Catalyst

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Making
a splash

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Catalyst

Volume 17 Number 4 April 2007

The front cover shows a humpback whale breaching (Masa Ushioda/Alamy).

Contents

Big science, small science

In this issue, three articles look at the Large Hadron Collider, an example of 'big science'. It is a collaborative project involving thousands of scientists and engineers from many different countries. They have an enormous budget — enough to buy every UK citizen a ride on a rollercoaster at Blackpool Pleasure Beach. Ironically, this giant machine is designed to study matter at a submicroscopic scale. If a big discovery is made, it is likely that the published papers will have over 100 names of scientific authors, each deserving part of the credit.

But not all science operates on such a large scale. Hazel Prichard describes her life as an exploration geologist which takes her all over the world in search of valuable resources. Mathias Disney's work, tracking carbon in forests, contributes to a much larger picture of the carbon cycle and how human activity is affecting it. He is one member of a small team of scientists based in a number of UK universities and research institutes.

Perhaps you have been studying 'How science works', an important part of the GCSE science courses. This issue of CATALYST should show you that there is no single way in which science works — scientists and their work are as varied as you will find in any branch of human endeavour.

David Sang

A message from the publishers

This will be the last issue of CATALYST to be published by Philip Allan Updates. The magazine has been a key GCSE science resource for 17 years; we hope you have found CATALYST a useful and enjoyable read. We would like to thank you for the support you have given the magazine.

In future, CATALYST will be published by the Science Enhancement Programme. Full details of how it will be made available and of individual and institutional subscriptions will appear soon on the SEP website (**www.sep.org.uk**).

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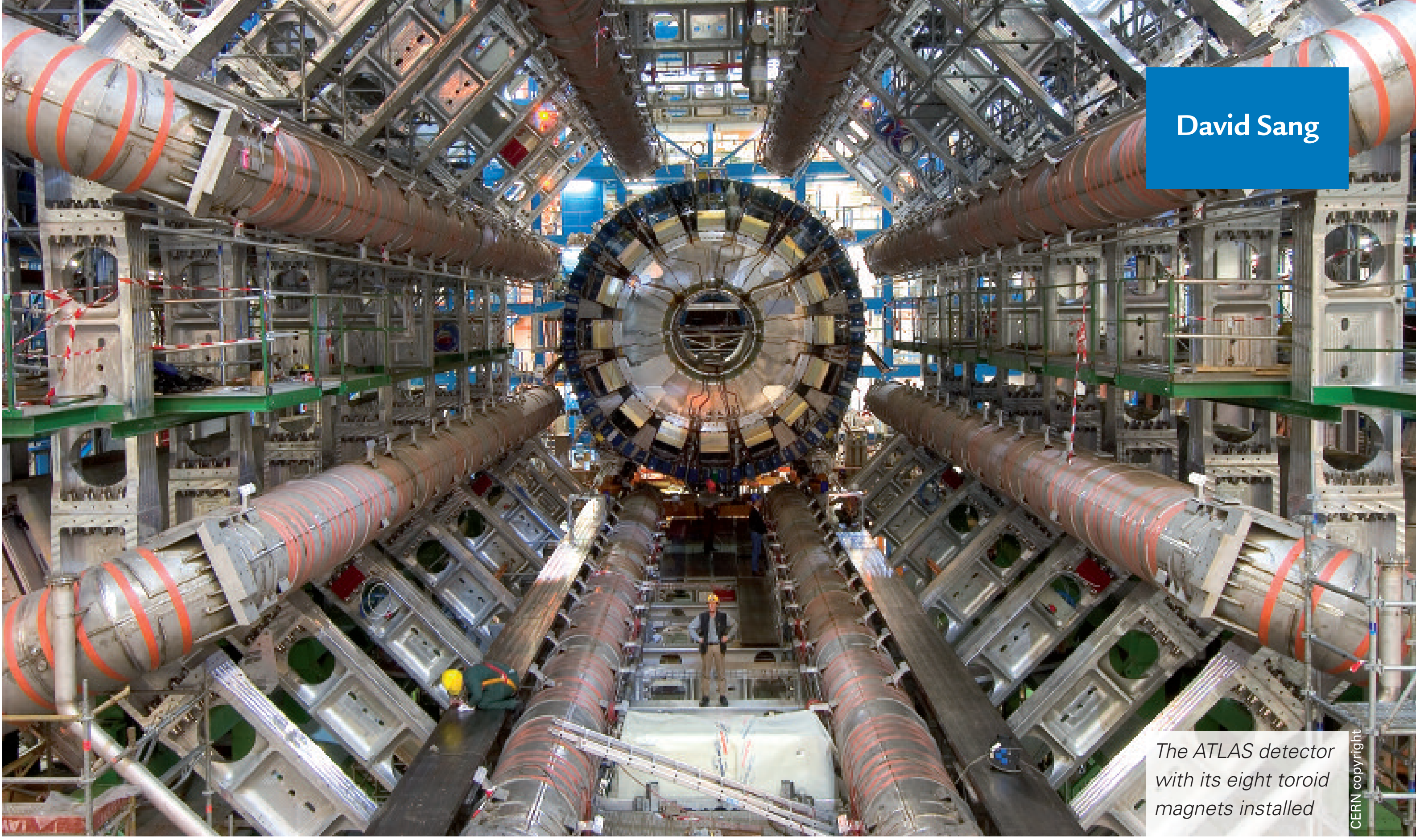

The ATLAS detector with its eight toroid magnets installed

CERN copyright

David Sang

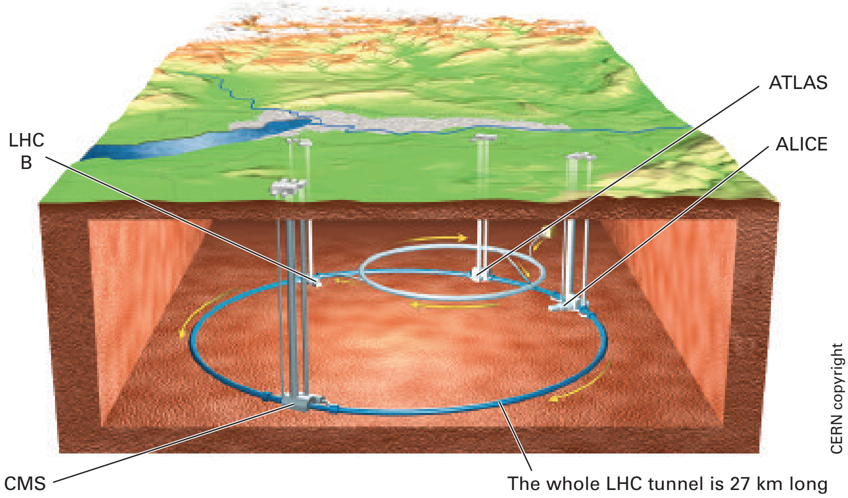
Journey into inner space

By the end of this year, physicists working at Europe's Large Hadron Collider hope to have received a most unusual Christmas present — the first results from what is probably the biggest, most expensive and most ambitious scientific experiment ever carried out. Later, they hope to solve the mystery of the fundamental forces of nature.

The Large Hadron Collider (LHC) is a giant particle accelerator nearing completion at CERN, the European nuclear physics lab near Geneva (Figure 1). It sits in a tunnel which forms a circle with a circumference of 27 kilometres, passing under the border between France and Switzerland. At intervals there are larger caverns which house huge detectors. Up on the surface are the control buildings where operators control the accelerator and scientists gather data. However, it is the equipment underground that is at the heart of the experiment.

When the accelerator finally goes into operation, two narrow beams of protons will circulate around this tunnel, in opposite directions, occasionally being directed towards each other so that they collide, producing showers of subatomic particles. By analysing these showers, scientists hope to answer some of the most tantalising questions remaining in nuclear physics.

There are four parts to the LHC: producing the beams of particles; controlling the collisions; detecting the results; and processing the data.



CERN copyright

Figure 1 *General plan of the LHC site. The four detectors are in large caverns around the LHC tunnel*

GCSE key words

Particle accelerator
Scattering
Proton
Solenoid

Box 1 The Standard Model

The Standard Model is the currently accepted theory of matter and energy, dealing with the fundamental particles of which matter is made, such as photons and gluons, which carry the forces of interaction. According to the Standard Model, there are two types of fundamental particle — leptons and quarks — which cannot be broken down into anything more basic.

- **Leptons** are lightweight particles (electrons and neutrinos).
- **Hadrons** are heavier particles, including protons and neutrons, and are not fundamental; they are made up of **quarks**.

Box 2 Approaching the speed of light

The LHC will accelerate protons to within a tiny fraction of the speed of light *c*. When a particle is accelerated, its mass increases as well as its speed. This effect is only noticeable at speeds approaching *c*. So the protons circulating in the LHC beams are not only very fast but they are also much more massive than when stationary. Hence their kinetic energy is enormous.

Einstein's equation $E = mc^2$ allows us to calculate the energy E which is released when a particle of mass m is converted entirely to energy.

Accelerator action

Protons are the positively-charged particles which are found in the atomic nucleus. According to a theory called the Standard Model (see Box 1), protons belong to a family of particles called **hadrons** (meaning *heavy particles*, as opposed to the much lighter **leptons**, such as the electron).

The nucleus of a hydrogen atom is a single proton.

To produce protons, a high voltage is used to strip electrons from hydrogen atoms. To produce the necessary beams of high-speed protons, the LHC has three accelerators which, in sequence, boost the energy of the protons before injecting them into the LHC ring. The protons eventually reach a speed of 99.999 9991% of the speed of light (see Box 2). Each proton will have an energy of 7 TeV (tera-electron-volts); 1 TeV is about the energy of a flying mosquito. This is small on a human scale, but it is exceedingly high on the scale of a particle as small as a proton.

1 eV = 1 electron-volt; this is the energy gained by an electron when it is accelerated through a voltage of 1 V. 1 TeV = 10^{12} eV.

Beam bending

Two beams of accelerated protons, travelling in opposite directions, enter the giant LHC ring. A force is needed to make these beams follow the curve of the tunnel; the force is provided by magnets (Figure 2).

A ring of large blue cylinders occupies the length of the tunnel. Each is a large electromagnet or solenoid — there are 1232 of them in total. Each of these is a coil of superconducting wire which must be cooled to 1.9 K, less than 2 degrees above absolute zero, using liquid helium. Only superconducting wires can carry the high current needed to produce a sufficiently strong magnetic field.

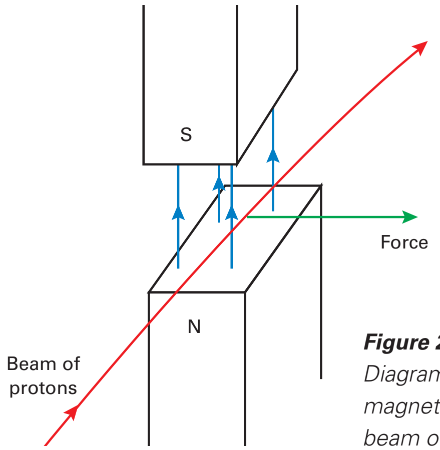


Figure 2 *Diagram of magnet bending beam of protons*

The proton beams travel parallel to one another, but in opposite directions, in two evacuated tubes inside the electromagnets. Each beam is in fact a series of 'bunches' of protons, each made up of about a billion particles. The bunches are separated by about 75 m in the tubes, or 25 nanoseconds (billionths of a second).

Collision control

Experiments have been set up at four points around the tunnel. At these points, the two beams can be directed so that they meet head on. In practice, only about 20 proton–proton collisions will occur from each bunch. This is because each beam is about 1 micrometre across, but a proton has a diameter of about 10^{-15} m. Hence, even with 10^9 protons in a bunch, head-on collisions are relatively infrequent.

The combined energy of two protons colliding is 14 TeV. This is enough to produce a shower of energetic particles and radiation, and these are detected as they emerge from the collision chamber. The detectors are enormous machines, built in layers capable of detecting the tracks of charged and

- **Find out more about the parts of the ATLAS detector shown in Figure 3 at http://hands-on-cern.physto.se/ani/acc_lhc_atlas/ endview.swf**

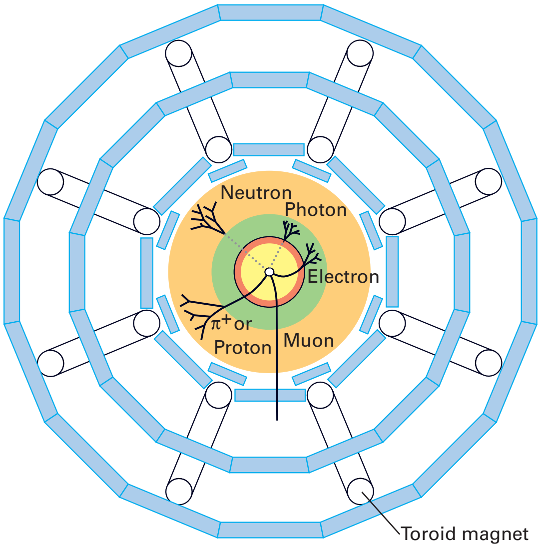


Figure 3 *Cross-section of the ATLAS detector showing particle tracks*

CERN copyright

A technician cycles to work in the LHC tunnel. This photograph was taken during the installation of the superconducting solenoids; two of the metal tubes will carry the proton beams

uncharged particles, as well as photons of electromagnetic radiation (Figure 3). As the spray of particles and radiation passes through the detectors, it is logged electronically and the path of each particle or photon is recorded. The length and curvature of each track reveals the charge and energy of the particle which produced it, and from this the researchers can deduce just what happened in the collision.

Demanding data

When it is up and running at full capacity, the LHC will produce 1 billion collisions per second. Of these, only 10 or 100 may be of serious scientific interest. So a system is needed to identify the collisions of interest. A lot of computing power is required for this. When an event of interest is identified, longer term recording is triggered and the less interesting data are wiped from the temporary store, to make way for more data flooding in. There will be some 4000 PCs linked in parallel at CERN to handle this data storage.

The scientists managing the project decided not to set up a single computer centre to analyse the LHC data. Instead, they have established an international grid, the Worldwide LHC Computing Grid, or GridPP, linking over 6500 computers in 75 sites around the world. This is known as distributed computing (see back cover). All the data are available to each of the 5000 scientists who will be working on the different experiments, and the available computing power will be shared according to demand.

Box 3 Useful websites

- The Large Hadron Collider homepage is at: http://lhc.web.cern.ch/lhc
- View an animation of the accelerator in action and the ATLAS detector at: http://hands-on-cern.physto.se/ani/acc_lhc_atlas/lhc_atlas.swf
- To find out more about the ATLAS experiment select *movie* at: www.atlas.ch/index.html
- You can learn more about the detector at: www.atlas.ch/detector.html

Click on *eTours* or *Detector Desc*.

- **You can find out about visiting CERN on page 11.**

Possible outcomes

Why is it important to achieve high-energy collisions? Rutherford's experiment of 1910 used alpha particles to probe gold atoms, and this established the existence of the atomic nucleus. However, the alpha particles which bounced off the gold nuclei had an energy of less than 1 MeV, a millionth of that achievable by the LHC. To penetrate more closely, and to achieve much stronger interactions between particles, higher energies are needed.

Among the debris of the billions of proton–proton collisions that the LHC will produce, scientists hope to spot evidence of some exotic events. In particular, they would like to see evidence of a particle called the Higgs boson. This particle is believed to explain why matter has mass, but it has yet to be observed because it is only expected to appear in high-energy collisions with energies of 1 TeV or more. This is an important test of the Standard Model (see Box 1).

The fast-moving, highly-energetic protons in the LHC beams reproduce the conditions in the early history of the universe, shortly after the Big Bang. So the LHC can be thought of as a 'telescope' which allows us to see back in time, to within a fraction of a second of the emergence of our universe.

One concern about the LHC is that it might result in the production of exotic forms of matter. For example, a tiny black hole might be created which would then suck in material from its surroundings, eventually engulfing the whole planet. However, this is thought to be extremely unlikely – such a black hole is predicted to evaporate in a fraction of a second.

***David Sang** writes textbooks and is an editor of* C*ATALYST*.

Your future

Exploration geology

The exploration and mining industries are booming, so it is an exciting time to be an exploration geologist. Read on to find out how to become one.


Hazel Prichard

We all use metals every day in items such as televisions, computers, mobile phones and cars, but where do they come from, how are they discovered and who looks for them? As well as needing metals, human beings have a great appetite for construction materials, oil and gas — the exploration geologist has the task of discovering new sources of all these materials.

It's a lifestyle

This career takes you to places no tourist would go. Much of your work will be in a team, which might be in a multinational or a junior exploration company, or based in a government or academic institute.

Locating mineral deposits is intellectually challenging. It involves chases across continents, putting scraps of evidence together from local people, old

Box 1 Hazel's career as an exploration geologist

I have had so many adventures. I remember enjoying 24 hours of daylight with Russian academics in the Polar Urals where breakfast was extremely fresh raw fish. Searching for chromite in the desert wadis of Oman, we fled flash floods caused by freak snowstorms in January. I have seen beautiful places such as the grasslands of southern Brazil with exotic birds and the perfumes and sounds of the Amazon jungle. We dodged icebergs to get to Greenland and I dived to the bottom of the Atlantic in a small yellow French research submarine.

At a very early age I was fascinated by multicoloured sediments and fossilised trees on the Isle of Wight. In my teens I learned about the plate tectonic revolution which occurred when people realised that the continents move and oceans are formed and destroyed at plate boundaries. I was lucky to discover some of the rare metal platinum on the Shetland Islands. I picked up a rock because it was a beautiful green colour. This was due to a nickel-rich mineral; an ideal host for platinum. Since then I have travelled to many platinum occurrences worldwide.


Hazel Prichard

Box 2 Exploration geology at Cardiff University

This undergraduate degree trains students so that they can quickly adapt to the frantic pace of mineral exploration. They do a lot of fieldwork in the UK and abroad. Between the 2nd and 3rd years students do a project either in the industry or making geological maps. Being close to coal mining in south Wales the course has a long tradition, and Cardiff today still hosts much mining expertise. Teaching is research-led on metals, industrial minerals, oil and gas.

Student comments on the course include:

Being able to use my initiative to manage my own project, organise my days, planning and digging trenches in the desert of Uzbekistan was great.

It was fantastic to map in western Australia where previous mapping was scarce, working with geologists who shared their knowledge and applying my university training.

Students from Cardiff exercising their observation skills on a field trip

publications, maps, modern satellite images, geochemical analyses, geophysics, and of course the rocks themselves. Not only does it give you the chance to comprehend the magnitude of geological events, it can also be very well paid.

Responsibility

Most geologists are keen observers, love to be in the open air and have a determined interest in what happens to the resources they are investigating. We need to ensure that metals are recovered in a responsible way, given the growing pressure on the world's finite resources. The exploration geologist can have a say in how and where mines are developed. Exploiting resources wisely is vital to society and human survival.

High metal prices

Metal prices are at a 25-year high; they have doubled in the last 3 years. Sustained Western demand and increasing demand from China and India suggests that new resources will have to be found, offering a great future for exploration geologists.

Training and employment

You need a broad skills base; being able to survive in extreme conditions is as important as understanding the geology. An undergraduate geology or exploration degree is a good start. It is possible to go straight into exploration after this, but an MSc gives further training. A PhD provides an opportunity to study an exploration challenge in detail. Graduates are employed in all sorts of situations, from the most remote parts of the world to offices where they analyse data using modern computer processing techniques.

***Hazel Prichard** runs the Exploration and Resource Geology degree at Cardiff University.*

Magnetite mine in China

Box 3 Useful websites

- Find out about Hazel Prichard's research at: www.earth.cf.ac.uk/people/personal-info-page.asp?id=39
- Details of the Cardiff University exploration and resources course are at: www.earth.cf.ac.uk/teaching/undergraduate/expl_geology.shtml
- All the other university geoscience/earth science/geology courses in the UK can be explored by links from the Geological Society website at: www.geolsoc.org.uk/template.cfm?name=university_links

A recent talk by a US geologist began 'there is a huge gap in the supply of exploration geologists; companies can place three times the number of geologists available'.

An Australian employer recently commented 'there is a massive global skills shortage; there are few Australian geology graduates.'

Improve your grade

Science beyond your textbook

What if your GCSE science textbook leaves you dissatisfied with the account it gives of a topic or wanting to find out more? The internet is a useful source of additional information, but it can be difficult to check the reliability and accuracy of all that is out there. Here we look at two other sources — broadcasts and popular science books.

- **You can find more about each book on the internet via Google or Amazon.**

- **Refer back to Catalyst Vol. 17, No. 1 to find out about evaluating websites.**

The BBC news website has links to authoritative sites for information about science that is in the news.

Science broadcasts

The home page for the BBC's science output on television and radio is at **www.bbc.co.uk/sn/**. Here you will find all sorts of ways to broaden and consolidate your knowledge and understanding of science. A useful listing of each day's science programmes is provided at **www.bbc.co.uk/sn/tvradio/listings/**. You can listen to them live, but many programmes are also available to download or stream on suitable software, such as Real Player or Windows Media Player, or as podcasts.

The science output of BBC Radio 4 is at **www.bbc.co.uk/radio4/science/** and there are three excellent 30-minute programmes on offer most weeks:

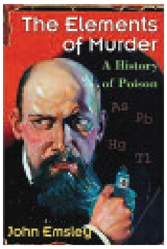
- ***Frontiers*** (Wednesday 9.00–9.30 p.m.) Peter Evans explores new ideas in science, and meets researchers who see the world through fresh eyes and challenge existing theories, as well as hearing from their critics. Many such developments create new ethical and moral questions and these are discussed. Great for the 'Science in the news' parts of your GCSE course.
- ***The Material World*** (Thursday 4.30–5.00 p.m) Quentin Cooper reports on developments across the sciences. Each week four scientists describe their work, conveying the excitement they feel for their research projects.
- ***Case Notes*** (Tuesday 9.00–9.30 p.m.; repeat Wednesday 4.30 p.m.) Each week Dr Mark Porter interviews an expert in the studio, tackling a particular medical topic. There are also reports from around the UK on the health of the nation — and the NHS.

You can also listen to past broadcasts of all three programmes, about many fascinating matters.

Popular science writing

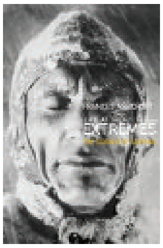
In recent years there has been a surge in the number of books in the category of popular science. Some are very well written, a great read and not too challenging technically. Here are some of the good ones that you might look out for. Reading any of these is well worthwhile, as you seek to improve your grade.

The Elements of Murder: A History of Poison by John Emsley



This features what the author calls 'the darker side of the periodic table'. It is a fascinating and very readable forensic history of five deadly chemicals (mercury, arsenic, antimony, lead and thallium) and their use in various murders. A reviewer commented: 'Reading *The Elements of Murder* is like watching a hundred episodes of CSI, but without having to sit through the tedious personal relationships of the characters.' Reviewers are equally enthusiastic about other books by John Emsley on chemistry, so look out for these as well.

Life at the Extremes by Frances Ashcroft



This book is something of an adventure story, addressing the challenges that humans face in extreme environments — including at high altitude, very low and high temperatures, and under pressure. In *Life at the Extremes*, Frances Ashcroft focuses on human physiology (her own area of research), but she ranges across medicine, the history of science, sport, exploration, and comparative

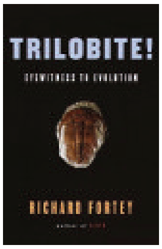
Box 1 Science writers

More popular science writers to look out for include:

- John and Mary Gribbin (astronomy and evolution)
- Marcus Chown (cosmology)
- Richard Feynman (physics)
- Steve Jones (DNA, genetics and evolution)

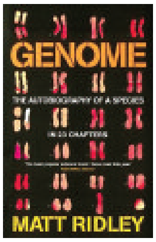
zoology, and throws in some biographical and autobiographical anecdotes as well. She introduces a cast of extraordinary scientific personalities — inventors and explorers who have charted the limits of human survival — and describes many intriguing experiments, showing how scientific knowledge has enabled us to push the limits.

Trilobite! Eyewitness to Evolution by Richard Fortey



One reviewer commented that this book 'is one of the best popular science books to have appeared for a considerable time'. It is a marvellously written, smart and compelling, accessible and witty scientific tale about the most ubiquitous and diverse of fossil creatures. Trilobites are interesting, not just in their own right, but because of what they can tell us about evolution and geology. They can help us to understand the vast geological shifts and processes that gave rise to our modern continents, for during their long existence of 300 million years the world was remade twice.

Genome by Matt Ridley



This draws on the latest genetic research. It helps you to understand what the human genetic code is, how it works, and how discoveries in the field of genetics are revolutionising medicine, pharmaceuticals, business, politics, and our own sense of what it means to be human. By picking one newly discovered gene from each of the 23 human chromosomes and telling its story, Ridley recounts the history of our species and its ancestors from the dawn of life to our latest developments in medicine.

Chain Reactions by Adam Hart-Davis

In this book, Adam Hart-Davis explores the links between different scientific pioneers and their discoveries, often across extraordinarily varied fields of human endeavour, and sometimes across centuries. Relationships — intellectual, amicable and implacable — are brought to light, as are the surprising roles played by happenstance, coincidence and sometimes downright error in many of the most fundamental scientific breakthroughs of our time. It is illustrated by vivid colour portraits of the scientists, from the National Portrait Gallery.

Nigel Collins *teaches biology and is an editor of* C*ATALYST*.

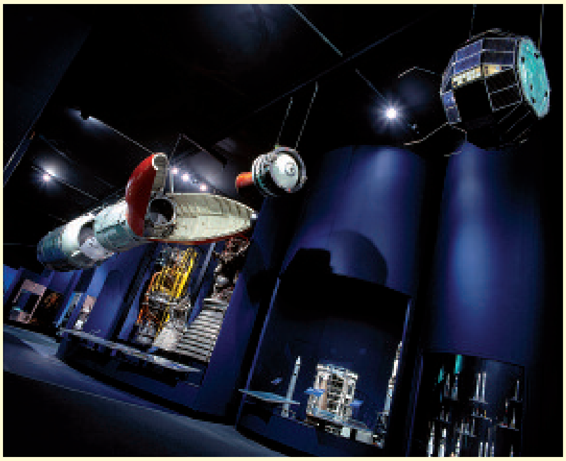
Amazon includes reviews by readers. These can act as a good guide to the content and level of a book.

Places to visit

Science Museum, London

An exhibition about the Large Hadron Collider opens in the Antenna Science News Gallery on 3 April. It features a combination of objects, video, images and interactive exhibits describing the science involved with the LHC and aims to increase your understanding of energy, matter, space and time. This material will soon feature on the excellent Antenna website. Clicking on: **www.sciencemuseum.org.uk/on-line/exhibitions.asp** will take you to many of the different exhibitions at the Science Museum, including Antenna. Lots of useful stuff here to help you improve your grade.

Many of you may have visited the old *Space Gallery* at the Science Museum, London. It has been shut for some time for redevelopment and reopens on 26 April as *Exploring Space*. This permanent gallery will celebrate our exploration of space so far and reveal the benefits of space science to everyday life. Opening on the 45th anniversary of the first British satellite launch, *Exploring Space* puts the spotlight on some of the greatest achievements of British space science over the past five decades as well as looking at the possibilities for the future.



The old *Space Gallery* at the Science Museum is being redeveloped.

Nigel Collins

GCSE key words
Sustainability
Conservation

Whaling

Humpback whale feeding, showing baleen plates

David Fleetham/Alamy

During the last century whales were hunted and killed by many nations for the valuable materials they provided. Whale populations collapsed as a result. Here we look in detail at this example of human impact on the environment.

Whales are mammals; they come in many different shapes and sizes. There are 15 species of so-called great whales, including the largest animal on Earth, the blue whale.

The 15 species of great whale fall into two groups according to how they feed: **baleen whales** and **toothed whales**. Fourteen, including the blue whale, are baleen whales, but the sperm whale is one of the toothed whales. There are 70 species of toothed whale; these are mostly much smaller than the baleen whales. Dolphins and porpoises are in the toothed whale group (see Table 1).

There is more detail about some of the great whales in Table 2.

Whales were killed for all sorts of products. For example, baleen whales were used to make whalebone corsets and the teeth of sperm whales were used to make ivory for piano keys and buttons.

Baleen whales

Baleen whales feed on small animals. Many species catch shrimp-like creatures called krill and some feed on small fish as well. Baleen whales have a special feeding mechanism in their mouths that acts as a giant sieve or filter. Several hundred elongated triangular baleen plates, 1–2 m long, grow down on either side from the roofs of their mouths. These plates are made of a fibrous horny material. The baleen plates are 1–3 cm apart and fringed on the inward edge with fibres. The plates grow continuously so that, as the fibrous edges fray in use, they are replaced.

After gulping a large volume of water and krill (or small fish) into its mouth, a baleen whale raises its tongue, which increases the pressure. This forces the water out between the baleen plates at the sides of the animal's mouth, back into the sea. The krill are trapped inside the whale's mouth because the gaps are narrow; the fibres contribute to the overall filtering effect. The whale can then swallow its meal.

Table 1 *Types of whale*

Group	Number of species	Examples
Baleen whales (*Mysticeti*)	14	Blue, fin, sei, humpback
Toothed whales (*Odontoceti*)		
Beaked whales	21	Includes bottlenose whale
Other species of whale	9	Sperm whale, narwhal, white whale
Porpoises and close relatives	6	Harbour porpoise
Dolphins and close relatives	34	Common dolphin, pilot whales, killer whales

Table 2 *Whale statistics*

Species	Average length (m)	Average mass (tonnes)	Distribution	Main prey	Estimated population	Status
Blue	25–26.2	100–120	Worldwide	Krill	1700	Once hunted extensively. Numbers very low but may be increasing
Fin	19–22.3	45–75	Worldwide but less common in tropics	Krill and small fish	30 000	A target for modern whaling. Numbers reduced in some areas, recovering in others
Sei	13.6–16	20–25	Worldwide to subpolar regions	Krill, small fish, squid and copepods	54 000	A target for modern whaling but numbers not reduced as much as blue and fin whales
Common minke	8–10	9	North Atlantic and Pacific from tropics to pole	Small fish and krill	174 000	A target for modern whaling
Antarctic minke	10–11	9	Circumpolar seas in southern hemisphere	Krill and sometimes small fish	761 000	A target for modern whaling
Humpback	12–14	25–30	Widely distributed from Arctic to Antarctic	Krill and small fish	11 750	Increase of 3.1% 1979–93 in North Atlantic; increase of 10.9% 1977–91 in southern hemisphere
Sperm	11 (female) 15 (male)	20 (female) 45 (male)	Worldwide	Squid, fish in some places	No estimates	Once heavily exploited but now reasonably abundant

Population estimates were made between 1982 and 2001.

Sperm whales

The sperm whale is a different shape from the various species of baleen whales. Its mouth is smaller and it has teeth, rather than baleen plates. It catches much larger prey, such as sizeable squid.

Catching whales

Whales are caught using whale catchers — small vessels, with engines powerful enough to pursue a whale.

The harpoon fired from the bows of the catcher is a heavy structure, made from a number of steel components (Figure 1). At the front is the hollow head, packed with explosive. The next section has three or four hinged bars, or flukes, with teeth at their ends, tied down in the closed position. This is attached in turn to a metal shaft, which attaches to the line to the whale catcher.

When the harpoon is fired into a whale, the sudden decrease in velocity drives a firing pin in the second section into a detonator in the explosive charge — as a result the hollow head explodes inside the whale. At the same time the second section is pushed backwards. The ties on the flukes break and hinge open. The teeth provide a firm grip inside the whale. If this does not kill the whale the line is played out as the whale swims on.

The whale catcher then uses its mast and a series of pulleys and springs to act like a huge fishing rod (see Figure 2). Once the whale dies it is towed to a factory ship. This has a large ramp at the stern, leading to a wide flat deck, to which the whale is hauled with cables for butchering.

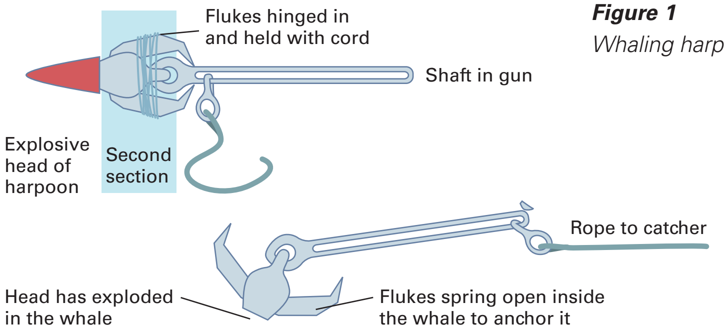


Figure 1
Whaling harpoon

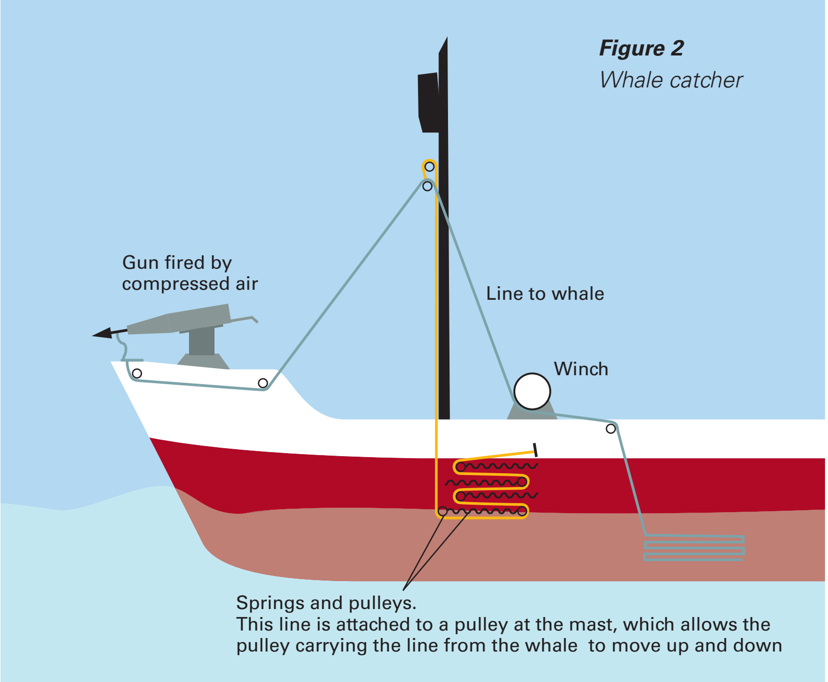


Figure 2
Whale catcher

Jeremy Sutton-Hibbert/Alamy

Minke whale killed by a Japanese whaling fleet for 'scientific purposes'

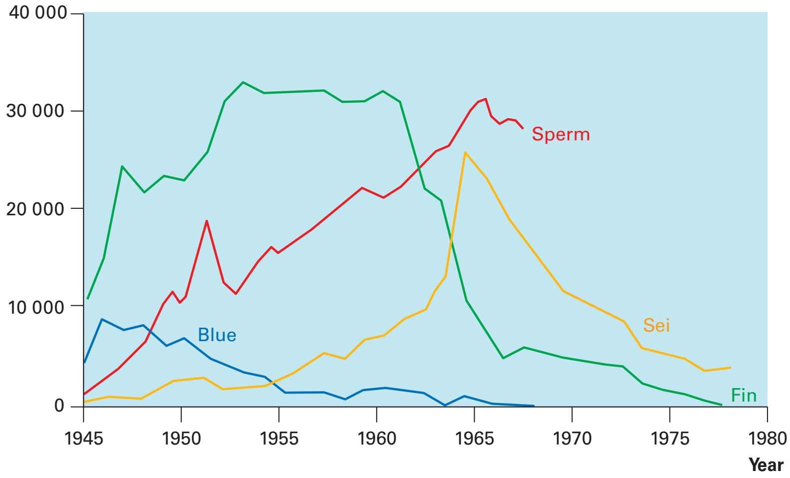


Figure 3 *Whale catches since 1945*

Inuit people used to use whale ribs and skulls to support the roof of pit houses dug into the ground and then covered with turf. There are no trees for house construction in the Arctic.

An end to the whale hunt?

Whale populations collapsed in the twentieth century (Figure 3). First the blue whale, then the fin whale, then the sei whale became more difficult to find and catch as numbers decreased. People became more concerned at the impact they were having on the planet and started to place a value on whales beyond the financial value of the materials their carcasses yielded.

Some people and governments started to become more active in defence of these creatures. The International Whaling Commission was formed in 1946 when commercial whaling was in full swing and it levied quotas as stock fell. In 1982, the International Whaling Commission decided by majority vote to implement a pause or 'moratorium' in commercial whaling, with effect from 1986. It was hoped that the moratorium would be in time to 'save the whales'.

Recent estimates of great whale populations for some parts of the world's oceans are given in Table 2.

Box 1 Useful websites

- If you want to research whales and whaling in more detail and find out more about the role of the International Whaling Commission visit: www.iwcoffice.org
- If you are interested in animal welfare issues raised by whale hunting, an IWC report on a workshop in 2003 is at: www.iwcoffice.org/conservation/welfare.htm#killing
- You can find out about British research on whales and seals, by the Sea Mammal Research Institute, at: www.smru.st-and.ac.uk/
- The Whale and Dolphin Conservation Society is a global charity. Go to www.wdcs.org to find out more.

At present there is ostensibly no commercial whaling. Since the moratorium, Japan, Norway and Iceland have issued scientific permits as part of their research programmes. All three countries caught whales in the past. The factory ships of Iceland and Japan, with attendant catchers, ranged all the way to the Antarctic.

In recent years, only Japan and Iceland have issued permits, maintaining that the catches are essential to obtain information necessary for rational management and other important research needs. Scientists advising governments of many countries take the view that there is little scientific merit in this renewed hunt and that it should not be extended further.

In fact, the meat from these whales is sold for human consumption, especially in Japan, so it could be argued that 'scientific purposes' are used as an excuse for what is in reality a small-scale commercial operation. At the most recent meetings of the IWC there has been renewed pressure to reopen commercial whaling.

Reasons for whaling

Economic arguments from Norway, Iceland or Japan for a lifting of the moratorium are relatively weak. Elsewhere such arguments are more convincing. Small communities of native people live scattered around the Arctic. Although they enjoy some of the benefits of modern living, until relatively recently they were entirely dependent on various species of smaller whales from the sea and reindeer or caribou on land for meat. These people are still allowed to hunt in the traditional way that has existed for centuries. The whales are chased in open boats and killed with hand-thrown harpoons.

Nigel Collins *teaches biology and is an editor of* C*ATALYST. Before teaching biology he visited old whaling stations when working in the Antarctic. He also lived in an Inuit village in Alaska, where whales were still being caught with hand-thrown harpoons.*

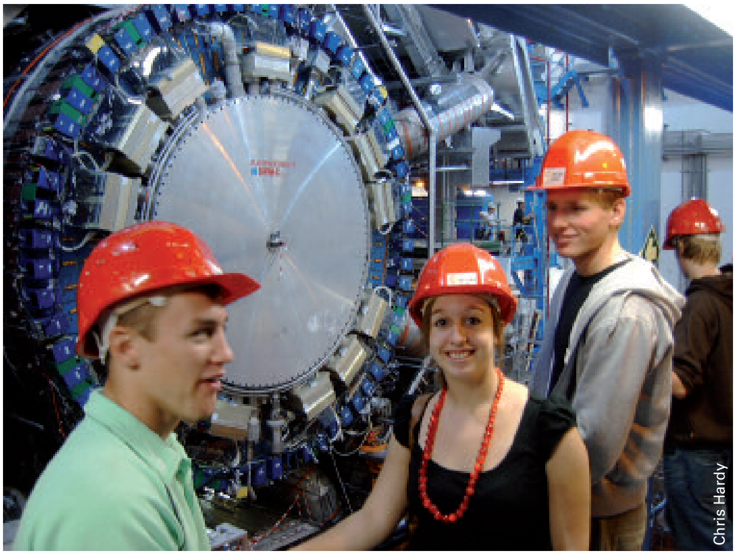
CERN, Geneva

The Large Hadron Collider (pages 1–3) is being built at CERN, the European Centre for Nuclear Research near Geneva. CERN offers some extremely exciting opportunities to see 'big science' in action.

Many students from schools and colleges across Europe visit CERN. What is there to see there? MICROCOSM is an excellent interactive museum telling the story of research into particle physics and the equipment used to support this. It is also possible to have tours of various parts of the site, guided by the scientists and engineers involved, and probably including a chance to visit the underground facilities.

In Box 1, Kelly Knight, a year 13 physics student, tells you something of what the experience was like for her on a visit organised by her school to see the Large Hadron Collider and the ATLAS detector. She was a member of a group who won a trip there in a competition organised by the Department of Physics and Astronomy, University of Birmingham.

School tours at CERN are free. It is also possible for individuals to go on free tours, although these have to be booked some way ahead.



Chris Hardy

Students from King Charles I School, Kidderminster, visiting the ATLAS detector in September 2006. You can just see the toroid magnets (see page 1), but the large space between them has now been filled with various components of the detector

Box 2 Visiting information

If you want to set up a visit to CERN check out the following site: http://visits.web.cern.ch/visits/english/practical.html

It provides links to the CERN site and to pages with information for teachers organising a visit. It also includes a description of MICROCOSM.

Box 1 Kelly's visit to CERN

On the first day of our visit, we had the opportunity to see the ATLAS detector we had heard so much about. Located in the centre of a large building, like an aircraft hanger, was a 100 m deep pit, lined with white concrete, at the bottom of which stood ATLAS.

Wearing hard hats, as the detector was still under construction, we travelled down in the mine-shaft style lift to the cavern at the bottom of the pit. Any descriptions you hear, or pictures you see, of the machine found there, cannot accurately represent the scale of it; it is huge. Later that day, dressed in lab coats and hairnets — yes hairnets — we were allowed to see a small segment of the detector being built in more detail. Around the shell of the pixel detector were rows and rows of intricately positioned wires and connectors, worth hundreds of thousands of pounds. Even if you had no interest in science at all, you would be impressed by the sheer feat of engineering required to build something so complex.

Later on in the trip, we visited the computing centre, where the data from the LHC will be processed. Literally thousands of computers, in uniform rows, provided computing power to all of CERN. This really put into perspective the volume of information that will be produced by the project. CERN is definitely something you need to see to believe and is well worth a visit if you ever get the opportunity.

Nigel Collins

Kelly (middle) with other students, wearing lab coats and hair nets, in one of the clean rooms at CERN


Tropical rainforest in Hawaii

Simon Fraser/SPL

Mathias Disney

Forests, carbon and climate

GCSE key words
Photosynthesis
Respiration
Carbon cycle
Climate change
Greenhouse gas

Scientists are only beginning to understand just how complex and fascinating the relationship between trees, the carbon cycle and climate really is. Here, Mathias Disney shows how aspects of your GCSE science course relate to his current research.

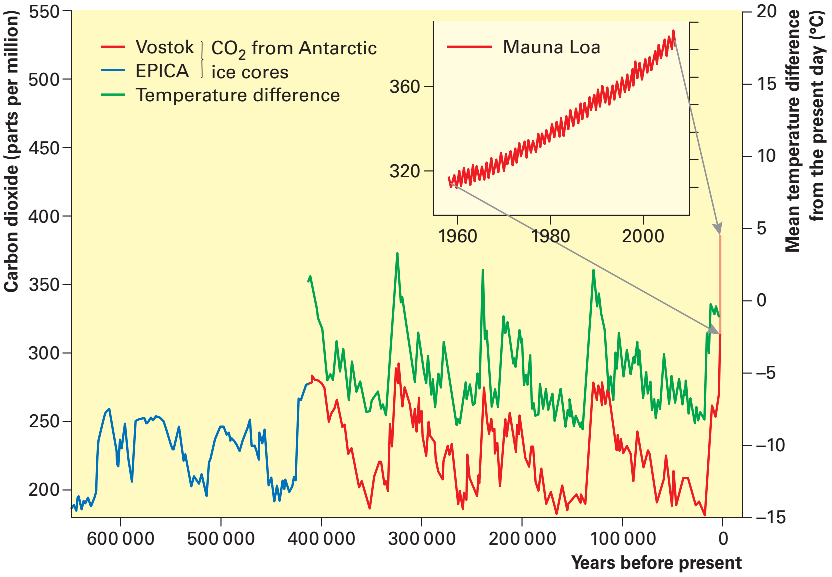


Figure 1 *Atmospheric carbon dioxide concentrations over the last 650 000 years from Antarctic ice cores. The inset shows atmospheric carbon dioxide in more detail from 1958 to the present measured in Mauna Loa, Hawaii. The green line shows historical temperature variations relative to the present day (right hand axis). (Sources: all data publicly available from NOAA — see Box 2)*

Trees are vital to life on Earth. They provide fuel, fibre, food and shelter for humans, and habitats for a vast range of animals. One of the most important functions of trees is their ability to use atmospheric carbon dioxide (CO_2), a greenhouse gas, in photosynthesis:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

The biomass produced stores large amounts of carbon, and oxygen is released.

Carbon dioxide levels

Reconstructions of Earth's past climate, and the observed impact of vegetation on global atmospheric carbon dioxide levels, have changed the way we perceive the Earth's system. Figure 1 shows past atmospheric carbon dioxide and temperature variations measured from tiny air bubbles trapped up to 3 km deep in Antarctic ice. Although there are major variations over glacial cycles of around 100 000 years, atmospheric temperature and carbon dioxide follow each other – we say that there is a close correlation between temperature and carbon dioxide levels. Notably, carbon dioxide remained below 300 parts per million (ppm) until the twentieth century.

The inset in Figure 1 shows atmospheric carbon dioxide levels from 1958 to the present, measured at Mauna Loa in Hawaii. These measurements highlight the link between vegetation and climate, as well as human influence. They show the annual rise and fall

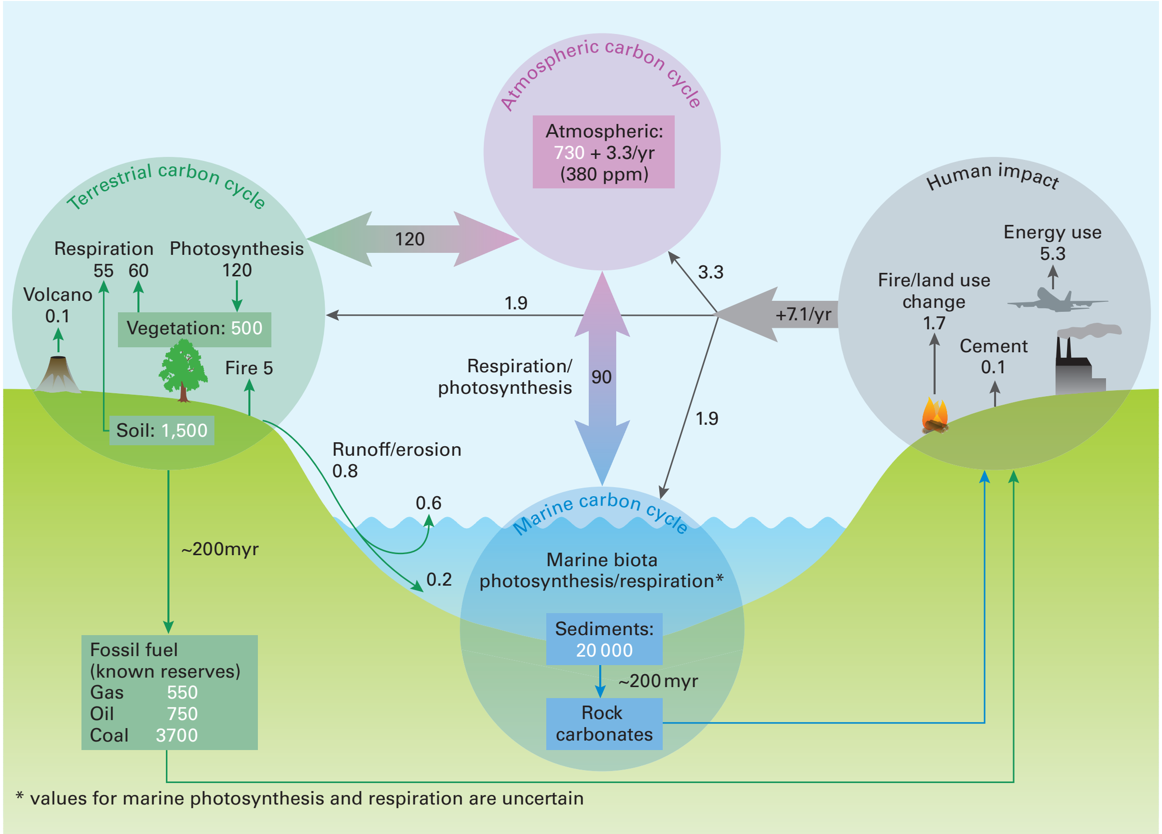


Figure 2 *The global carbon cycle showing the reservoirs (white) of carbon in billion tonnes (gigatonnes, Gt) of carbon. Fluxes are in GtC/year. Geological changes are measured in millions of years (myr)*

- **Can you manage the global carbon cycle and climate? Have a go using this simple online model: www.sei.se/forests/breathingforests.htm**

of carbon dioxide caused by the vegetation in the northern hemisphere growing up during summer and dying back during winter; the whole Earth is 'breathing'. There is much less land mass supporting vegetation in the southern hemisphere. Figure 1 also shows there has been an increase of nearly 20% in carbon dioxide levels since 1958. This rapid increase is mainly due to burning fossil fuels (gas, oil, coal). There is strong evidence that this is having a measurable impact on climate.

Trees and climate

So how do trees fit into the picture? Figure 2 shows the stores of carbon and the fluxes (flows) that make up the global carbon cycle. The soil/plant system acts as a huge store for carbon. It contains three times as much carbon as the atmosphere. The land and ocean each absorb approximately a quarter of all fossil fuel emissions; the other half remains in the atmosphere. As atmospheric carbon dioxide concentration rises, trees grow more rapidly (so-called carbon dioxide fertilisation) and hence absorb more carbon dioxide. At a certain concentration of carbon dioxide, however, this increase will level off as other factors become limiting.

Figure 2 also shows that soils are a vital part of the carbon cycle. Microbes in the soil decompose dead organic plant matter, storing huge quantities of carbon. But they respire while doing so, releasing carbon dioxide. As global temperatures rise, these microbes will become more active, releasing more carbon dioxide and further increasing warming.

Box 1 The history of the greenhouse gas concept

1827 Fourier developed the greenhouse gas concept in which carbon dioxide raises the atmosphere's temperature by about 15 °C.

1860 Tyndall found that water vapour makes the largest contribution to greenhouse warming.

1896 Arrhenius calculated that doubling atmospheric carbon dioxide would bring about a 5°C temperature increase.

This is just one of many feedbacks between the forest system and climate, some positive (reinforcing warming) and some negative (slowing down warming). One of the most fascinating and important challenges facing scientists is how to measure the carbon balance of forest systems over many life cycles and predict how this may alter with changing climate.

Measuring how forests 'breathe'

Each year a large amount of carbon cycles through the Earth's vegetation and soil. Because forests are not closed systems, measuring the carbon balance of a forested region is difficult. We need to know how much carbon flows in and out over a given time period. To do this, scientists draw an imaginary box around the forest system and, using instruments mounted on towers above the forest canopy (see pages 18–19), measure the flux of carbon dioxide, resulting from flow, into the system (due to photosynthesis) and out of it (due to plant and soil respiration).

Although scientists refer to carbon in the environment, it is usually in a compound: carbon dioxide in the atmosphere; hydrocarbons in fossil fuel; carbohydrates, proteins and lipids in plants and animals; and carbonates in rocks.

EPICA is the European Project for Ice Coring in Antarctica. The ice core went to 3190 metres covering 720 000 years. The Vostok ice core went back 420 000 years.

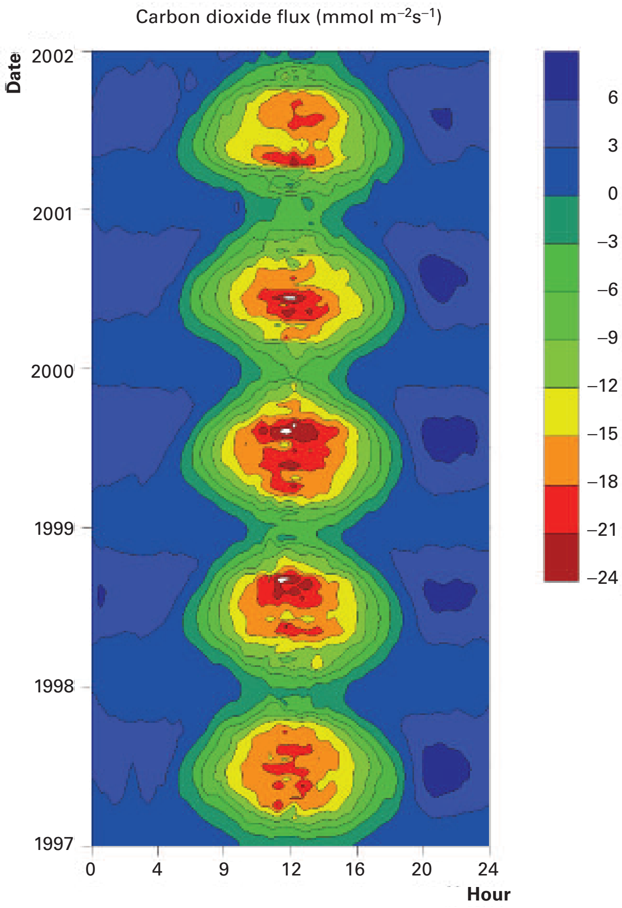


Figure 3 *Daily variations in carbon dioxide fluxes (horizontal axis) measured at Aberfeldy in Scotland, over a 5-year period. We see the forest breathing in carbon dioxide (green to red, negative values) due to photosynthesis during the day and during the summer; and out (blue, positive) due to respiration at night and during the winter. (Source: J. Moncrieff)*


Robert Brook/SPL

It may take a young forest 15 or 20 years to become a net carbon dioxide sink


David C. Clegg/SPL

Deforestation reduces the amount of carbon dioxide absorbed from the atmosphere

A typical forest

Figure 3 shows a forest breathing (a localised version of the global breathing in Figure 1). From bottom to top it shows 5 years of seasonal variation in the net carbon flux; horizontally it shows variations over each day. Negative values (green to red) indicate where the forest is a **sink** of carbon dioxide, when more carbon dioxide is absorbed through photosynthesis than is released by respiration (during the day and in summer). Positive values (blue) indicate where the forest is a **source** of carbon dioxide (during the night and in winter). By adding up all the positive and negative values we can calculate the forest carbon balance over time.

Biomass is the total dry mass of an organism such as a tree.

Soil respiration

Instruments placed on the soil enable us to measure how much of the total carbon dioxide flux comes from soil respiration. This is vital to understanding how soil respiration will change with climate. Such measurements show that forest systems can be very different from each other, and that the carbon balance of a forest varies over its life cycle.

Young and old forests

A young forest may be a net source of carbon dioxide to the atmosphere because the soil disturbed during planting may emit more carbon dioxide than is taken up by the vegetation. It may take 15 or 20 years to become a net carbon dioxide sink. As a forest gets old, the size of the sink may decrease as the trees near the end of their lives. Crucially, after death, tree biomass decomposes, releasing most of its stored carbon back into the atmosphere. So the long-term store lies in the soil.

Satellite observations

Scientists complement their detailed forest measurements with observations from satellites which monitor forest productivity on a global scale. Figure 4 shows satellite estimates of global vegetation productivity over the globe for 1999.

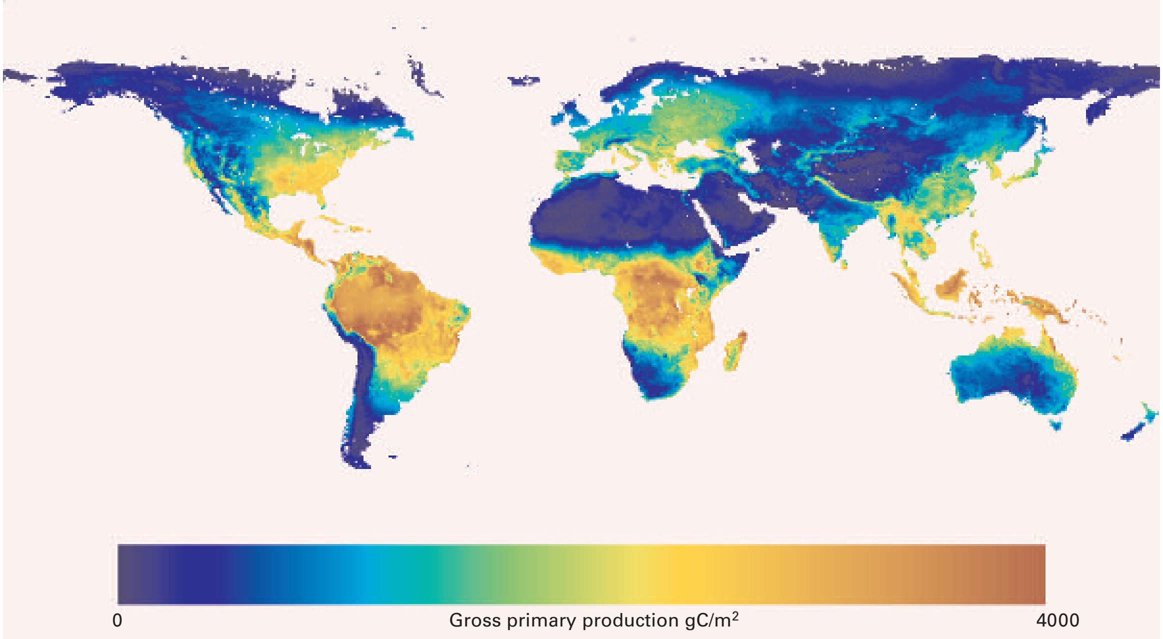


Figure 4 *Satellite-derived map of gross primary production, the total amount of carbon absorbed due to photosynthesis, in grams of carbon per square metre during 1999. Values range from 0 (dark blue) to 4 kg C/m^2 (brown). The heavily productive regions can be clearly seen across the tropical forests in the Amazon and Central Africa (Source: T. Quaife)*

Developing models

All these measurements help us to develop models of how the system works and make predictions about what will happen as climate changes. We can also use such models to make predictions about the impact of actions such as deforestation, increased fossil fuel consumption and planting trees to offset carbon emissions.

Other feedbacks

One of the difficulties in considering how forests and climate interact is that there are many other factors involved, in addition to carbon dioxide. Some of these factors have positive effects, some negative.

Recent research suggests that forests may be a source of methane (CH_4), another important greenhouse gas. Forests, being large and dark, absorb more sunlight energy than light-coloured areas, making the surface warmer. Trees can also encourage the production of clouds both by transpiring water into the atmosphere and through production of compounds which encourage cloud formation. Clouds can reduce heat loss from the ground and atmosphere beneath (clear nights are colder than cloudy ones), but also reflect light from the sun before it reaches the ground. The net impact of forests on climate is a combination of all these (and other) factors, whose complexity scientists are still trying to unravel.

Box 2 Useful websites

- This site shows the way many nations are collaborating in research on the carbon cycle: www.globalcarbonproject.org
- The website of the Intergovernmental Panel on Climate Change is at: www.ipcc.ch
- A great place to learn more about the carbon cycle is at: http://earthobservatory.nasa.gov/Library/CarbonCycle
- You can find ice core data at: www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_data.html
- You can find data on carbon dioxide concentrations at: www.cmdl.noaa.gov/projects/web/trends/co2_mm_mlo.dat

A limiting factor is one that controls the rate of a process.

Conclusion

At the start of the twenty-first century, it is clear that managing the Earth's carbon cycle is crucial to the planet's wellbeing. Scientists are revealing how much we have left to learn about the subtle interplay between trees, carbon storage and climate. This science is fascinating, because we don't know the answers. It is also urgent if we are to predict the full consequences of humanity's global climate experiment from burning fossil fuel.

Mathias Disney *wrote this article with input from Shaun Quegan, John Grace and Andreas Heinemeyer. All are members of the Centre for Terrestrial Carbon Dynamics research team. Find out about the team's work at* **http://ctcd.group.shef.ac.uk/ctcd.html.** *Click on* People *to read their biographies.*

Melissa Mercer

Diamonds

Sinclair Stammers/SPL

Industrial diamonds are usually irregular in shape and may be coloured due to impurities

The element carbon exists in a number of allotropic forms, but diamonds have always held a special allure, whether it be for their hardness or for their transparency. This article looks at how they can be made artificially and at some of their uses.

GCSE key words
Carbon
Allotrope
Bonding

Allotropy is when an element can exist in two or more different forms. The atoms are arranged differently in different allotropes.

Diamond and graphite can be shown to be allotropes of carbon — both will give only carbon dioxide if burnt in oxygen.

- **Read Professor H. Tracy Hall's account of the preparation of diamonds at www.htracyhall.org/HTracyHall/pdf/19610151.pdf**

In diamond, carbon atoms are held together by four strong covalent bonds in a rigid three-dimensional network. It is these strong bonds which give diamond its hardness (Figure 1). Natural diamonds are found in geographical formations called diamond pipes, where the high pressures and temperatures occurring at 150–200 km below the surface of the Earth have caused carbon in the rocks to rearrange into diamond. The processes involved are still not fully understood, but it is believed that thousands or even millions of years under stable conditions are needed.

Synthetic, or industrial, diamonds are produced using chemical or physical means in a factory.

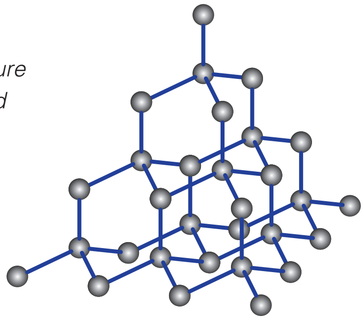
Industrial diamonds

Industrial diamonds were first reported in 1880 by Hannay and again in 1894 by Moissan, who heated iron and graphite in a crucible with an electric furnace. It is thought that these first experiments were fortuitous as the procedure did not prove to be easily reproducible. Although industrial diamonds were first made in commercial amounts in 1953 in Sweden, the results were unpublished. H. Tracy Hall independently synthesised diamonds in 1954 in America and was the first to publish his results in *Nature* magazine.

Making industrial diamonds

In order to produce the necessary pressures and temperatures, electrically heated presses have been developed which can heat graphite to temperatures higher than 1400 °C and subject it to pressures of more than 60 000 atmospheres (Figure 2). A graphite sample is sandwiched between two layers of cobalt in a cylindrical die. This is then squeezed and heated. The metal melts and the graphite starts to dissolve, forming a supersaturated solution. Diamond begins to crystallise out under the conditions used.

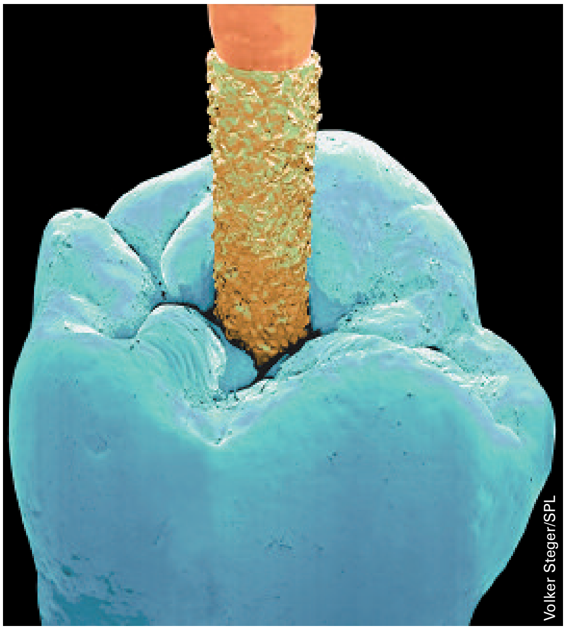
Figure 1
The structure of diamond



The diamonds are usually very small as there are many sites upon which the crystals can form. The size and shape of the crystals can be altered by varying the temperature and pressure under computer control. Once the crystals have formed the molten mass is allowed to cool to room temperature and the pressure is reduced slowly to atmospheric pressure. The solid mass of cobalt, unreacted graphite and diamond is broken into pieces and the cobalt removed by dissolving in acid. The diamonds can be separated from the remaining graphite by sieving.

Grades of industrial diamonds

It is the use of the cobalt, which acts as both a solvent and a catalyst, that makes this process economically viable. Diamonds made this way are usually coloured due to traces of nitrogen atoms trapped within the diamond giant molecule. Different grades of crystal may be used for different purposes — whether it be fragments for a diamond tipped drill, or needle shaped pieces for grinding discs.



Diamond fragments are used on the tips of dental drills. Here we see a scanning electron micrograph of a dental drill entering a tooth

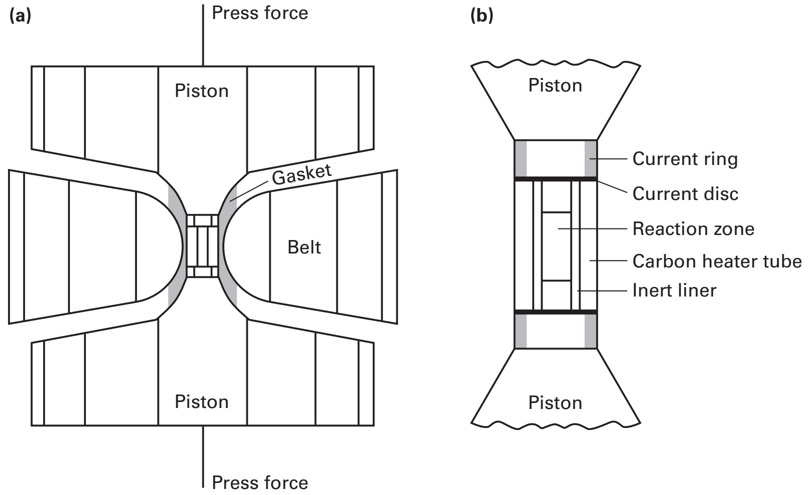


Figure 2 *(a) Diamond press and (b) close-up of the reaction chamber*

Box 2 Types of synthetic diamond and their uses

- High pressure/high temperature diamond grit (1 μm–1 mm) — used in grinding and cutting processes.
- High pressure/high temperature polycrystalline compact diamond — diamond particles sintered together at high temperature. Large surfaces can be made for abrasives.
- High pressure/high temperature large single crystal diamond — diamonds up to 10 mm in length used in chemically reactive environments, or for industrial gems.
- Vapour deposition polycrystalline diamonds — flat diamond wafers up to 5 mm thick used as abrasives or in the optical, medical or environmental industries.
- Vapour deposition single crystal diamonds (few millimetres in length) — used as an abrasive or in the electronics industry, or for sensors or detectors.

Vapour deposition

Vapour deposition allows a diamond film to be 'grown' onto another surface. A variety of different methods are used, but all involve feeding a carbon-containing gas (usually with hydrogen as well) into a chamber. The molecules are energised using microwaves, hot filaments or arcs. A plasma results and the carbon atoms can form as diamond on a surface. Low pressures are used.

Areas 15 cm in diameter can be covered in a layer of diamond. Other elements may be incorporated into the layer in order to give it specific properties. This process is quite slow and the applications for it are few at present. However, as the chemistry behind the process becomes better understood more uses may be found.

Currently, films are being grown on valve rings and cutting tools. University researchers have managed to make a colourless 2 g single crystal diamond by vapour deposition. Researchers hope to make diamonds up to 60 g by this method eventually.

Applications

The major application for industrial diamonds is as an abrasive. Small fragments of diamond are distributed in cobalt and then fused on to the surface of a cutting tool. This is particularly good when machining non-ferrous metals. Diamond-tipped drills are also used when drilling for oil.

The largest use of industrial diamonds is in the automobile industry. The aluminium alloys used for making cars wear down cutting tools very quickly. Diamond-coated tools are a cost-efficient way of overcoming this. Vapour deposited diamond films have also been used in electrodes in conditions which would normally destroy traditional materials.

Diamonds can be 'doped' with boron and phosphorus to give them transistor-like properties, turning them into n-type or p-type semiconductors. These may be developed further for use in highly corrosive or high temperature environments.

Synthetic gems are also being manufactured at 1500 °C and 58 000 atmospheres pressure by coating a tiny sliver of natural diamond in molten carbon. These have a slight yellow tint due to one carbon in every 20 000 carbon atoms being replaced by a nitrogen atom. Rough gems up to 550 mg are grown which can be cut to 300 mg (1.5 carat). These gems are profitable as they are relatively quick to manufacture and the yellow colour is popular.

Melissa Mercer *teaches chemistry at St Edward's School, Oxford.*

Box 1 Lifegem

It is now possible to create a diamond from the carbon contained in a lock of hair, or in the ash remaining from a cremation. These diamonds can act as a permanent reminder of a person. See www.lifegem.com for information on the process used and how it is carried out.

Each year 600 metric tonnes of synthetic diamond are made. Only 26 metric tonnes of diamond are mined each year.

A plasma is an ionised gas which is a good electrical conductor.

Although diamond is the hardest substance known it is also remarkably brittle — a sudden shock, such as hitting it with a hammer, can cause it to powder.

Mathias Disney

Measuring carbon cycling

GCSE key words
Carbon cycling
Climate change
Data logging

Mathias Disney explains how to measure parts of carbon cycling as it happens in forests.

Scientists devise novel instruments and equipment to observe and record aspects of carbon cycling. Here are two systems they use.

Flux towers

Variations in carbon dioxide concentration are caused by changes in the balance between photosynthesis (carbon dioxide uptake) and soil and plant respiration (carbon dioxide released). Measurements of this flux of carbon dioxide, taken using instruments on tall towers, assume that air turbulence mixes up the air close to the ground. As a result, air flowing past the sensor contains a well-mixed sample of atmospheric gases from within the forest canopy. We also make assumptions about where measured carbon dioxide fluxes originate from – roughly 100 metres distant for every metre height of the tower. So a 10-metre high tower measures carbon dioxide fluxes originating from within 1 kilometre upwind.

Normally we want to measure fluxes from a specific area (e.g. a piece of forest), so we fix the tower so that it just clears the forest canopy (Figure 1). The sonic anemometer measures wind speed and direction. Samples of air are captured and fed into an infrared gas analyser (IRGA).

IRGA is short for infrared gas analyser. It is set up here to measure carbon dioxide concentrations.

Measurements are made every few seconds, 24 hours a day all year round, to build up a picture of the carbon balance of the forest system. Solar panels provide power. Measurements are either downloaded manually, or transmitted via a mobile phone connection. Radiation sensors on the tower measure changing light levels which can be related to changes in photosynthesis (and hence to carbon dioxide).

Soil chambers

To determine how much carbon dioxide is taken up by the trees, we need to separate soil and canopy respiration. For that we use soil chambers (Figure 2).

The shallow collar (with a circular opening) is fixed to the soil surface, not cutting any roots. Every hour the dark chamber closes automatically for about 2 minutes. This makes an airtight seal over the soil collar, trapping ambient air inside. Carbon dioxide released by respiration of soil microbes and roots is trapped, causing carbon dioxide in the chamber to increase during closure time.

The air is circulated in a loop between the chamber and an infrared gas analyser (IRGA), which measures this rise in carbon dioxide every second. This tells us how much of the carbon dioxide in the air is coming from the soil. After a measurement is made, the chamber opens in order to allow the soil system to be exposed to ambient conditions.

Figure 1 *Taking flux tower measurements*

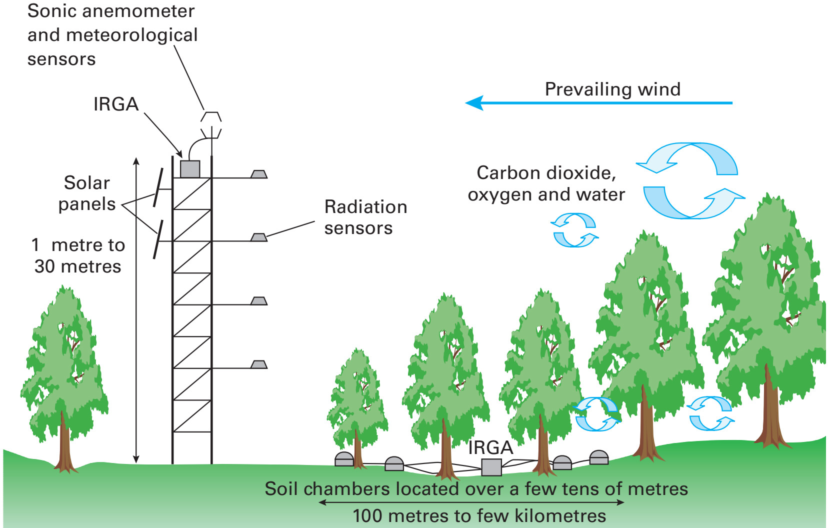
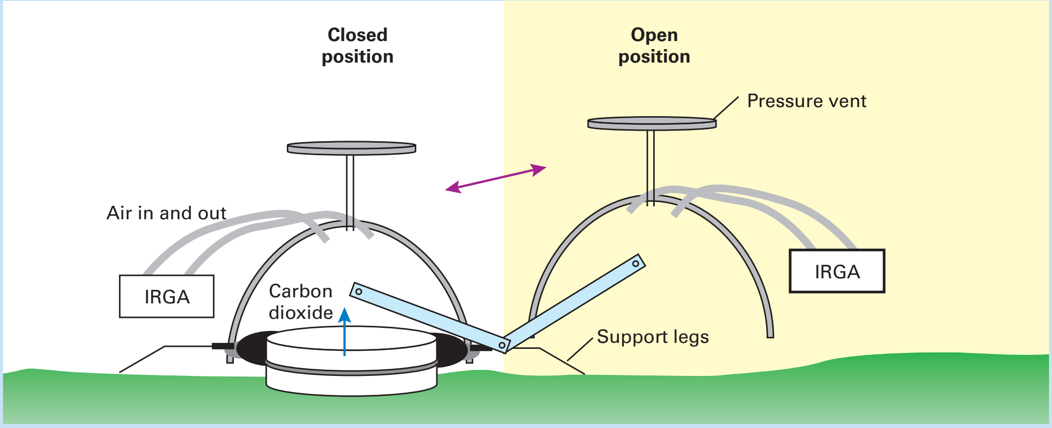


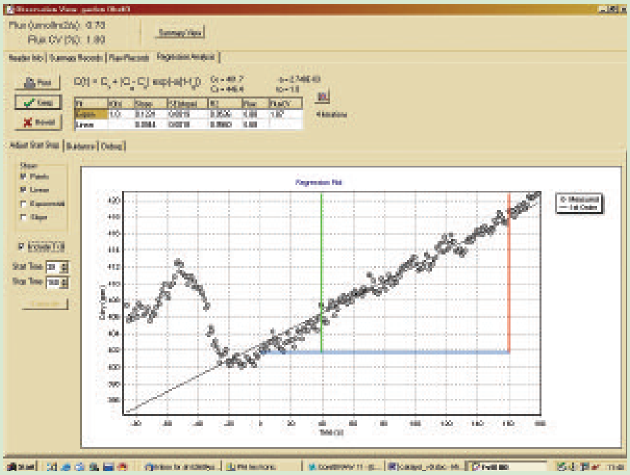
Figure 2 *A soil chamber with infrared gas analysers*




Closed soil chamber


Open soil chamber


Batteries and IRGA



Above: *Multiple chambers connected to a single IRGA in an 'Octopus' configuration*

Right: *Data from an IRGA. When the chamber closes carbon dioxide concentration rises steadily as a result of 'soil' respiration*

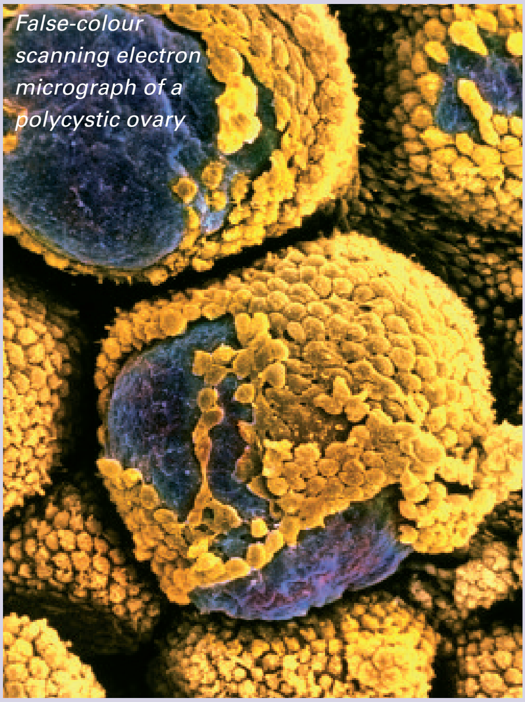
A life in science

Dr Gillian Lockwood

Dr Gillian Lockwood specialises in IVF and the ethical issues surrounding fertility treatments. She is the medical director of Midland Fertility Services, one of the largest IVF units in the UK. Here she tells us about her life in science.

Box 1 Polycystic ovary syndrome

Polycystic ovary syndrome is very common but is a 'cinderella' of the gynaecological world. Some of the classic symptoms include weight gain and hairiness, as well as difficulty conceiving. There is some genetic basis linked with the complex of genes involved in diabetes.



False-colour scanning electron micrograph of a polycystic ovary

Professors P. M. Motta & S. Makabe/SPL

It may surprise you to discover that I did not have any desire to be a doctor when at school. I didn't even study sciences – I only took O-level biology. I studied arts A-levels and went to St Hilda's, Oxford, to study philosophy, politics and economics. After my degree I won a cadetship to study applied statistics, but there was a price to pay – I was expected to work for the Government Statistical Service for 2 years. This led to me becoming a civil servant in the Cabinet Office, calculating the retail price index (an important measure of inflation).

O-levels were the equivalent to GCSEs.

At the time inflation was a serious problem. Prices and wages were on an upward spiral and the economy was in trouble. Things came to a head during the 'winter of discontent' in the late 1970s. Many workers, particularly local authority employees, were on strike. The streets were full of uncollected rubbish, which made life difficult. Each day I commuted from Oxford to London on the train.

Change of direction

One particular day my boss phoned me and told me to work at home rather than risk the train. I switched on the television for the lunchtime news and saw instead a documentary about the work of Dr Paul Tessier. He was a craniofacial surgeon working with newborn babies with deformities of the head. Disenchanted with statistics, I realised that was what I wanted to do with my life. So I set out to become a plastic surgeon.

I resigned from my job and went to a college of further education to do science A-levels in a year alongside students resitting their A-levels. I supported myself by teaching some A-level history and politics. At the time it was rare for people to take gap years or go to university as mature students so finding a university that would look kindly on a mature retrainer wasn't easy. I applied to Oxford again, took the exam for would-be medical students and was offered a

Gillian Lockwood examining an ultrasound scan

Box 2 Useful websites

- Find out more about Midland Fertility Services at: www.midlandfertility.com
- The Human Fertilisation and Embryology Authority website is at: www.hfea.gov.uk/cps/rde/xchg/hfea

place at Lincoln College. I took a 3-year physiological science course, gaining a first-class degree, followed by 3 years of clinical medicine. I qualified in 1986.

Another change

I still wanted to do neonatal plastic surgery and went to Boston to observe Dr Paul Tessier's work. Unfortunately a major reorganisation of plastic surgery units reduced the opportunities to start in plastic surgery, and being older and female didn't help either. A senior plastic surgeon suggested I should think of IVF work instead — the first test-tube baby, Louise Brown, had recently been born. More training in obstetrics and gynaecology followed and then I moved to the John Radcliffe Hospital for IVF training.

A big clinical trial involving IVF was getting underway so, with my expertise in statistics, I was recruited to the trial. As a result I spent 10 years as clinical research fellow at the Oxford Fertility Unit, researching polycystic ovary syndrome (see Box 1), premature ovarian failure and recurrent miscarriage, gaining a doctorate on the way.

In 2000 I joined Midland Fertility Services. This work is very rewarding. There are so many places where the process of having a baby can go wrong. Most infertile couples have a clear medical pathology for which there is a reasonably cost-effective solution. However, it is difficult for them to obtain NHS treatment for their condition, so many have to fund their own treatment.

IVF

I am particularly proud that the clinic was the first, and is still the only, UK clinic to successfully use frozen eggs for producing a child. The main purpose was to help young women who were about to lose their ovaries as a result of cancer treatment, for example. There are other reasons too, such as premature menopause. The eggs can be thawed and used at a later date. The clinic has a useful test that can indicate a woman's ovarian reserve — that is how much longer she can expect to produce healthy eggs.

Using frozen eggs bypasses many of the ethical problems linked to using frozen embryos, such as what to do with surplus embryos, and what happens if the parents part before the embryos can be implanted. For many years I have sat on ethical committees for the Royal College of Obstetrics and Gynaecology and the British Fertility Society. My background and formal training in ethics, as part of my philosophy degree, is useful for this role. Medical schools are now encouraging ethical thinking throughout a doctor's training.

You may have seen Gillian on television talking about investigating the extent of a woman's reproductive age.

- **Find out about more polycystic ovary syndrome.**

Grid computing

Some of today's large-scale scientific activities – modelling climate change, Earth observation, studying the human genome and particle physics experiments – involve handling millions of bytes of data vary rapidly. Such activities would not be possible without a new type of computing. It is not possible for one single institution to store and analyse all these data, so scientists share computer storage and processing power around the world at hundreds of different locations. This is called grid computing. Much of it is based on vast numbers of PCs linked to process data in parallel with other tasks. In the past, individual supercomputers might have been used but these could only deal with single, although very large, tasks.

CERN

CERN's Large Hadron Collider (LHC) goes live this year (see pages 1–3 and page 11). It will produce 15 petabytes (1 petabyte = 10^{15} bytes) of data a year – equivalent to a stack of CDs 20 km tall. Data from the LHC will be analysed by more than 100 000 PCs in 100 institutions linked up in a worldwide grid.

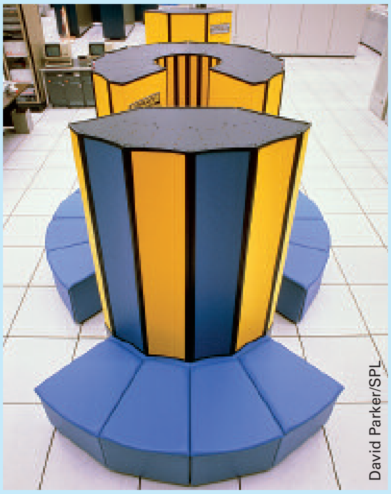
Useful websites

- To find out more about the LHC computing grid go to: http://lcg.web.cern.ch/LCG/overview.html
- The website for GridPP is at: www.gridpp.ac.uk


Nigel Collins

The computer hall at CERN with 2000 PCs per floor

CRAY supercomputers have been replaced by grid computing

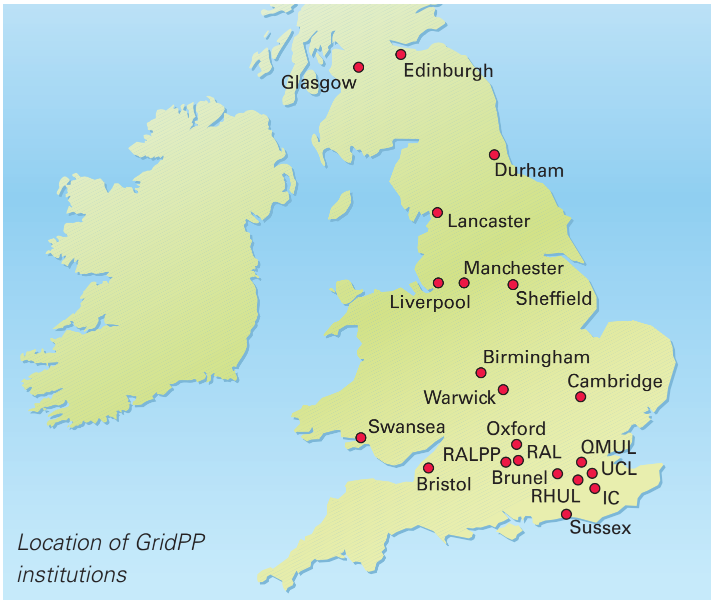

David Parker/SPL

GridPP

GridPP is the UK computing grid for handling particle physics data. It is also part of the global grid for handling LHC data. It involves collaboration between around 100 researchers in 20 UK universities, at research centres and at CERN. It currently utilises more than 2000 computers at 16 locations. This will rise to 10 000 computers later this year. It allows scientists to access data and processing power seamlessly, wherever they are.

GridPP has also been responsible for the middleware, which allows the software being used by the scientists to talk to the grid's hardware, distributing computing jobs efficiently around the network. Only authorised users can access the grid.

GridPP is a 6-year project, and is funded by the Particle Physics and Astronomy Research Council as part of its e-science programme.



Location of GridPP institutions