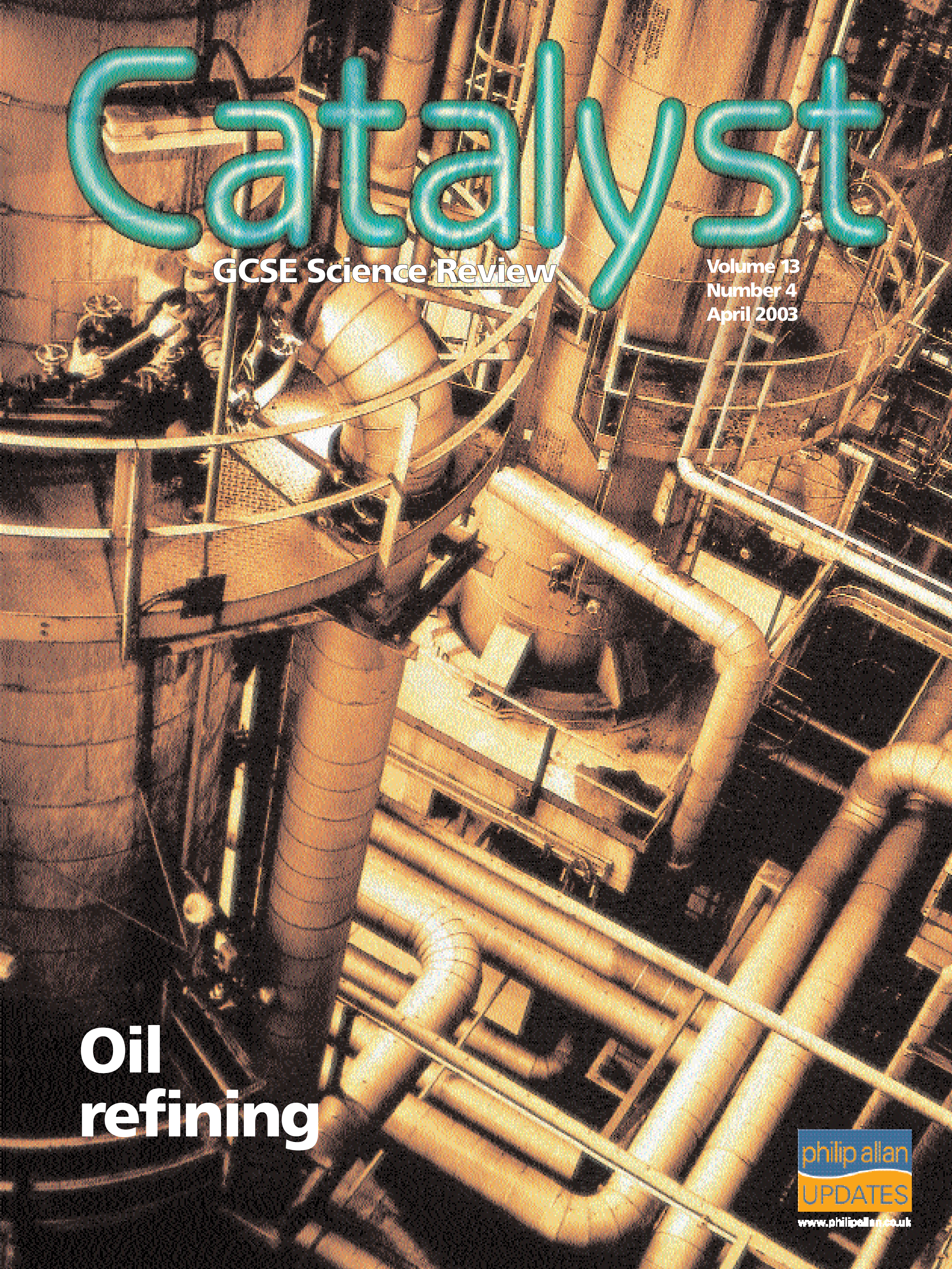

Oil refining

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The front cover shows part of an oil refinery (Simon Lewis/SPL).

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Editorial

The double helix

The structure of DNA was first described 50 years ago. On 25 April 1953, James Watson and Frances Crick published their account of the double helix. It was a short note filling one page of *Nature*, a weekly scientific journal in which many firsts in science have been published. We will be marking the anniversary of the discovery of DNA's double helix with some special articles next September.

DNA has two key features — it contains information (in the form of coded instructions for assembling proteins) and it has the capacity to replicate (make copies of) itself. Watson and Crick had spotted this probable method of copying and commented, 'It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.'

Since 1953 DNA and genetic engineering have often been in the news — in stories about food (genetically modified crops), health (genetic disorders and gene therapy), crime (genetic profiling or fingerprinting) and gene patenting. These subjects, together with related topics such as cloning, often raise ethical issues.

A recent landmark was the publication of the first draft of the human genome sequence, our entire genetic coding, on 15 February 2001, again in *Nature*. Sections of the code had already been published, some of them on the internet to ensure easy access for research scientists everywhere.

DNA lies at the heart of our existence and is entwined around our futures. The editors wish you success in your GCSE science examinations and hope that Catalyst has helped you towards this. And if you see science as a path you wish to follow, maybe you will be helping to unravel further mysteries of the wonderful double helix in a few years' time.

Nigel Collins

MICHAEL DOCKERY AND STEPHEN TOMKINS

A life in brine

Brine shrimps can easily be kept in a jar or aquarium. This article explores some aspects of their lives which are relevant to your GCSE science course.

A brine shrimp seen from above.

Astrid and Hanns-Frieder Michler/SPL

Brine shrimps are sometimes sold under the name 'sea-monkeys' but they are never found in the sea and are not related to monkeys. So what are they and where do they live? Brine shrimps are small feathery Crustacea (Figure 1) that live in salt water (brine) lakes. This brine may be even saltier than the sea. The shrimps swim about incessantly on their backs. They feed by using their leaf-shaped legs to gather microscopic algae from the water.

Salt lakes are formed in hot countries in places where rivers do not have an outlet to the sea but run into lakes. The lake water evaporates quickly, concentrating the salts that are dissolved in it. One such lake is Lake Utah, USA, near Salt Lake City.

In Bangladesh, brine shrimps are grown by the million in huge salt pond farms. They are used to feed prawns that are farmed for human food: so algae, shrimps, prawns and people make a simple food chain.

LIFE CYCLE

Brine shrimps are tiny when they hatch but grow to around 1 cm in length in just 2 weeks. They have two small eyes on stalks on their heads and one eye in the middle of their foreheads. They have two pairs of antennae, 11 pairs of leafy legs (phyllopodia) and they swim upside down. Brine shrimps filter minute single-celled green algae from the water. The shrimps are transparent so you can see the algae inside their guts.

After 2 or more weeks the shrimps are adults and pair up. Males are white or greeny-blue, with long clasping antennae which they use to hold on to their partners. Females are white to orange in colour, with smaller antennae, and they carry a big egg sac on their abdomens. The male and female swim together for several hours, even a few days, before they mate.

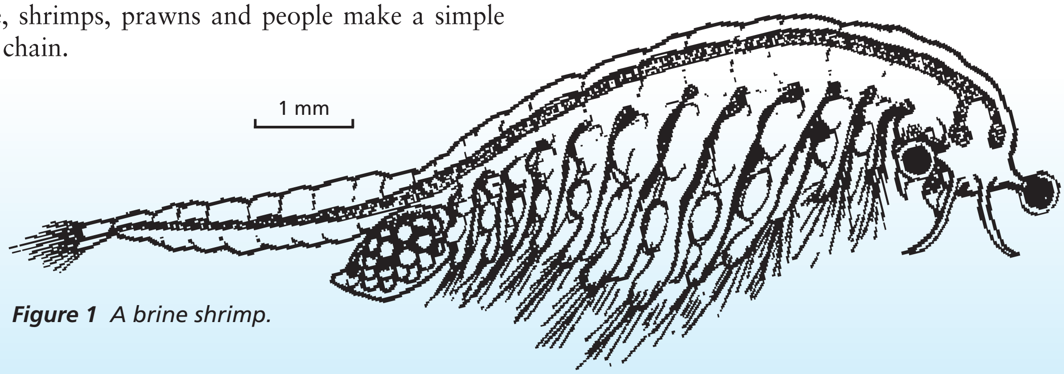
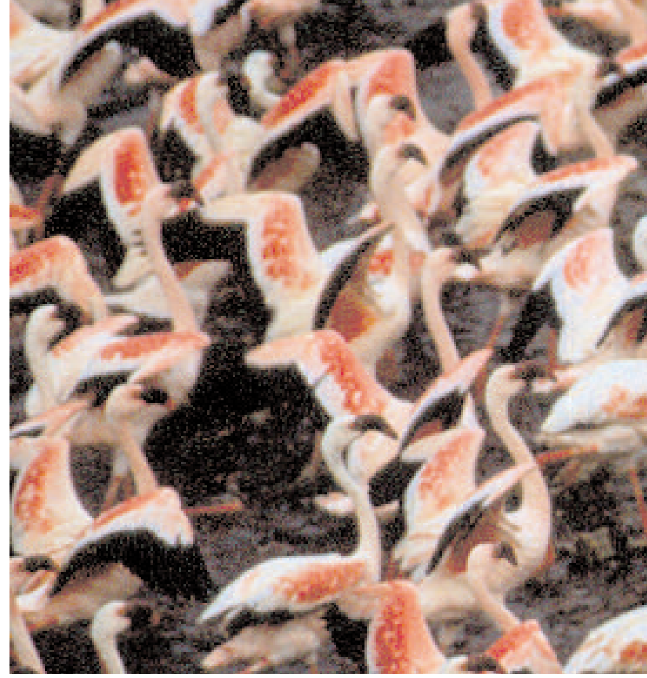


Figure 1 *A brine shrimp.*

GCSE key words
- Osmosis
- Active transport
- Producer
- Consumer
- Food chains and webs

• Look up 'sea monkeys' in an internet search engine and prepare to be amazed!

Brine shrimps are rich in protein, fats and carotenoid pigments. The carotenoids are photosynthetic pigments in the algae. The pink colours in the feathers of the flamingo come directly up the food chain from this algal source. This is an example of bioaccumulation.



Dr Jeremy Burgess/SPL

Male and female brine shrimps swimming together.

Michael Dockery

Above: *Electron micrograph of hatching brine shrimp egg-cysts. Their thick walls, clearly visible, allow them to survive dry conditions.*

You can observe this 'mate guarding' easily yourself (see Box 2). Mating itself happens very quickly.

Male brine shrimps seem to be attracted to larger females. This may be because larger females are able to produce more eggs and therefore more offspring. Females get a powerful boost from swimming with a bigger, faster male. This helps them to gather more food — and perhaps to escape being eaten.

Females may produce about 20 young each week. They can be in two possible forms — either a swimming nauplius (*naw-plee-us*) larva or a dormant egg-cyst.

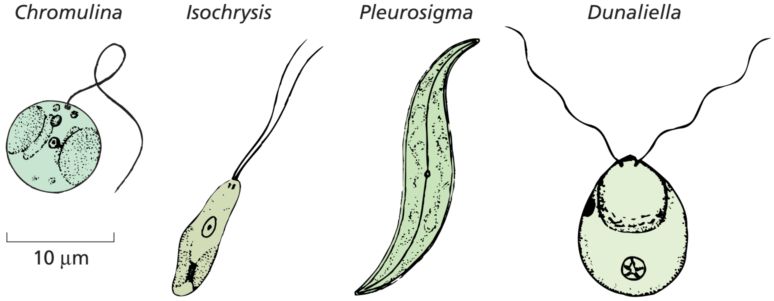


Figure 2 *Algae eaten by brine shrimps.*

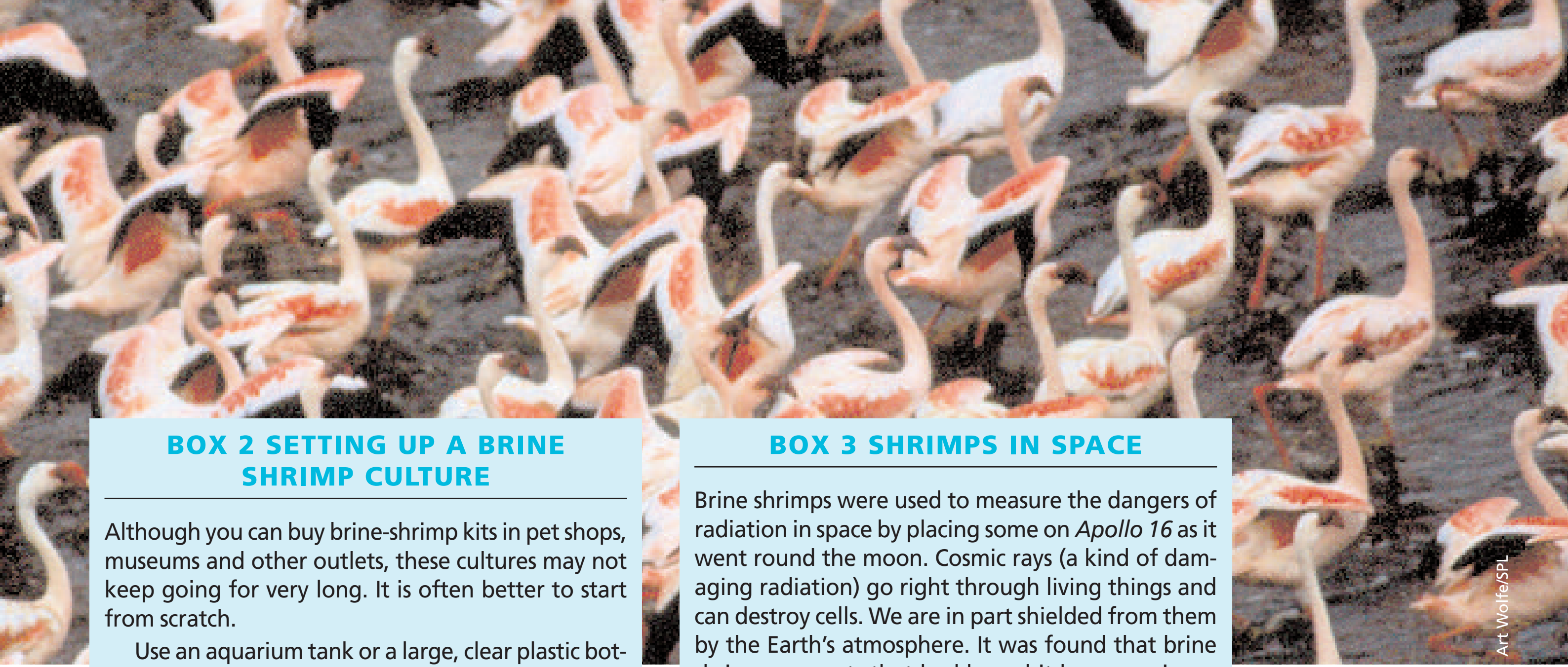
YOUNG SHRIMPS

A nauplius has two small antennae from birth and feeds immediately on algae in the water. Initially it has only one eye, in the middle of its head. The

BOX 1 SHRIMPS IN A PICKLE

We use brine and salt to preserve things, but brine shrimps can live in water seven times as salty as sea water! Like ours, the blood inside their bodies is less salty than sea water. As their surface is partially permeable, water will diffuse out of them by osmosis. So how do they manage not to shrivel up completely?

Brine shrimps seem to drink water to replace what is lost by osmosis, but this will make them even more salty inside. Their secret is to pump out sodium ions from the gill surfaces of their leafy legs using energy provided by respiration. This is a form of **active transport** and takes a lot of energy, so in very salty water brine shrimps grow more slowly. They have to use their food energy to fight the challenge of osmosis.


Art Wolfe/SPL

Above: *A flamingo can eat more than a litre of solid crustacean food in a day, filtering the animals from the water at the rate of several hundred animals per minute.*

BOX 2 SETTING UP A BRINE SHRIMP CULTURE

Although you can buy brine-shrimp kits in pet shops, museums and other outlets, these cultures may not keep going for very long. It is often better to start from scratch.

Use an aquarium tank or a large, clear plastic bottle such as a clean lemonade bottle. Keep this in a bright sunny place, like a south-facing window sill. Obtain a culture of the algae and microbes*, add some sand and gravel and put it all into the tank. Make up a solution of sea salt (obtainable from pet shops and supermarkets) using 35 grams of salt per litre of tap water. (It is best to let the tap water stand in a bucket or bowl overnight before you put it in the tank. This will reduce the chlorine content.) Brine-shrimp egg-cysts come with the culture* or may be bought as egg-cysts or adults from pet shops.

When caring for the brine shrimps remember that they need warmth, light and some mineral nutrients in the water (e.g. a few drops of Baby Bio or similar plant food). Stirring the water and cleaning the sides of the tank every week will help them grow well and allow you to see what is going on.

*Your teacher can purchase a brine shrimp culture from David Barnard, Homerton Brine Shrimp Project, Department of Biological Sciences, Homerton College, Cambridge CB2 2PH, tel: 01223 507175.

young nauplii (*naw-plee-ei*) are attracted to the light, which is where the algae grow best. Nauplii moult as they grow bigger. Each time they shed their exoskeleton they swell more and then grow a bigger outer covering. This may happen up to 15 times in the animal's life. Soon the young are swimming everywhere on their backs and feeding with their leafy legs. They may live for months.

Salt lakes sometimes dry up completely and the adult brine shrimps then die. However, they first produce egg-cysts which can survive the drought. These may hatch as soon as it becomes wet again, but if there are few nutrients in the water they may stay dormant. Egg-cysts hatch best in warm, well-lit, slightly salty water with a neutral pH.

Fish cannot produce drought-resistant eggs, so the shallow salt lakes which periodically dry out often have no fish to prey upon the brine shrimps. Without predators, the shrimps multiply rapidly and in summer there may be thousands of brine shrimps to a bucketful of water.

BOX 3 SHRIMPS IN SPACE

Brine shrimps were used to measure the dangers of radiation in space by placing some on *Apollo 16* as it went round the moon. Cosmic rays (a kind of damaging radiation) go right through living things and can destroy cells. We are in part shielded from them by the Earth's atmosphere. It was found that brine shrimp egg-cysts that had been hit by a cosmic ray were three times less likely to hatch and four times less likely to make it to adulthood. As a result of this study great care goes into making the suits for men and women who go into space.

FOOD CHAINS AND WEBS

The salt lake environment is so extreme that few species are able to live there. This makes the food web quite simple. The unicellular green algae (Figure 2) are the **primary producers**, using energy from sunlight to convert water and carbon dioxide to carbohydrates in the process of photosynthesis.

In good conditions algae may double in number every day. One cell can grow and divide to make 100 cells by the following week. We normally think of cows, sheep and rabbits as herbivores, but in a salt lake the brine shrimps are the herbivores or **primary consumers**, filtering out the tiny algae from the green muddy water.

In the absence of fish, the brine shrimps are a significant food source for **secondary consumers**. Flamingoes and avocets are two carnivorous birds that feed on shrimps in shallow salt-lake waters. Flamingoes feed using a pump action and filter system. They have a large muscular tongue that draws water into the mouth through fine peg-like filters in the beak. The brine shrimps are caught and swallowed and the filtered water passes out of the beak again.

Although they are themselves predators, both types of bird are preyed upon in turn by **tertiary consumer** bird raptors. Fish eagles eat many flamingoes and Egyptian vultures commonly take flamingo chicks from the nest.

Michael Dockery *is Education Officer for the Association for the Study of Animal Behaviour (ASAB) and is based at Manchester Metropolitan University.* ***Stephen Tomkins*** *is the Director of Studies for Natural Sciences at Homerton College, University of Cambridge.*

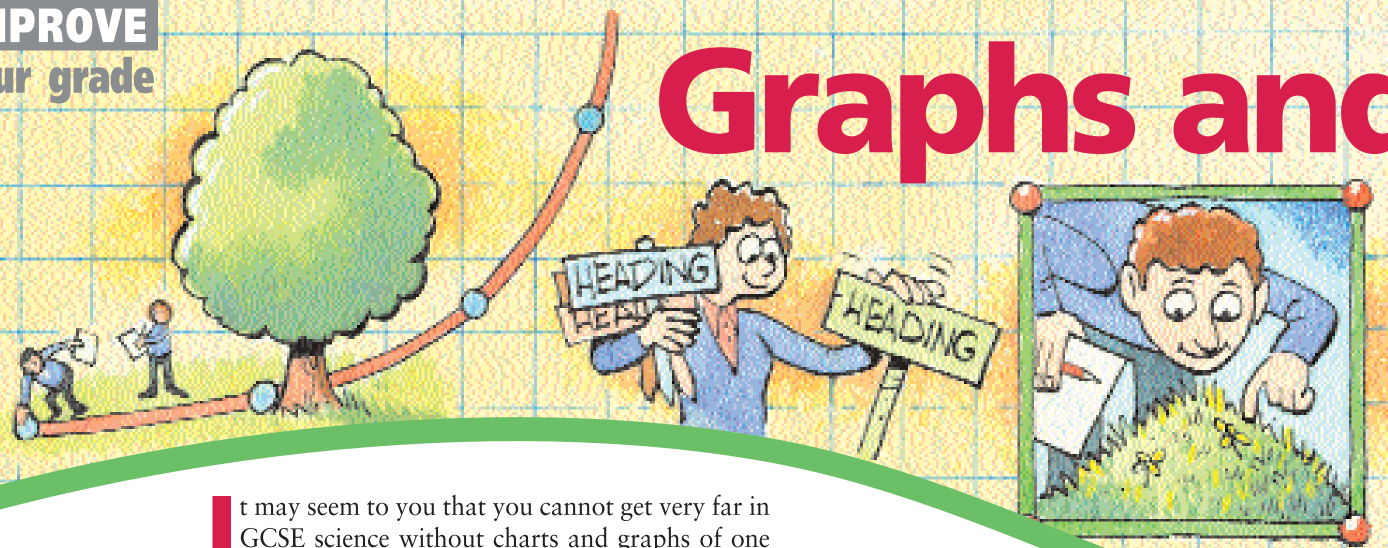
● **Draw a food web linking together the organisms mentioned to include the possible flow of energy and materials from the tropical algae.**

Osmosis is the movement of water molecules across a partially permeable membrane from an area of high concentration of water to one of low concentration.

If you set up a brine shrimp culture you can try the investigations on page 16.

IMPROVE
your grade

Graphs and



It may seem to you that you cannot get very far in GCSE science without charts and graphs of one sort or another. They are useful because they show a lot of quantitative information (numbers) in a way that can be quickly understood. The same information could be given in words, or in a table, but it would not be so easy to see what was going on. This Improve Your Grade looks at some important points to think about when plotting graphs.

DISPLAYING DATA

Suppose you have been out in a local wood to collect data about plant species. You have found a sycamore tree and you have measured a line out from the tree for about 10 m. Using your quadrat, you have made an estimate of the percentage of ground cover by certain types of plant. When your findings are put into a table they might look like Table 1.

Table 1 *Ground coverage by plants near a sycamore tree (%)*

Plant	Distance of quadrat from tree (m)				
	2	4	6	8	10
Sycamore seedling	0	5	10	2	0
Daisy	0	5	5	5	10
Chickweed	10	5	0	0	0
Grass	10	60	80	85	85

The chances are that the data will be easier to understand if they are represented as some kind of graph. Two possibilities are the bar chart and the line graph, shown in Figures 1 and 2.

It is important that the graph or chart should convey information *clearly*. Accuracy may be important, especially if you are intending to read data from the graph (such as a **calibration graph**), but clarity is the main thing. It must be possible to work out very quickly:

- what the graph is about — the **heading;**
- what is being plotted on each axis — the **axis labels;**
- what numbers or categories are involved — the **scales;**
- where the 'points' are on the graph — the **plotting.**

Check Figures 1 and 2 to see if they keep to the principles outlined below.

The heading

- Keep it simple. No-one wants to have to read an essay to find out what is on the graph.
- Avoid just re-using the information on the axis labels.

The ground coverage data could be presented as a kite diagram. Find out what this is.

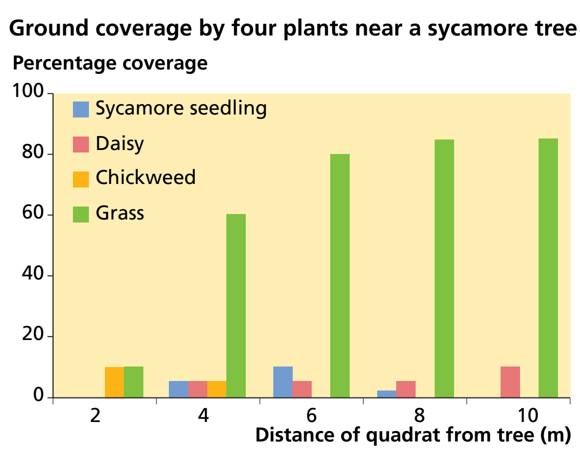


Figure 1 *Bar chart.*

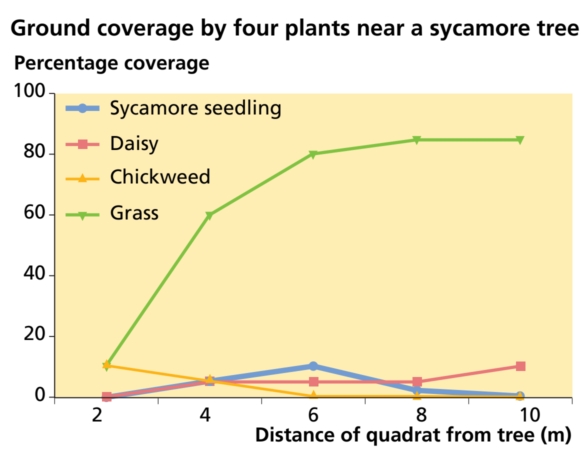
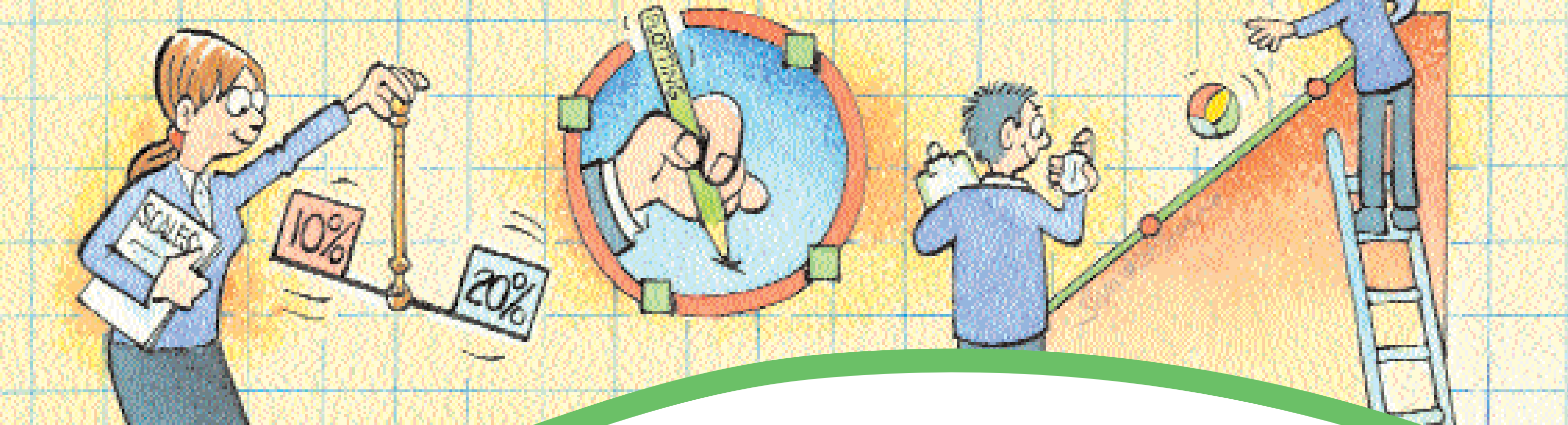


Figure 2 *Line graph.*

charts in science



- Give some idea of the experiment which produced the data. 'A percentage vs distance graph' tells us nothing that cannot be read off the axes. 'Ground coverage by four plants near a sycamore tree' does tell us something additional and useful.

The axis labels

- Each axis must be labelled with brief but precise information about what is being plotted.
- If what is being plotted is a physical quantity, then the **units** must be given in brackets after the name of the quantity, e.g. Distance of quadrat from tree (m).

The scales

- The scale must be *uniform* all the way up the axis. If you start off using one big square for 10%, then you must not switch to one big square for 20% a bit further along the axis, even if it makes the plotting much simpler.
- Make the scale easy to plot and *to read from*. Avoid awkward scales like three squares for every 10%, especially if you are hoping to read off values from that axis later on.
- Although your graph should be large enough to be read clearly, it does *not* have to 'fill the graph paper', especially if this means using unhelpful scales or A4-sized graphs with only three or four points. Use your judgement. About A5 is a good rule-of-thumb size. It can be even smaller if you are not going to take readings from it.

Plotting

- If you are plotting by hand on graph paper, try using a + to plot points. They are much easier to see than dots and they are also easier to plot — simply draw a short vertical stroke at the *x*-axis value and a short horizontal one at the *y*-axis value. They will cross at exactly the right place.
- Only plot the given data, do not put extra points on a curve from which you have been asked to read off a value. Use the 'dotted-line method' to read off values (see Figure 4 on page 6).

CONNECTING THE POINTS

You will sometimes have to decide whether to connect the 'points' you have plotted using a 'best-fit line' or with a series of individual straight lines joining up neighbouring pairs of points. The choice is between a mathematical function and a bar chart. In the case of the quadrat measurements mentioned at the beginning, the bar chart approach works well, and a graph with straight lines connecting neighbouring points is also a useful way to display the data.

Another example might be the melting points and boiling points of elements in a group of the periodic table. The inert gases form an interesting set of elements for this purpose (Figure 3). The temperatures could be shown on a bar chart, but a line graph gives a better sense of the trend of the data and of the fact that the differences in the two temperatures are roughly equal throughout the group. There is obviously no such thing as a 'best-fit line' for this graph.

Which way round? Usually the independent variable (some call it the input variable) goes on the *x*-axis and the dependent variable (output) goes on the *y*-axis.

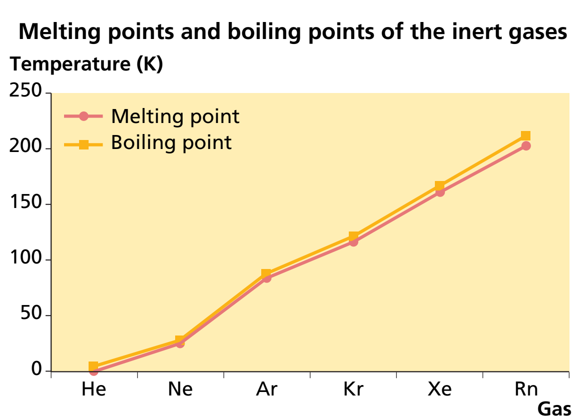


Figure 3 A graph in which the points are joined up using a series of straight lines.

Table 2 Results of rolling a ball down a slope

Time after release (s)	Distance rolled down slope (cm)
0	0
2	2.1
4	8.5
6	19
10	48
15	115
20	200

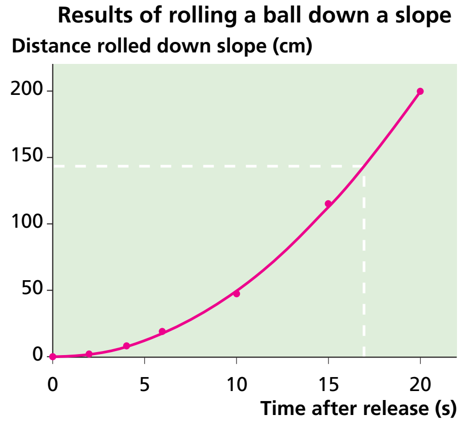


***Figure 4** Best-fit graph of continuous variables. It plots the data given in Table 2.*

The individual connections between the points are simply intended to point out the pattern.

CATEGORIES AND CONTINUOUS VARIABLES

The variable on the horizontal axis (x-axis) in Figure 3 is a **category** — which inert gas — it is not part of a continuous stream of possibilities, unlike for example values of distance or time. This is a common situation with biological and geographical data and, to a lesser extent, may be met in chemistry and physics. In general, if the data are discontinuous and could be plotted as a bar chart or a pie chart, then a 'best fit' approach is not appropriate.

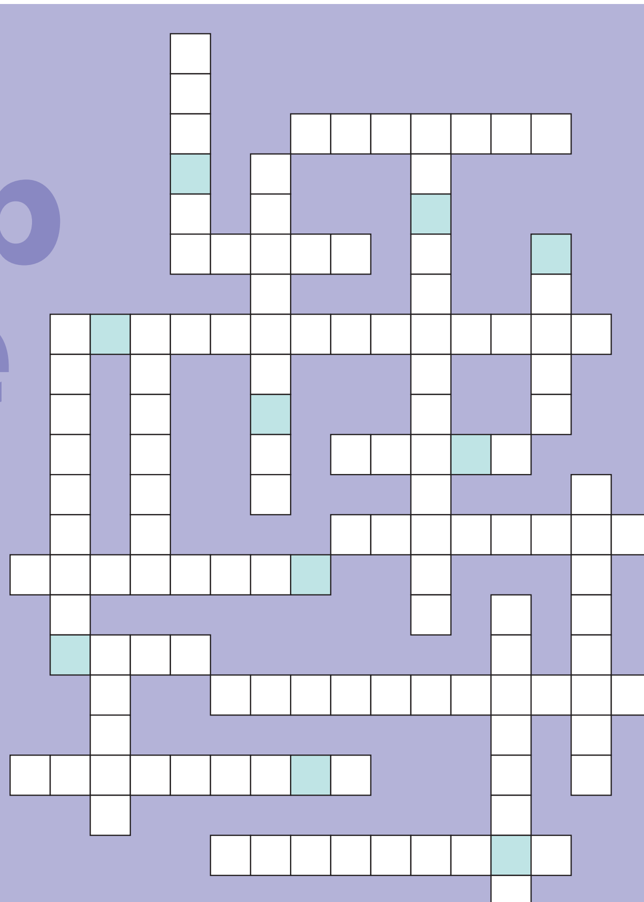
The graph shown in Figure 4 is quite different, because the variables are continuous; they could have any value within the range covered by the experiment. In this case, it is obvious that both sets of data are continuous; any value of the time could have been chosen in principle (although very small time intervals would have been difficult to measure with a stopwatch) and the ball might have been at any corresponding distance along the slope. In fact, it would be possible to use the graph to make an estimate of where the ball would have been at say 17 seconds. (Note the dotted lines on the graph.) What do you make it? Have you noticed the rule that connects distance and time in this experiment?

It is possible to make a 'best-fit' line or curve on charts plotted in Excel but note that it is not very easy to take readings from the resulting picture, since it is difficult and messy to include as many 'grid-lines' in an Excel graph as there are on a sheet of graph paper.

***John Tucker** teaches chemistry at St Edward's School, Oxford and is in charge of ICT training at the school.*

Brine shrimp puzzle

Read the article 'A life in brine' on pages 1–3. Fit the words into the grid (right). Take the letters that fall on the shaded squares and rearrange them to give another word which describes brine shrimps.



salt (4)
brine (5)
algae (5)
prawn (5)
larva (5)
shrimp (6)
osmosis (7)
egg-cyst (7)
producer (8)
consumer (8)
antennae (8)
nauplius (8)
transport (9)
predators (9)
crustacea (9)
sea monkey (9)
phyllopodia (11)
carbohydrates (13)
photosynthesis (14)

Hidden word:

____

Answers on page 10.

THE OBSERVATORY SCIENCE CENTRE

The Observatory Science Centre in Herstmonceux, East Sussex, is a hands-on centre with a difference. As well as the interactive exhibits, there is a discovery park, a water feature — and there are the telescopes.

● Visit **http://www.the-observatory.org for more details, or call 01323 832731.**

Herstmonceux was home to the Royal Greenwich Observatory's telescopes from the 1950s to the 1980s. During that time it was teeming with astronomers observing the night sky. Make sure you set aside some time to visit the three telescope domes that are open to the public. When you wander around the site, imagine what it was like to work there. Would you have included the lily pond if you had been the architect?

VISITING

The Observatory Science Centre is in East Sussex, 2 miles east of Herstmonceux village, on the Boreham Street to Pevensey road. Look for the sign to 'Herstmonceux Castle and Science Centre' from the A271 (see Figure 1).

It is open during the local February half term holiday, and from April to November, 10 a.m. to 6 p.m. (5 p.m. February, October and November).

Admission charges are:

Adults: £5.40

Under 16s: £4.00

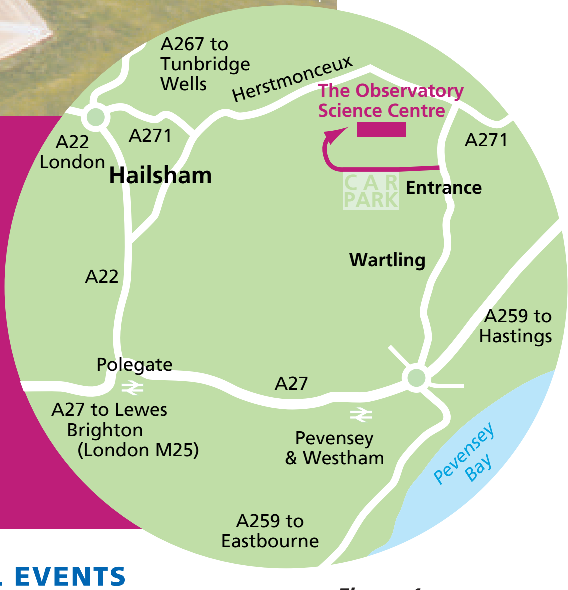


Figure 1
How to find the Observatory Science Centre.

CHALLENGING YOUR BRAIN AND YOUR BRAWN

The corridors and two of the domes house plenty of hands-on exhibits. The exhibits are changed on a regular basis, but might include a section on time, forces and gravity, or optics. Be prepared to do more than push a button — the Observatory doesn't work like that. It is designed to keep you busy and challenge your brain just a little bit.

The discovery park is a playground with a difference. You won't find roundabouts, swings or slides there (although you will find a climbing frame, but even that is shaped like a strand of DNA). The park is full of hands-on (and feet-on) equipment, all based around science. Find some friends and try to get the balancing board flat. If you are feeling strong, you could try lifting yourself up in a chair with a pulley system.

SPECIAL EVENTS

During the year, there are plenty of opportunities for night owls to attend a viewing evening. You get to see those lovely telescopes in action, and maybe even try your hand at finding planets and stars in the sky. If you don't fancy a late night there are plenty of other special events and science experience days.

The centre is run by Science Projects, which makes (you guessed it) hands-on, interactive exhibits. This means a new exhibition can be brought to Herstmonceux while one is on loan to another centre. If you want to know exactly what will be there before you go, just check the website or give the centre a call.

***Rosalind Mist** is the Project Manager of sciZmic, a network of Science Discovery Clubs* (**http://www.scizmic.net**).

DAVID SANG

About 20% of the UK's electricity supplies come from nuclear power stations. Many of these power stations are approaching the ends of their working lives. What are the future prospects for nuclear power?

A nuclear future?

GCSE key words
Nuclear energy
Nuclear fission
Isotopes
Radioactive decay

France, which has only small reserves of fossil fuels, produces 75% of its electricity using nuclear power.

Namibia in southern Africa is the biggest producer of uranium ore.

The nuclear industry starts with uranium mines. Uranium is the fuel for most nuclear power stations (some use plutonium), and uranium-rich minerals are found in many parts of the world, including Namibia, Canada and Russia. Uranium is the heaviest element found in nature — its atomic number is 92 — and it is a concentrated store of energy (see Box 1).

Natural uranium consists almost entirely of two isotopes, ^{235}U and ^{238}U, with different numbers of neutrons in their atomic nuclei. Both are radioactive, and so they gradually decay away. However, their half-lives are very long, so their stored energy is released only very slowly.

FAST REACTIONS

The nuclear reactor at the heart of every nuclear power station is designed to speed up the release of energy from uranium. It makes use of the fact that atoms of ^{235}U can be split in a process called **nuclear fission**, releasing much more energy than simple radioactive decay.

Here's how fission works (see Figure 1). A single neutron strikes the nucleus of a ^{235}U atom. The neutron is absorbed, but the nucleus is now highly unstable, and it splits in two. In the process, two or three neutrons are released. Energy is released during fission, some in the form of gamma radiation, and some as the kinetic energy of the particles which fly apart at high speed.

The next trick is to establish a **chain reaction**. If, on average, just one of the neutrons released by one nucleus goes on to split another nucleus, and so on, we have an ongoing chain reaction, releasing energy at a steady rate. The uranium gets hot. If *more* than one neutron goes on to cause further fission, the reaction escalates out of control, and we have a nuclear explosion. The design of reactors in power stations makes this impossible.

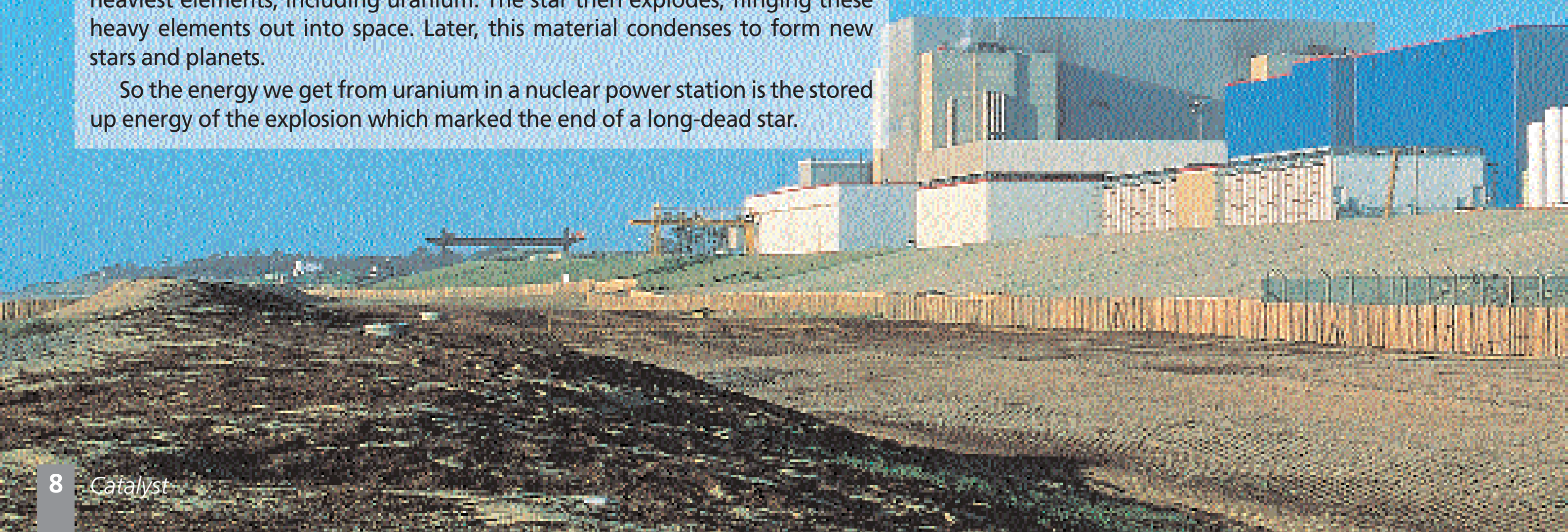
The daughter nuclei formed when a ^{235}U nucleus splits are highly radioactive, and release more energy as they decay. However, they do not decay entirely during the lifetime of the reactor, so the material inside the reactor core is dangerously radioactive. This is one of the big problems with nuclear power.

BOX 1 THE ENERGY OF STARDUST

Uranium has been here since the Earth formed. But how did it get here? Uranium atoms were present in the cloud of dust and gas from which the solar system formed. They have their origins in a massive stellar explosion — a supernova — which occurred billions of years ago.

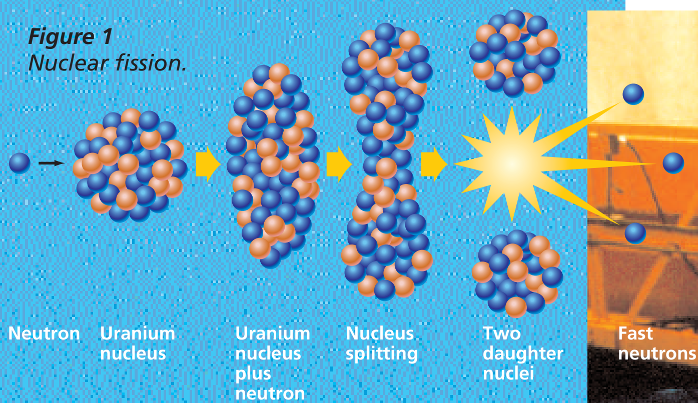
When massive stars die, they collapse inwards, causing enormously high pressures and temperatures. In these conditions, medium-sized atoms such as iron and nickel are forced together and merge (fuse) to form atoms of the heaviest elements, including uranium. The star then explodes, flinging these heavy elements out into space. Later, this material condenses to form new stars and planets.

So the energy we get from uranium in a nuclear power station is the stored up energy of the explosion which marked the end of a long-dead star.



Sizewell nuclear power station in Suffolk. Below is Sizewell A, an advanced gas-cooled reactor, and on the right, with the white dome, is Sizewell B, the UK's first pressurised water reactor.

Figure 1 *Nuclear fission.*



CORE STRUCTURE

The core of a nuclear reactor is quite complex (see Figure 2).

- The **fuel** is in the form of rods. These can be withdrawn and replaced when they are spent.
- A **moderator**, such as graphite or water, helps to slow down the neutrons, so that they interact more with the uranium nuclei. Without moderation, they would mostly escape from the core.
- **Control rods**, made of boron or cadmium, absorb neutrons to keep the chain reaction at the desired level. In an emergency they drop into the core automatically.
- The **coolant**, water or carbon dioxide, carries the heat out of the core.

The coolant is used to generate high-pressure steam, just as in a coal or gas-fired power station. The steam turns turbines, which cause generators to spin and produce electricity.

Martin Bond/SPL

Positioning a fuel rod crane over the reactor core of a US nuclear power station. To the right of the crane is the new fuel rod ready for insertion. The top of the reactor core is covered with 10 m of water to protect workers from radioactivity.

US Department of Energy/SPL

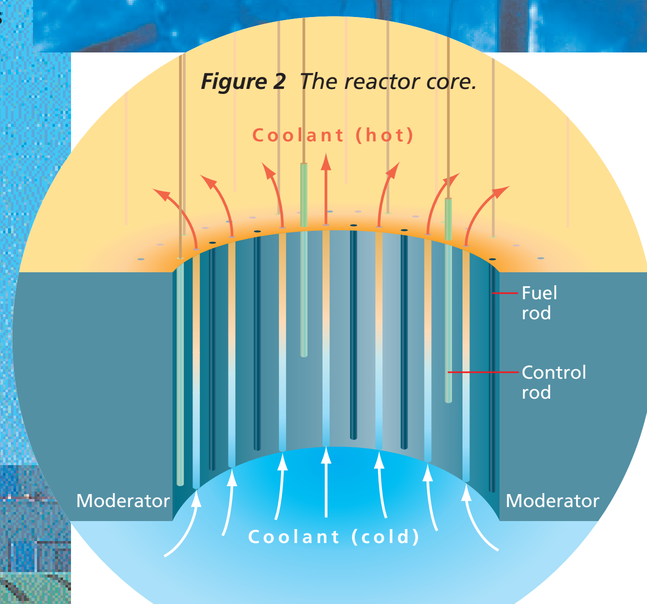


Figure 2 *The reactor core.*

In a nuclear reactor, some uranium atoms are transformed to even heavier elements such as plutonium and americium.

- **Explain why, when the Earth formed, there must have been a higher proportion of ^{235}U than there is today.**

Table 1 *The two most common isotopes of uranium. The most useful isotope, ^{235}U, makes up only 0.7% of mined uranium*

Isotope	Number of protons	Number of neutrons	Proportion in natural uranium	Half-life (millions of years)
^{235}U	92	143	0.7%	710
^{238}U	92	146	99.3%	4500

US Department of Energy/SPL

Left: *Decommissioning of a pressurised water reactor at Shippingport, USA. It was built in the 1950s and shut down in 1982. Here the wall from the reactor pit is being removed.*

Answers to brine shrimp puzzle, page 6

Hidden word:

HERBIVORES

ENVIRONMENTAL QUESTIONS

Nuclear power is being used increasingly, particularly in Europe and North America. One argument in favour of its use is that it does not produce greenhouse gases, unlike power stations which burn fossil fuels. So is nuclear power 'clean'?

Of course not. To appreciate the problems, we need to think about the complete fuel cycle, starting with mining. Uranium ore contains only a small percentage of uranium, and extracting it produces large volumes of radioactive waste. The uranium is then usually enriched, to increase the proportion of ^{235}U relative to ^{238}U. More waste results.

Once the fuel rods are spent, they must be removed from the core and replaced. The old rods are highly radioactive, and must be cooled in large tanks of water for several months before they can be taken away and stored. Sometimes the spent fuel is reprocessed; this is what happens at Sellafield in Cumbria. The idea is to extract any remaining ^{235}U and re-use it; plutonium is also separated, for use in reactors or bombs. The most hazardous waste products are concentrated, with the intention of storing them safely. However, no-one is sure how best to do this. The problem will be around for thousands of years, because of the long half-lives of the substances involved.

At the end of its life, a power station must be decommissioned. It is dismantled, and the most radioactive parts are taken away for safe storage. The site is eventually levelled and is unlikely to be fit for other uses for several decades.

PROLIFERATING CONCERNS

In practice, nuclear power stations have proved relatively safe. There have been some spectacular accidents — notably the fire at Chernobyl in the Ukraine in 1986, which resulted in thousands of deaths and illnesses. The UK's nuclear stations have been carefully operated, but many are now reaching the ends of their lives. Should they be replaced?

In fact, there is a glut of electricity, and prices have fallen. Most new power stations use natural gas (a fossil fuel), and nuclear power cannot produce electricity as cheaply as these. Are we being short-sighted, burning gas which is a non-renewable resource and which contributes to climate change?

Keep an eye on these questions. The government is developing an energy strategy for the next 20 years. Will it give the nuclear industry a new lease of life?

David Sang writes textbooks and is an editor of CATALYST.

Plants and soil nutrients

NIGEL COLLINS

GCSE key words
Plant nutrients
Active uptake
Root hairs
Surface area/volume ratio

Plants need various things from their environment. They develop very large surface areas both in the air and in the soil — in the form of leaves and root hairs respectively — to take these in. Here we explore the relationship between plants and the soil in which they grow. We also look at some new research on the activity of fungi in soil and their involvement with the mineral nutrition of plants.

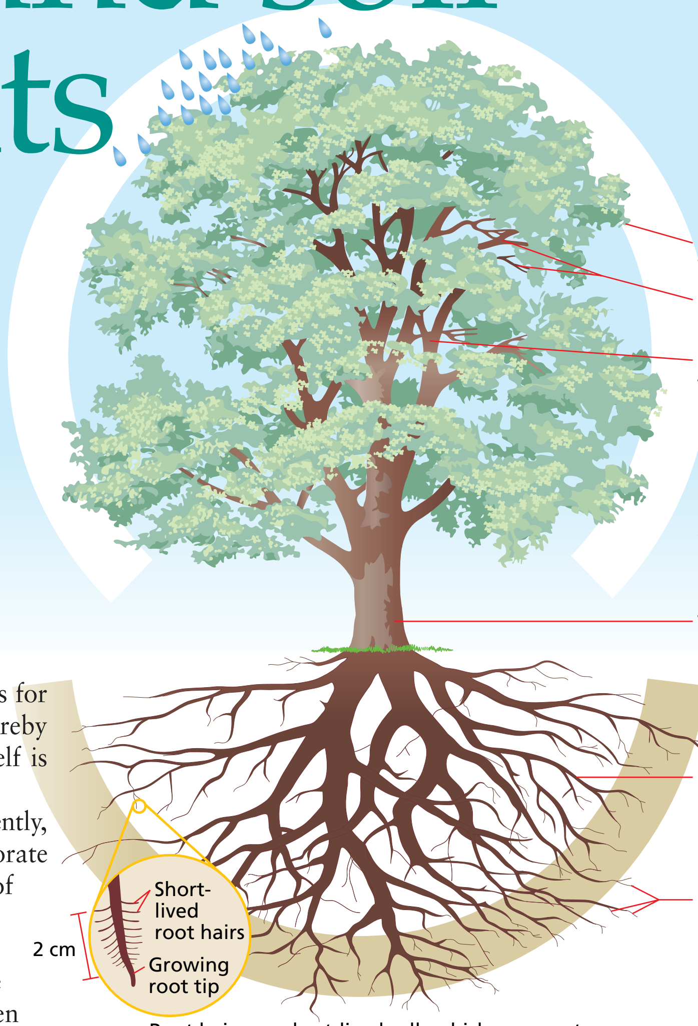


Figure 1 *Trees develop large surface areas in the air and in the soil.*

Plants need water as one of the ingredients for making sugars by photosynthesis, and thereby making their own tissues. But water itself is also a large part of the structure of a plant.

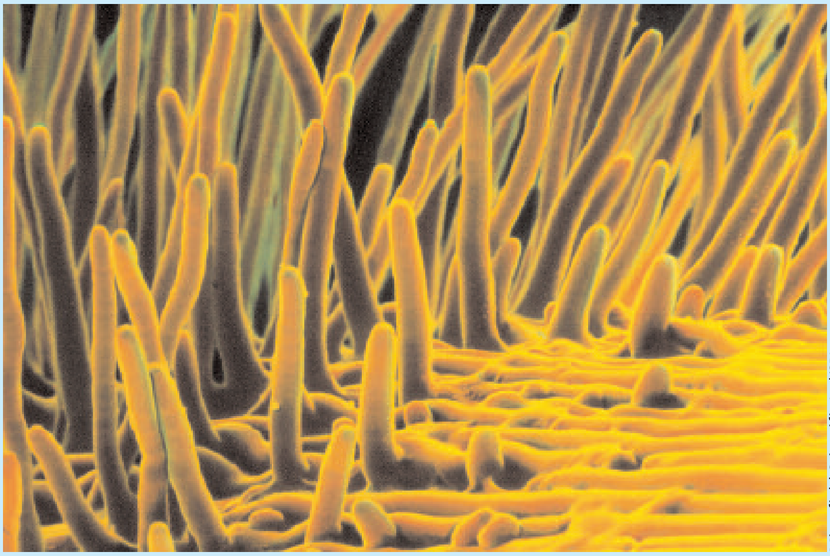
If you take some leaves and heat them quite gently, at about 100°C, this structural water will evaporate and you will be left with the dry matter out of which the plant is made. Burn the dry plant material and you will be left with 'ash'. During burning all the chemicals synthesised from the sugars made in photosynthesis will have been oxidised to carbon dioxide and water. Some nitrogen and sulphur will have been lost as well, in the form of oxides of nitrogen and sulphur dioxide. What is left behind as ash is mostly the mineral nutrients plants take up from the soil.

Plants obtain water and three important elements from the soil in which they grow. Nitrogen (N) and phosphorus (P) are taken up as compound ions, while potassium (K) is taken up as simple ions. Table 1 summarises why each of these elements is needed, and how plants are affected when they are in short supply. Another element plants require is magnesium (Mg), which sits as individual atoms in the heart of each chlorophyll molecule. Plants need many other elements in much smaller amounts — the so-called micronutrients.

Table 1

Element	Ion in soil	Functions	Symptoms shown by plants when in short supply
Nitrogen	Nitrate ions, NO_3^-	Needed for the synthesis of amino acids and then proteins, also in DNA	Stunted growth and yellow older leaves
Phosphorus	Phosphate ions, $H_2PO_4^-$	Part of ATP, an important molecule involved in the trapping and release of energy in photosynthesis and respiration, and in cell membranes and DNA	Poor root growth and purple younger leaves
Potassium	Potassium ions, K^+	Helps the action of enzymes involved in photosynthesis and respiration	Yellow leaves with dead spots
Magnesium	Magnesium ions, Mg^{2+}	Part of the chlorophyll molecule	Yellow leaves

- **Check that you know the basic equation for photosynthesis and that you know all the other compounds plants make from sugar, such as amino acids.**



Microfield Scientific Ltd/SPL

***Above:** Electron micrograph of root hairs from a cress root.*

How do plants take up minerals from the soil? It is far too simple to say 'through their roots'.

CHASING MINERAL NUTRIENTS

The bulk of a tree's roots provide firm anchorage — roots can be as massive and as tough as the above-ground branches of a tree. Inside the roots is the transport system which stretches to their extremities. It is in these actively-growing extremities, for the most part in extraordinarily delicate root hairs, that the plant takes up materials from (and loses them into) the surrounding soil. The roots are constantly growing into soil which the plant hasn't exploited, in which mineral nutrients may not have been used up or may have only just been made available by decomposition.

New roots are very fine structures. The cells in the root's tip divide and then elongate, pushing the root tip through the soil. The tip is protected by a **root cap** of dead and dying cells. A short distance back from the tip the elongated cells inside the root start to develop into distinct and different types of cells — a process called **differentiation**. The cells that are to transport water and minerals upwards start to become isolated from surrounding cells. Their cell walls fill in, the end walls break down and they form tubular **xylem vessels**.

Water cannot enter these vessels from the surrounding soil; instead it enters the youngest parts of the roots, in the first few centimetres behind the tip. Here the surface area is increased enormously by delicate **root hairs**, cells which grow outward from the root into the surrounding soil. Root hairs last for only a few days. They shrivel as the xylem vessels inside that part of the root start to develop thickened walls. A root hair's life may be brief, but it is essential to the survival of the plant.

Inside leaves and at the tips of roots, cells have cell walls that are fully permeable. Transport cells such as xylem vessels have solid walls which form tubes to transport water and dissolved substances.

BOX 1 THE NEED FOR FERTILISERS

Sugar beet is grown for its root, which contains 16% or more sugar. As it is harvested, the leafy top of the plant, together with the point of attachment, called the crown, is separated from the root. After the root has been lifted it is taken away (with the nutrients it contains) for processing. The remaining parts may either be used as animal feed or ploughed back in to decompose.

Table 2 shows what a crop of beet giving a good yield of 50 tonnes per hectare removes from the soil. These losses must be made up, either with inorganic fertilisers or with organic manures or both.

A hectare is 100 m × 100 m.

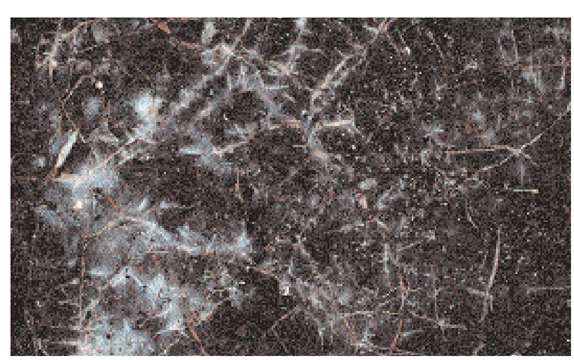
***Table 2** Nutrients removed from the soil by a beet crop (kg/hectare)*

Element	Tops and crowns ploughed in	Tops and crowns removed
Nitrogen	65	170
Phosphorus	30	65
Potassium	90	235
Magnesium	10	20
Sodium	10	90
Calcium	60	85

MINERAL UPTAKE

The cells of the root contain minerals dissolved in the cell sap, making the cells more concentrated than their surroundings. Root hair cells and other cells in the youngest part of the root will therefore take in water by osmosis. However, the uptake and movement of water through the xylem vessels, from the root via the stem or trunk to the branches and leaves, is driven by the evaporation of water from the leaves during transpiration — water is literally pulled upwards through plants. Mineral ions dissolved in the water are also transported — but there is more to the uptake story where minerals are concerned.

First, plants can take up minerals through their roots when transpiration isn't occurring; similarly aquatic plants absorb minerals from the surrounding water but do not transpire. Second, plant cells usually contain higher concentrations of mineral ions than those in the surrounding soil. So uptake cannot



Dr Jeremy Burgess/SPL

Mycorrhizal fungi growing symbiotically with the roots of a lime tree.

BOX 2 RESEARCH ON SOIL FUNGI

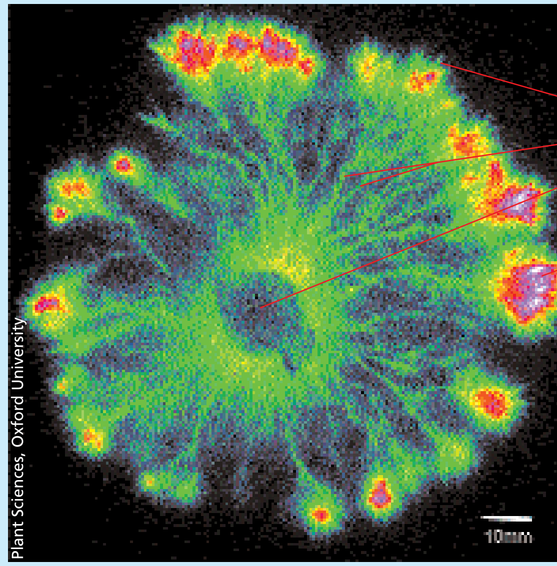
Toadstools are the visible part of a fungus, but the biggest part is a vast underground network of microscopic filaments or hyphae, collectively known as a **mycelium**. Under a hectare of British woodland there will be a tonne of fungal mycelia.

Scientists at Oxford University are examining how materials are moved through soil inside fungal mycelia. They have been looking especially at amino acid movement in live mycelia of a fungus called *Phanerochaete velutina*. They grow the fungus across a solid scintillation screen. The fungus is provided with a food source containing amino acids that have been 'labelled' with radioactivity. The fungus takes these up and transports them.

The scintillation screen emits light when radiation from the labelled amino acids affects it. The light can be measured using a special photo-counting camera (Figure 2). The team takes a series of photographs over time and can track the direction and speed of movement of the amino acids.

It turns out that the amino acids are transported quickly — at up to 30 mm per hour. A surprising finding, which the scientists are not sure how to interpret, is that they aren't transported continuously but in pulses at regular 12–15 hour intervals.

You can find out more about this work and look at some amazing photographs of transport inside the fungus at **http://www.plants.ox.ac/uk** Click on Research and then on Dr P. R. Darrah and Dr S. C. Watkinson.



Left: *Radio-labelled amino acid moving from the central food source to the colony margins via the mycelium.*

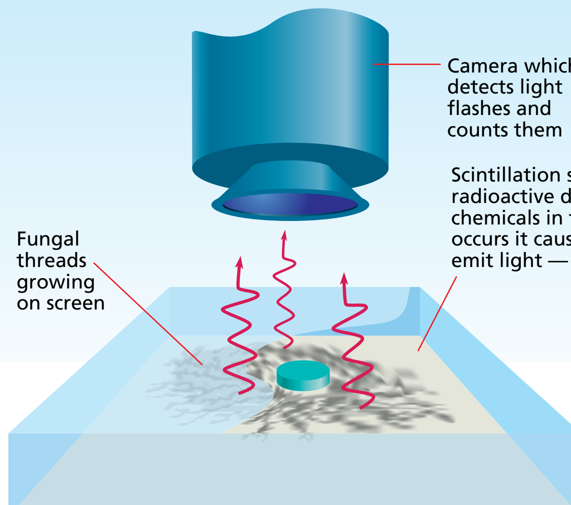


Figure 2
The scintillation imaging equipment.

involve diffusion, because this occurs from high to low concentrations. Plants must 'work' to take up minerals from their surroundings. They expend energy as they do this work — so respiration is an essential process and, not surprisingly, uptake slows if oxygen is in short supply. This process is called **active uptake** and involves **active transport** across the cell membrane.

FUNGAL ASSISTANCE

Many plants form a **symbiotic** relationship with fungi — a relationship of mutual benefit, without harming either partner. These associations between roots and some soil-dwelling fungi are called **mycorrhiza.** Roots with mycorrhiza are more efficient at absorbing minerals from their surroundings than those without (Table 3). This is because the way the fungus grows, as fine threads or hyphae through the soil, provides an enormous surface area across which mineral nutrients are taken up. The nutrients are passed to the plant. The fungus benefits by receiving carbohydrates and other organic compounds from the plant.

Very little is understood about the activities of microorganisms in soil (see page 21). Some research on soil fungi underway at Oxford University is described in Box 2. This sort of work is very important because it is the basis upon which plant life and therefore the life of all living things depends.

Table 3 *Uptake of nitrogen, phosphorus and potassium by pine tree seedlings*

Type of root	Nutrients absorbed (% dry mass)		
	N	P	K
With mycorrhizal fungi	1.24	0.196	0.744
Without mycorrhizal fungi	0.85	0.074	0.425

BOX 3 WEBSITES

Find out more about interactions between fungi and plants at

http://www.hri.ac.uk/site2/research/fres.htm

and about how some fungi might help plants take up phosphate at

http://helios.bto.ed.ac.uk/bto/microbes/ mycorrh.htm

Nigel Collins *edits* Catalyst *and teaches biology. He is grateful to Peter Darrah for help with the section on research at Oxford University.*

Lessons from Mount Everest

What is a science teacher doing on the summit of the world's highest mountain? Chris Mothersdale reached the top of Mount Everest on 16 May 2002. Here he describes his experience.

The percentage of oxygen in the air is the same at the summit of Everest as at much lower altitudes, but the total number of molecules of all gases — the density of the air — is much lower. This is reflected in the drop in atmospheric pressure.

Chris now holds the world record for preparing a science lesson at the highest altitude, as authenticated by Guinness Superlatives.

Climbing Everest was a boyhood dream. I have been climbing for years, enjoying the physical and mental challenges, as well as the often fabulous surroundings. Last year the opportunity to fulfil my dream came along — a project to make scientific observations while climbing the highest mountain on Earth.

THE EXPEDITION

Our expedition was led by Dave Pritt, an experienced Everest mountaineer. We followed the North Ridge route from Tibet, first tackled by the pioneering British expeditions at the turn of the twentieth century. These included the explorers George Mallory and Andrew Irvine who died near the summit in 1924.

We arrived in Kathmandu at the end of March and spent some time acclimatising to high altitudes with short walks up to 5500 m en route to the base camp at 5200 m on the Rongbuk Glacier. From here we set up a series of camps at different altitudes. After 7 weeks we reached Camp 3 at 8200 m, from where the final summit push was made (Figure 1).

To reach the summit was a dream come true. It took 10 hours from the top camp to the summit and 7 hours to go back down, and I had just 45 minutes on top of the world.

BOX 1 ROUTE TO THE TOP

At school, I took A-levels in physics, maths and biology which I followed with a degree in sport science and a teaching qualification. I wasn't certain what I wanted to do when I left college. I started off as an accountant and then moved into teaching. I have been a science teacher for 10 years. I have a fascination for the world around me and for finding out how things work, and I enjoy passing on my enthusiasm.

My climb was part of Science Year. It was sponsored by several companies one of which, New Media Ltd, produces science software including *Multimedia Science School* which you may have used. New Media set up a website which allowed schools to receive data like those in Table 1 direct from Everest during my climb.

FOOD AND EQUIPMENT

Our food supplies consisted of local produce (which meant that we contributed to the local economy), as well as boil-in-the-bag rations bought in the UK. To this we added snacks such as chocolate, cereal bars, jelly, dried fruit, nuts, cheese and salami. We needed food with a high energy content to meet the high energy demand made by the climbing and the cold.

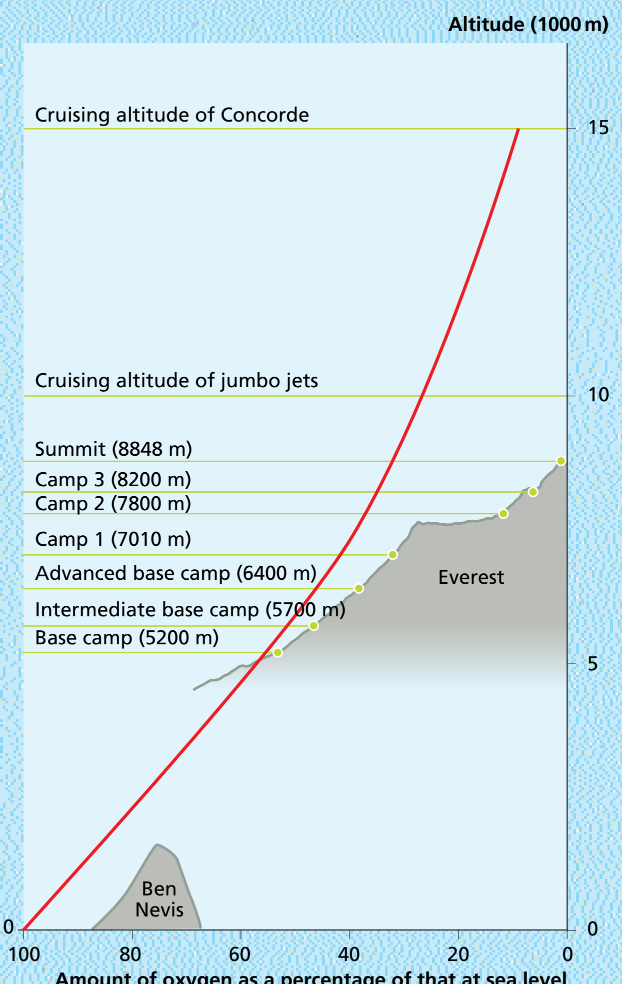


Figure 1 *The effect of altitude.*

BOX 2 ADAPTATIONS TO ALTITUDE

One part of acclimatisation to altitude is a marked increase in the number of red blood cells. Someone who lives at low altitude will have red blood cells making up 40% of the volume of their blood, but after time at high altitude this can increase to 60%. People breathe faster and deeper and the body changes its response to the amount of carbon dioxide in the blood.

People who always live at high altitudes have various important adaptations. They have larger chests and lungs, more capillaries in their lungs and larger hearts, to pump blood more efficiently round their bodies, which are generally smaller than those of lowlanders.

Chris recording his blood pressure.

Chris Mothersdale

At the summit.

Chris Mothersdale

Table 1 *Chris collected scientific data to show how his body responded during his climb. At the highest altitudes his heart rate reached 160 beats per minute while he was actively climbing*

	Week 0	Week 2	Week 4	Week 6	Week 9
Altitude (m)	75	5165	6555	7010	8200
Air temperature (°C)	9	27	3	–1	–6
Barometric pressure (kPa)	99.3	55	42	38	24
Blood oxygen saturation (%)	99	84	79	65	50
Average heart rate at rest (beats/min)	44	79	64	83	95
Average breathing rate at rest (breaths/min)	9	14	14	15	23

● Look at the data in Table 1. How did Chris's body respond to the lack of oxygen at high altitudes?

Most of the equipment was similar to that used for climbing in the Alps, but there were some differences because of the intense cold and the lack of oxygen at very high altitude. We used special thermal boots and full down clothing — suit, mitts, jacket — for effective insulation against heat loss. From 8200 m, we had to use oxygen — one bottle while sleeping, then three to the summit and back. A bottle will last about 6 hours at a flow rate of 2 litres per minute.

LIFE AT ALTITUDE

The problems caused by low pressure and lack of oxygen are worse the higher you get. Everything from cooking to walking is very slow — it can take 2 hours to melt snow and boil enough water for a drink. Life-threatening conditions such as pulmonary oedema, where fluid accumulates in the lungs, can develop and at that altitude they are very difficult to deal with.

If you manage to sleep as you go higher up the mountain, your dreams become more vivid and more strange, due to the lack of oxygen. Your thinking can become more muddled. Table 1 shows how my physiological functions changed.

CLOSER TO THE EDGE

What's it like being at the Earth's highest point? You feel closer to the edge and closer to history. When I was on the summit I was too tired and befuddled by the altitude to take it all in. Only after we had all made it safely down did it really sink in.

Chris Mothersdale *teaches at William Howard High School, Brampton, Cumbria.*

Life at the Extremes **is a great tale by Frances Ashcroft of how our bodies are challenged by and respond to extreme conditions, including those on Everest.**

Photodisc


Michael Dockery

TRY this

Investigating brine shrimps

Try these investigations with brine shrimps, either in school or at home. Use a culture set up as described in the article on page 3, Box 2.

CHOOSING LIGHT OR DARK

Fill a small, but tall, clear plastic bottle (say, 1.5 litre) with salt water from your tank. Add to it an even number of adult brine shrimps that you can easily count at a glance, e.g. 8, 10 or 12.

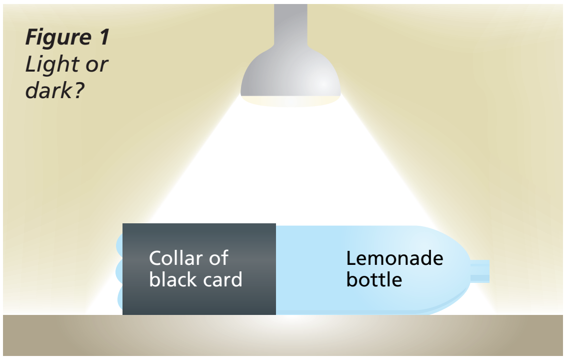
Make a cylindrical collar of black paper to fit around exactly half the height of the bottle. Screw on the cap and lay the bottle on its side. Light the bottle from above (a desk lamp would be fine), keeping the light above the centre of the bottle (Figure 1).

- **What is the effect of using different coloured cellophane paper instead of black cardboard?**

Looking from the side, count the number of brine shrimps in the lit half of the bottle. Repeat the count every 30 seconds. Do this 10 times and take an average.

As a fair test, put the collar on the other end of the bottle and repeat the investigation. What are your conclusions? Do brine shrimps show a preference for the 'light' or 'dark' half of the bottle?

Figure 1
Light or dark?



COMPETITION FOR FOOD.

For this investigation you need a small clear plastic box (a 200 g Ferrero Rocher chocolate box is ideal). Fill the box to two-thirds of its depth with fresh salt water (35 g salt per litre) and then add eight adult brine shrimps (perhaps four males and four females).

Put the brine shrimps in the container and leave them for half an hour. There will be no food in the water. When brine shrimps find no food to eat they explore the bottom substrate for food.

Now spread a level teaspoonful of some rich substrate from your main tank on two shallow Petri dishes (cleaned jam jar lids would also do). Carefully lower one dish in to the bottom of the box, placing it in the centre. Record how many animals are feeding from it every 30 seconds for 10 minutes.

Now add the second dish, placing the two dishes at roughly one-third and two-thirds along the length of the box (Figure 2). Again record how many feed at each dish every 30 seconds for 10 minutes.

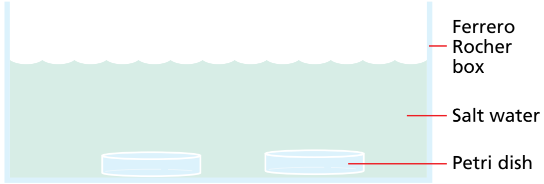


Figure 2 *Competing for food.*

Calculate means. When there are two dishes in the box, is there less feeding competition?

Michael Dockery and Stephen Tomkins

Oil refining

GARRETT NAGLE

GCSE key words
Fractional distillation
Crude oil
Fossil fuels

Oil supplies from the North Sea and the Middle East are often in the news. This article describes how oil is extracted and refined in another part of the world. Apart from some straightforward science it also looks at human impact on the environment, an important topic in your GCSE science course.

The most important commercial energy sources in the Caribbean are oil and natural gas, found mostly around Trinidad and Tobago. Oil and natural gas are fossil fuels, formed from organic matter deposited in sediments beneath the sea millions of years ago. As the layers of sediment built up, heat and pressure transformed the organic matter in the rocks into oil and gas. Most of the oil in Trinidad is found in rocks which were laid down about 10 million years ago.

An oil field is an area where oil is held in the pore spaces and joints of some layers of permeable rock. Oil is less dense than rock so under the right conditions it may seep to the surface.

OIL IN TRINIDAD AND TOBAGO

The Pitch Lake in southern Trinidad is a large mass of oil and other substances which has found its way to the surface. In fact, Trinidad was one of the world's first producers of oil:

- bitumen from the Pitch Lake was used to tar ships as early as the sixteenth century;
- the first oil well was sunk in 1857;
- commercial oil production started in 1908;
- the first refinery was opened in 1912.

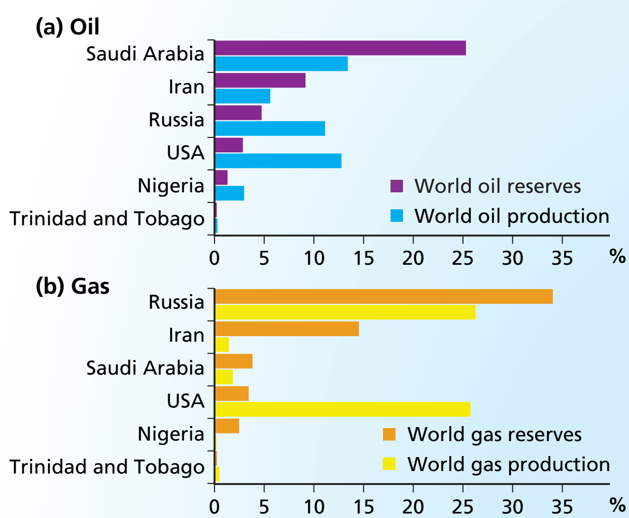
Drilling a well is an expensive business (see Figure 2). Most oil wells in Trinidad are over 1100 m deep and the deepest are between 5000 m and 6000 m. Drilling a well on land costs around US$2 million. At sea it may cost four times as much. On average, only 10% of wells find commercial quantities of oil.

Trinidad and Tobago is the only Caribbean country which is a net *exporter* of oil. The industry in Trinidad is small by international standards because Trinidad has only 0.05% of the world's proven oil reserves (Figure 1). Oil production peaked in 1978. It has declined since then, because reserves are running out.

Much of the oil in Trinidad's reserves is difficult and costly to extract. This is because:

- the rocks are strongly folded and faulted, with many small oil traps, each needing a well;
- in many oil fields there is no longer enough oil to flow naturally to the surface so it has to be forced out by injecting water, steam, or gas into the oil-bearing strata;
- over 75% of the oil is now extracted from marine oil fields, where drilling and extraction costs are much higher. The most productive oil and gas fields are off the east coast, in rocks beneath the sea which is 60–180 m deep. As these run dry, there are plans to drill in water up to 1500 m deep.

***Figure 1** World oil (a) and gas (b) reserves.*



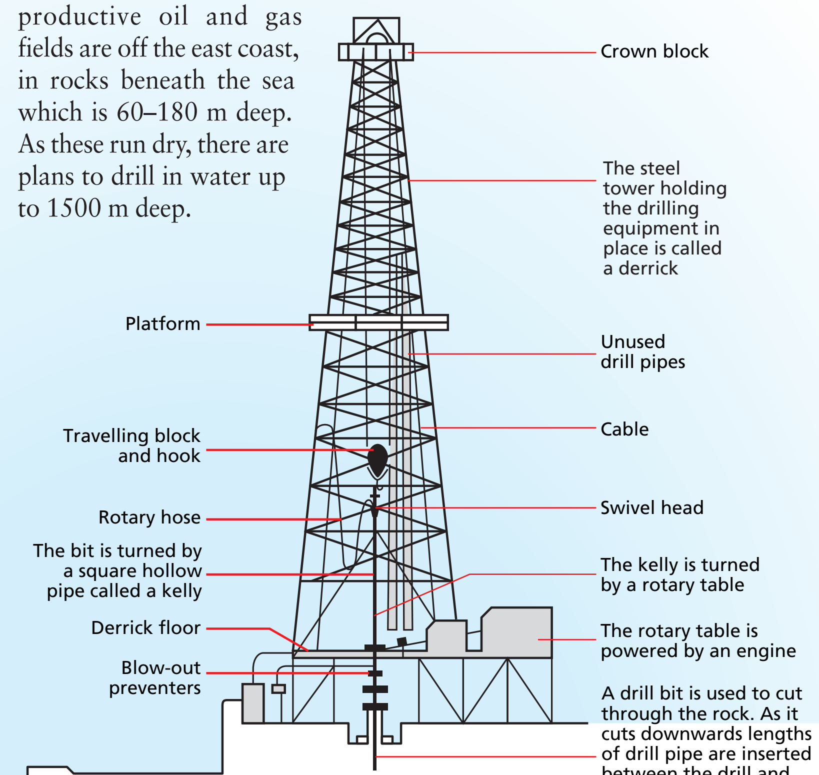


***Figure 2** A drilling rig.*

Go to http://www.hydrocarbons-technology.com Click on *industry projects* to find out more about the refinery mentioned in this article. Find out about planned developments in Alaska, where concern has been expressed about impacts on the environment.

When a marine oil well has been drilled a production platform is used to extract oil or gas.

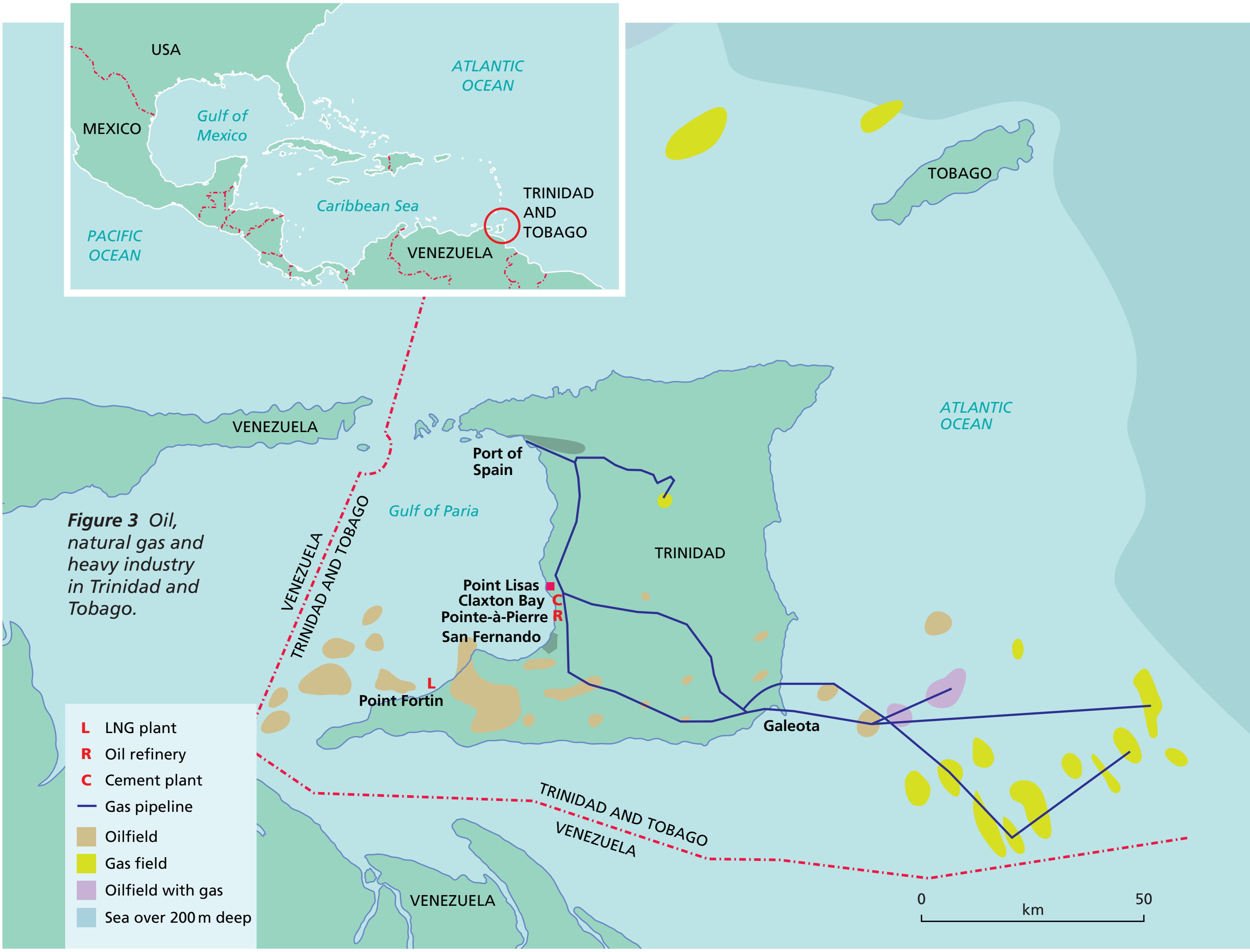


Figure 3 Oil, natural gas and heavy industry in Trinidad and Tobago.

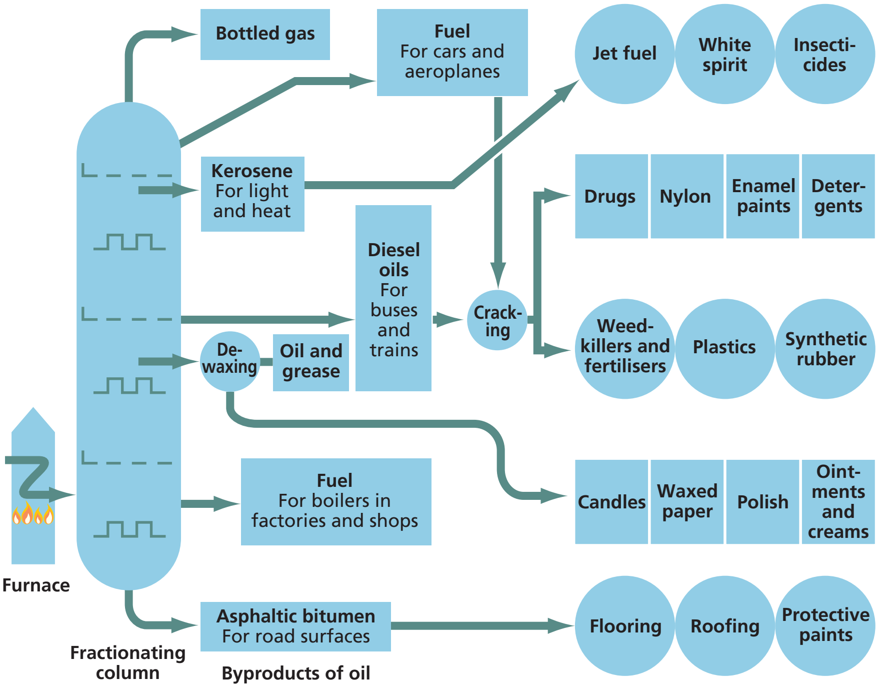


Figure 4 How oil is refined

OIL REFINING

Trinidad's only oil refinery is at Pointe-à-Pierre in the south of the island (see Figure 3). Although the refinery was modernised between 1991 and 1996, it is not as efficient as some of its international competitors. Oil refining is described in Box 1 and Figure 4.

Half the crude oil extracted in Trinidad is refined locally, together with some imported from South America, but crude oil from the east coast fields is refined overseas.

CRACKING

Oil refineries do not only produce fuels. Chemicals produced by fractional distillation may then be broken down (or 'cracked'), using catalysts and high temperatures and pressures to produce other hydrocarbons. These liquids and gases are used by the chemical industry to make products such as fertilisers, plastics, dyes, solvents, resins, paints, adhesives, medicines and

BOX 1 OIL REFINING

Crude oil is a black, tarry substance, made of a mixture of different hydrocarbons. In a refinery, the different constituents or fractions of crude oil are separated by fractional distillation.

- ❖ Crude oil is heated to 300°C in a furnace. The furnace is usually fuelled by natural gas.
- ❖ In the furnace, all the fractions in the crude oil evaporate, and become gases.
- ❖ The gases are fed into a 40 m high metal tower called a fractionating column.
- ❖ The fractionating column contains horizontal trays. The trays have holes with bubble caps which allow vapours to pass through.
- ❖ The gases cool down. The heavy fractions become liquid again at quite a high temperature. The liquids condense out and separate from the other gases at the bottom of the column.
- ❖ Lighter fractions travel to the top of the column, and condense there.
- ❖ Gasoline and aviation fuel are much more valuable than the heavier fractions. A modern refinery contains equipment which splits the large molecules which make up the less valuable fractions. This equipment allows the refinery to produce additional gasoline. Sulphur is also extracted. High-sulphur fuel produces sulphur dioxide and other pollutants when it is burnt. Only low-sulphur fuel can be exported to the main international markets. Sulphur which is extracted by a refinery can be sold for use by the chemical industry.

textiles. A petrochemical plant at Pointe-à-Pierre produces MTBE (methyl tertiary butyl ether), a liquid which is added to gasoline to reduce pollution.

HEAVY INDUSTRY LOCATION

Trinidad and Tobago has the main concentration of heavy industry in the Commonwealth Caribbean (Caricom). Heavy industries do not always have to be close to their raw materials, but they need large amounts of energy, and good transport facilities. Water transport is much cheaper than land transport for large quantities of heavy goods.

The main centre of industry is Point Lisas industrial estate (Figure 5) which has:

- a port, with a deep-water dredged channel and turning basin for large bulk carriers;
- a very large electricity-generating station;
- a plant which extracts liquid fuels such as propane and butane from natural gas;
- plants producing methanol which is added to petroleum to reduce pollution and used by the chemical industry.

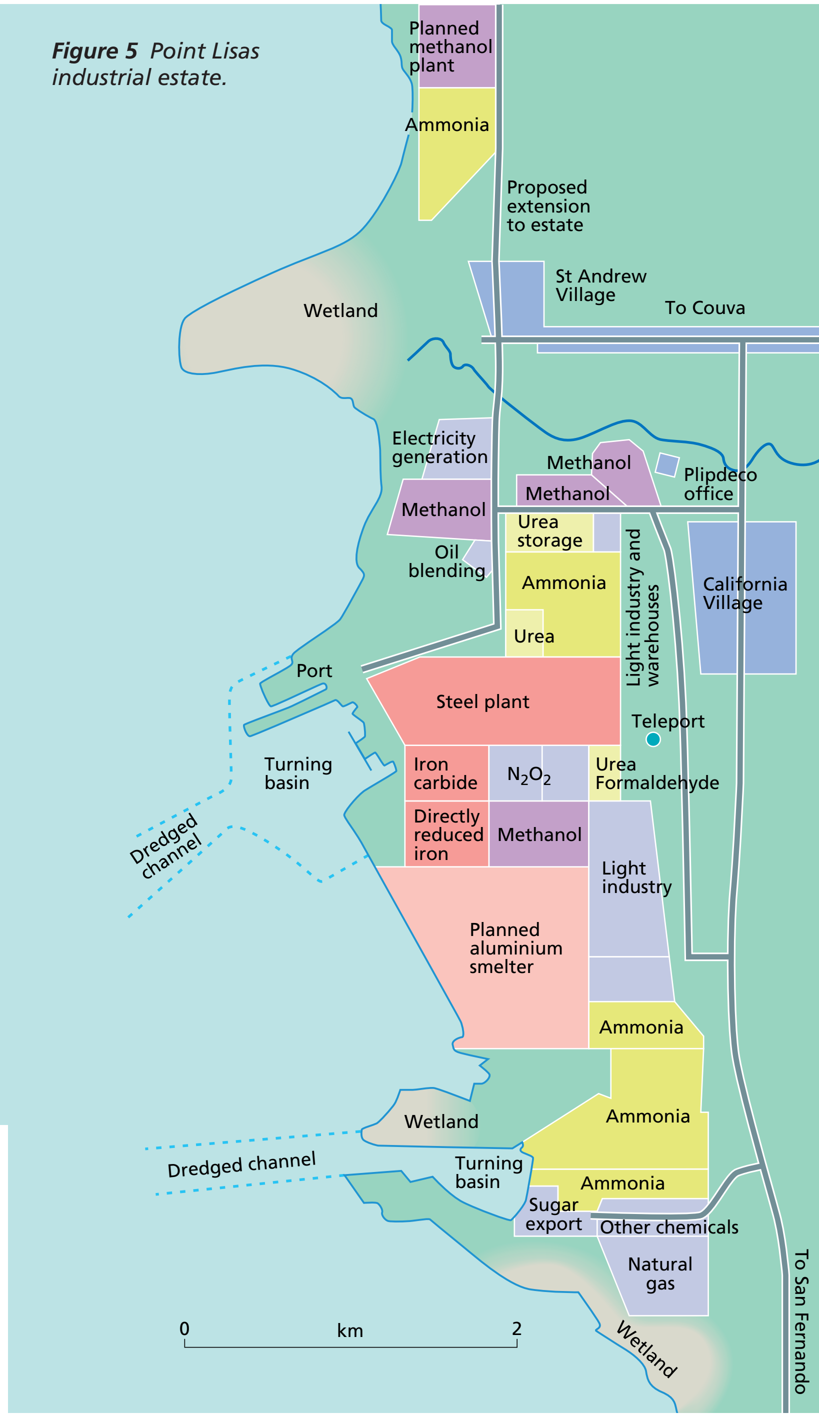


Figure 5 *Point Lisas industrial estate.*

Trinidad is one of the world's leading exporters of methanol and ammonia. Petrochemicals are exported by tanker to North and South America and Europe.

Heavy industries like those at Point Lisas:

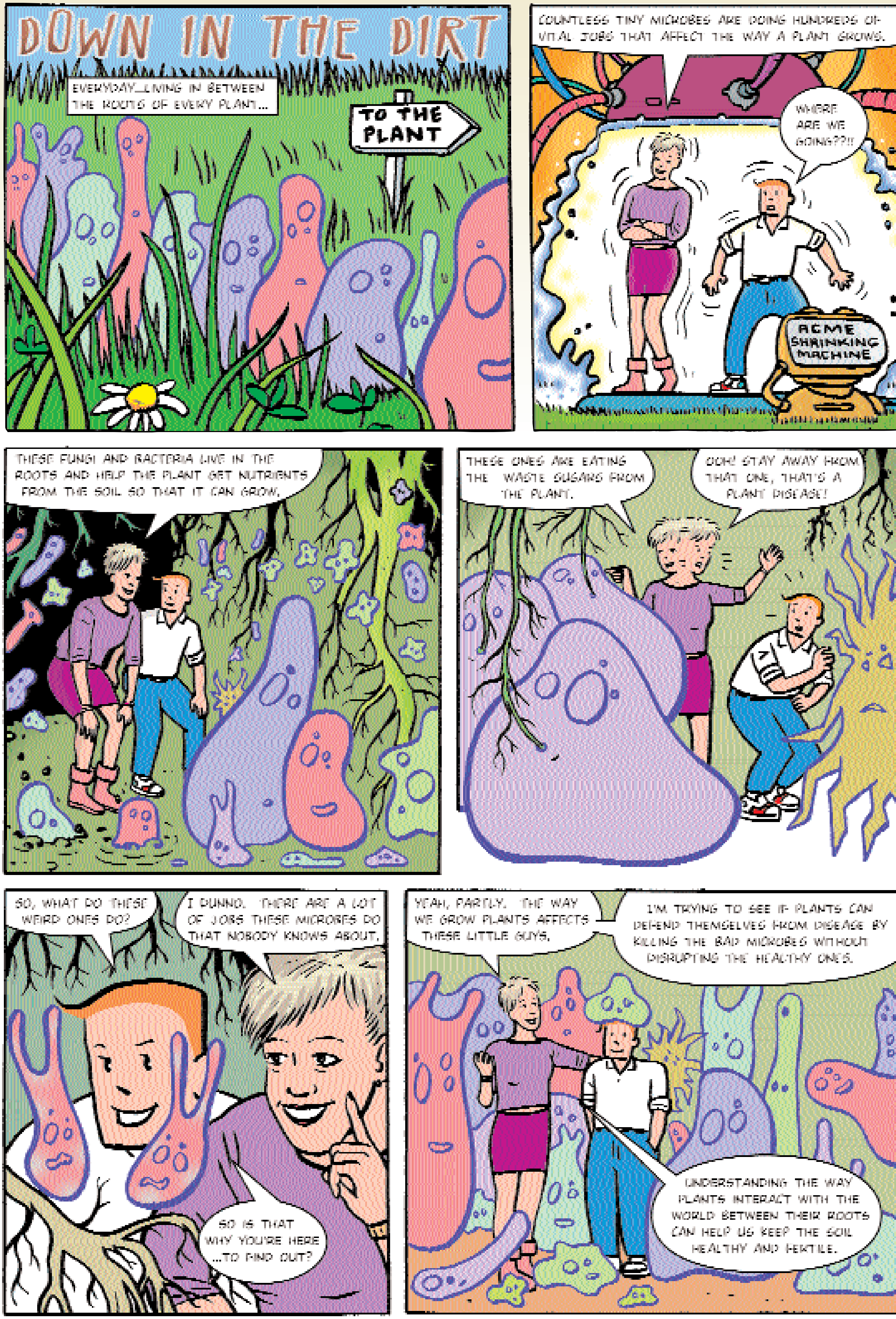
- have a high output;
- produce goods which can be exported;

but also:

- are expensive to set up;
- use a large area of land;
- do not provide many jobs.

Garrett Nagle teaches at St Edward's School, Oxford.

● Look at Figure 5 and identify chemical industry plants at Port Lisas other than those mentioned in the text. How is aluminium smelted? Find out what iron carbide and ammonia are used for.



Rothamsted Research

Down in the dirt

LUCY GILLIAM AND ELSPETH BARTLET

Elspeth Bartlet interviewed Lucy Gilliam and asked her to explain the science behind the cartoon in which she appears.

Lucy Gilliam is happily devoting 3 years of her life to studying soil. Her studies for her PhD at Rothamsted Research involve rinsing the soil from around the roots of crop plants and examining the bacteria and fungi that live there. 'Soil microbes are vital for a whole host of reasons,' she explains. 'They're an essential part of the carbon and nitrogen cycles, they keep the soil healthy and they're increasingly being recognised as an important component of biodiversity.'

Rothamsted Research

Above: Lucy at work.

SOIL COMMUNITIES

The soil around plant roots, known to soil scientists as the **rhizosphere**, is a hot spot of microbial activity, with a special ecology of its own. Although certain microbe species have been studied in detail, almost nothing is known about the ecology of soil communities, and for good reason. Soil communities are amazingly complex and diverse. It's been estimated that there are up to 10 000 different species of bacteria in every gram of soil.

LUCY'S RESEARCH

Lucy tackles this immense task by subjecting each soil sample to a battery of tests, ranging from analysing the DNA and RNA in the soil to measuring enzyme activity. Her tests aim to characterise each community with a broad profile of its enzyme activity, as well as identifying species. 'It's a tall order for me,' says Lucy. 'I'm having to get to grips with lots of techniques at once and handle huge amounts of data. But once I have a feel for the natural variability that is out there I can start comparing root communities in different systems.'

For example, farmers value the oilseed rape crop as a natural way of cleansing the soil of plant disease. It is thought to do this by releasing its own anti-microbial agents. Lucy is expecting to find that the oilseed rape rhizosphere is noticeably different from that of other crops. She also plans to use her methods to look at how new crops or crop cultivars, including genetically modified crops, might affect soil ecology.

And what does she think of the cartoon about her work? 'It's great! I've been trying to explain my research to my Dad for the past year. When the cartoon came out, I was able to just e-mail it to him and say "read this!"'

Rothamsted Research

Diverse bacterial colonies cultured from soil.

BOX 1 SCIENCE STORIES

Science Stories are real research stories from Rothamsted Research. Five scientists were turned into cartoon characters by artist Phil Elliott, with the help of funding from the Biotechnology and Biological Sciences Research Council. The full set of cartoons will be available in spring 2003, as a free comic or on the web (**http://www.rothamsted.bbsrc.ac.uk**). Want to know more? You can e-mail the scientists, including Lucy Gilliam, directly at **rothamsted.science@bbsrc.ac.uk**

A cultivar is a cultivated variety of a plant that was originally produced from a natural species.

Rothamsted Research is a government-funded institute researching arable crops.

Lucy Gilliam's research should earn her a PhD — she will be Dr Gilliam. People who carry on into research after a first degree at university often write up their work to gain a PhD.

● You probably know what DNA is and stands for. What is RNA?

Hazchem

You will have seen the hazard warning labels on chemicals and other hazardous materials in school and you will have passed tankers and lorries containing chemicals on motorways. These chemicals may range from the harmless to the highly toxic. The haulier must display a hazard warning panel that identifies the content and what action needs to be taken in the event of an accident or spillage. Use the following information to find out what types of chemicals you have passed next time you are on the move.

Table 1
UN substance identification numbers

Chlorine	1017
Hydrochloric acid	1789
Nitric acid	2031
Sulphuric acid	1831
Ammonia — anhydrous	1005
Sodium hydroxide solution	1824

Other substances can be found at **http://hazmat.dot.gov/erg2000/unidnum.htm**

● Log on to **http://www.hazchem.freeuk.com to learn more about warning signs and accident procedures.**

BOX 1 EMERGENCY ACTION CODES

The number refers to the agent that should be used to treat spillages:

1 Jets of water
2 Fog or spray of water
3 Foam
4 Dry agent

The first letter

P	Violently reactive	Full protective clothing	May be washed down the drain with plenty of water
R		Full protective clothing	
S	Violently reactive	Breathing apparatus	
S	Violently reactive	Breathing apparatus for fire only	
T		Breathing apparatus	
T		Breathing apparatus for fire only	
W	Violently reactive	Full protective clothing	Prevent spillage from entering drains or water courses
X		Full protective clothing	
Y	Violently reactive	Breathing apparatus	
Y	Violently reactive	Breathing apparatus for fire only	
Z		Breathing apparatus	
Z		Breathing apparatus for fire only	

The second letter (E) means consider evacuation of all in the vicinity.

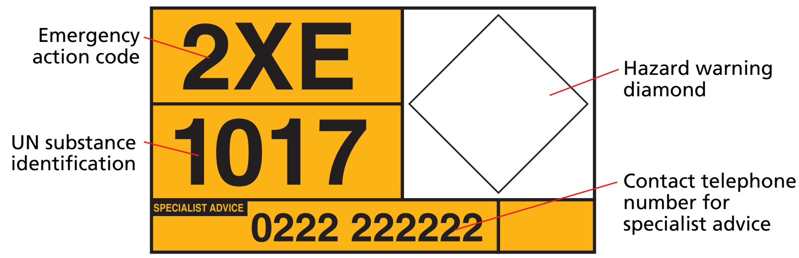


***Figure 1** The layout of a hazard warning panel.*

***Figure 2** Warning diamonds*