Catalyst

GCSE Science Review

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Impact Earth

philip allan UPDATES
www.philipallan.co.uk

Catalyst

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The front cover shows an asteroid approaching Earth (Detlev van Ravenswaay/SPL).

Contents

Welcome to issue 1!

As the new school year starts some of you will be heading into year 11, the last group to follow the old-style GCSE science courses; those of you in year 10 will be embarking on a new type of course.

The editors of Catalyst have always sought out interesting stories linked with the science courses to include in the magazine, and help you gain good grades. We also regularly look at other matters, such as how the science you do at school links into scientific research and the lives of scientists.

We address topical issues in science and often have sections about science in the news. For example, in the April 2006 issue we covered a story on possible changes in ocean currents, first aired in the science journal *Nature* in December 2005. By the April issue we had secured a group of three related articles describing this research and linking it to your GCSE science courses, as well as suggesting suitable websites for you to find out more.

Nigel Collins

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For more information or to place an order, contact Turpin Distribution, Pegasus Drive, Stratton Business Park, Bedfordshire SG18 8TQ.
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Julian Baum/SPL

Impact Earth

David Sang

***Left:** Jupiter provides us with some protection. Its strong gravity hoovers up many NEOs, such as Comet Shoemaker-Levy 9, which was observed as it collided with the giant planet on 18 July 1994. This artist's impression shows that the comet was pulled apart by Jupiter's gravity before impact*

GCSE key words
Asteroid
Comet
Risk

Astronomers say that, one day, a giant rock from space will collide with the Earth and cause mass devastation. This could lead to the extinction of many species, including humans. Is there anything we can do to prepare for such an impact?

On 18 March 2004, asteroid 2004 FH passed between the Earth and the Moon. At its closest, it was within 43 000 km of the Earth (that's just 3.4 Earth diameters). The asteroid was 30 m across, big enough to do serious damage if it reached the Earth's surface. However, that was unlikely, for two reasons:

- Its orbit did not bring it close enough for the Earth's gravity to pull it down.
- Friction with the atmosphere would have caused it to burn up before it reached the ground.

Small asteroids come as close as this every year or two. The unusual thing about the fly-past of 2004 FH was that astronomers saw it coming and could observe it as it went by (Figure 1).

Rocks from space

Astronomers keep an eye out for any object in space whose orbit may bring it within 50 million km of the Earth's orbit. Such space rocks are known as **near-Earth objects (NEOs)**. There are two types:

- **Asteroids**: rocky lumps, mostly in orbit between Mars and Jupiter.
- **Comets**: frozen balls of dust and ice which approach the Sun from orbits far out in the solar system.

The way in which the solar system formed explains why these two types of object exist. A swirling cloud of dust and gas collapsed under the pull of its own

The total mass of all the asteroids is only about 3% of the mass of the Moon. The two largest (Ceres and Vesta) account for half of the total mass.

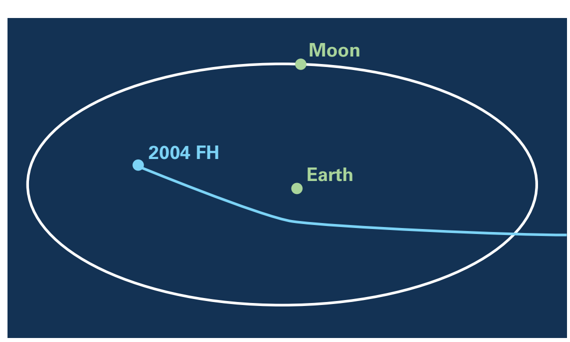
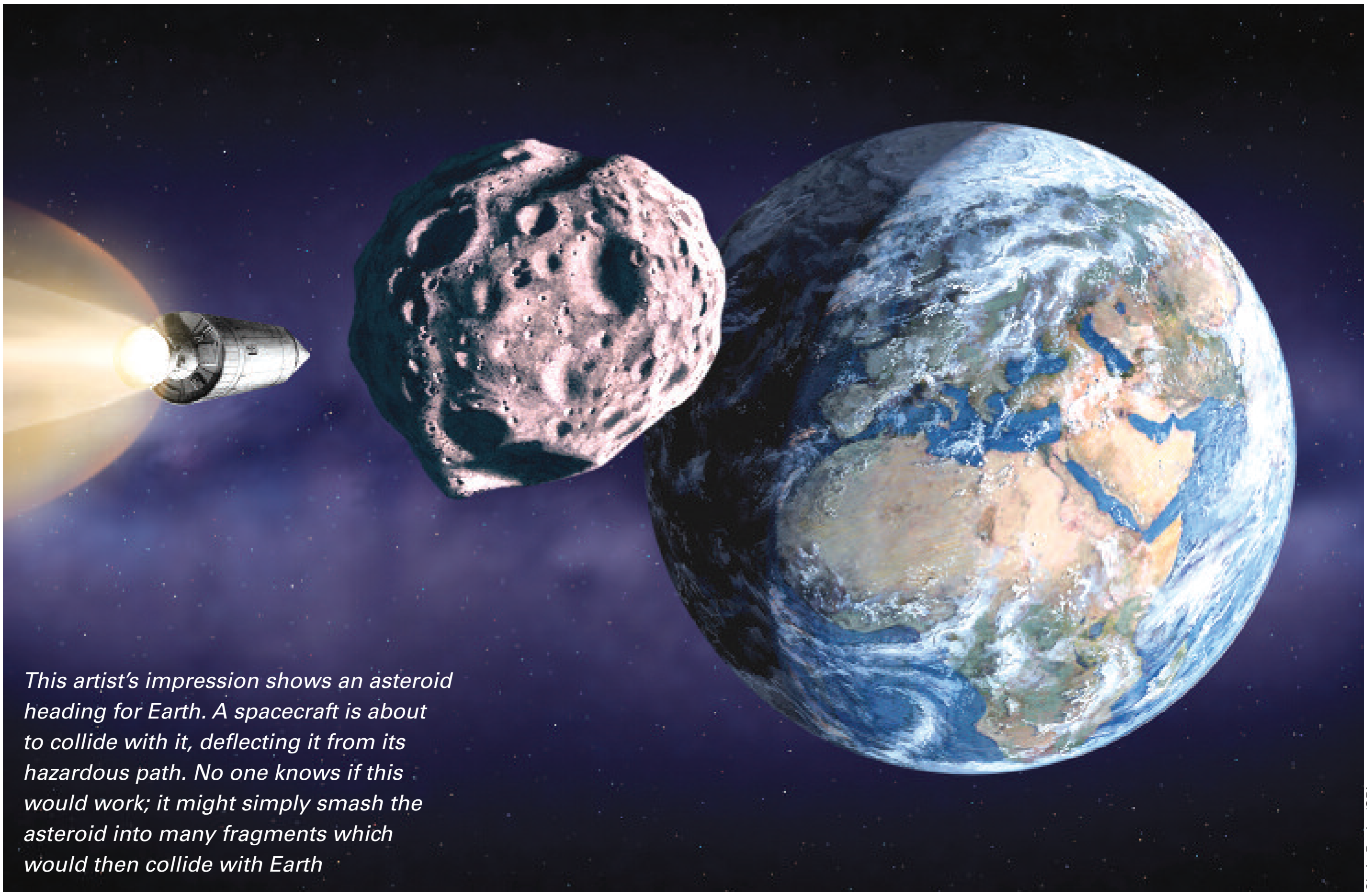


***Figure 1** Orbit of 2004 FH*



This artist's impression shows an asteroid heading for Earth. A spacecraft is about to collide with it, deflecting it from its hazardous path. No one knows if this would work; it might simply smash the asteroid into many fragments which would then collide with Earth

Chris Butler/SPL

- **Visit http://neo.jpl.nasa.gov/neo to download a multimedia presentation on NEOs.**

gravity. The Sun (mainly hydrogen) formed at the centre. The planets formed from dust and gas circulating round the Sun. The closest planets (Mercury, Venus, Earth and Mars) are rocky, because their temperatures are too high for gases to condense. The outer 'gas giant' planets, particularly Jupiter and Saturn, are made of frozen gases.

Another rocky planet tried to form between Mars and Jupiter. However, the gravitational pull of massive Jupiter prevented it from becoming a planet, and so the asteroid belt was created. Comets formed further out in the icy depths of space.

Occasionally, asteroids jostle one another, and one may be pushed out of the belt so that it plummets further in towards the Sun. If its orbit crosses that of the Earth, it may become an NEO (Figure 2).

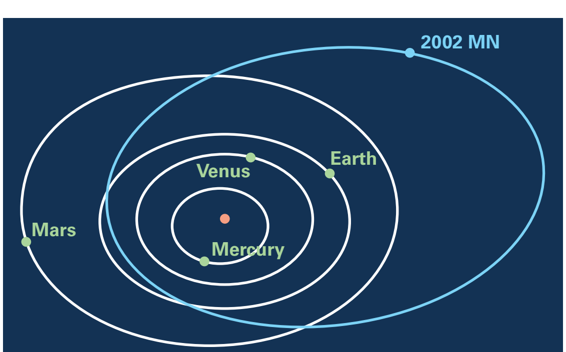


Figure 2 *NEO orbit for 2002 MN*

- **You can download a movie showing orbits of known NEOs at http://szyzyg.arm.ac.uk/~spm/neo_map.html**

It has happened before

The Earth has been hit by NEOs before (see Box 1). We know this because impact craters can be seen in a number of places. Among the most famous is Meteor Crater in Arizona. Over 1 km wide and hundreds of metres deep, it has been dated to 49 000 years ago. It is estimated that the cause of this crater was a lump of iron and nickel about 40 m across, moving at about 25 km/s. That's a lot of kinetic energy, equivalent to 20 million tonnes of TNT!

Such craters on Earth are rare. However, the Moon's surface is covered in craters. The difference is that here on Earth, craters are eroded by wind and water. In addition, the movement of tectonic plates has resurfaced the Earth over millions of years, hiding the evidence of ancient impacts. But the Earth's stronger gravity means that it must have been hit with a greater frequency than the Moon.

NEO scares

The effect of an NEO impact depends on its size (see Table 1). It is only within the last two decades that astronomers have established programmes to track NEOs. You may have heard about potential hazards in the media. The usual pattern is something like this:

- Astronomers announce that they have spotted an NEO whose track might bring it into collision with the Earth.

Box 1 Did a comet kill off the dinosaurs?

In 1980, Luis and Walter Alvarez published a paper suggesting that the extinction of the dinosaurs could be traced back to an asteroid impact 65 million years ago. Palaeontologists had established that dinosaurs and many other species became extinct at that time, but the cause was unknown. The father-and-son team examined rocks at the boundary between two geological zones, the Cretaceous and Tertiary. They found a thin layer, called the K/T boundary, containing two elements — iridium and osmium — which are rare on Earth but common in asteroids. They deduced that an asteroid about 10 km across had collided with the Earth; it evaporated, so that its material was spread around the Earth.

The impact must have produced a mass of dust which darkened the skies, causing freezing temperatures for several years, and this resulted in mass extinction. Fortunately for us, some mammal species survived.

Ten years after the Alvarez paper, a giant crater on Mexico's Yucatán peninsula was identified from observations by a space shuttle. Most scientists now accept this theory of dinosaur extinction, although some believe that other factors, including volcanic activity, may have been involved.

Table 1 *The effect of NEO impacts*

Diameter of NEO	Effect of impact
< 50 m	Disintegrates in atmosphere
< 500 m	Local damage around impact site
> 1 km	Worldwide effects
> 10 km	Mass extinctions

- After a few weeks, the NEO's orbit has been determined more accurately; astronomers announce that it is very unlikely to strike Earth.
- The media declare that this was a scare story put about by astronomers, perhaps to justify their research programmes.

Such media criticism is a bit unfair. Like all observations of moving objects, first measurements have a large degree of uncertainty. As an NEO moves across the sky, its track can be determined with greater precision. Should astronomers keep quiet when they first become aware of a possible impact?

The hazard associated with an NEO is represented by its position on the Torino scale (see Box 2).

Deflecting NEOs

Dr Alan Harris is a UK scientist based at the German Aerospace Centre in Berlin. He is chairman of a project called NEOMAP (NEO Mission Advisory Panel), which has been looking at what we might do if we detect an NEO heading our way. He describes the problem we face:

> If you think about the chain of events between detecting a hazardous object and doing something about it, there is one area in which we have no experience at all and that is in directly interacting with an asteroid, trying to alter its orbit.

Various methods of deflecting an asteroid have been proposed, but we do not know enough about asteroids to decide what would be best. The Don Quijote mission has been proposed to the European Space Agency (ESA) to rendezvous with an asteroid and find out more. Dr Harris thinks this is important:

> Don Quijote has the potential to teach us a great deal, not only about the internal structure of an NEO, but also about how to mechanically interact with it. Don Quijote could provide a vital missing link in the chain from threat identification to threat mitigation.

Don Quijote will consist of two spacecraft. The first will make preliminary observations of the target asteroid; the second will impact with it, so that the first can measure the effect on the asteroid's orbit. ESA will make a final decision on the target asteroid in 2007.

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

Box 2 The Torino scale

The Torino scale runs from 0 (minimal chance of impact) up to 10 (global catastrophe likely).

Figure 3 shows how the rating of an NEO depends on its energy and its probability of colliding with Earth. Kinetic energy is given in megatonnes of TNT equivalent (1 MT = 4×10^{15} J approximately).

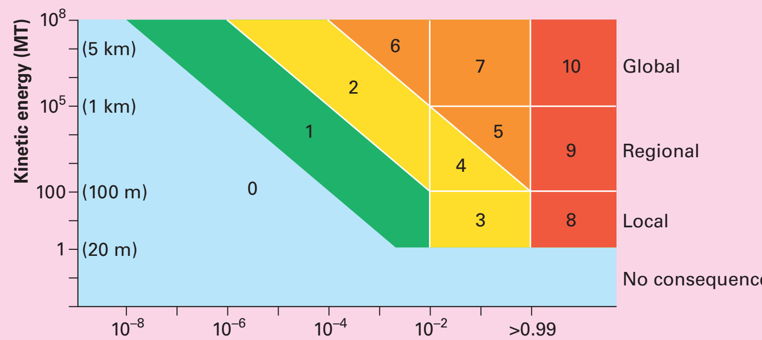


Figure 3 *Torino scale*

Box 3 Taking chances

You are more likely to die as a result of a near-Earth object impact than in an air crash — true or false? It's probably true. Air crashes are rare events, and cause only 1 in 30 000 deaths. (Road accidents cause about 1 in 100 deaths.) NEO impacts are even rarer, but the death toll could be vast, so scientists estimate that the chance of an individual dying is about 1 in 10 000.

A near-Earth object which strikes the Earth is more likely to land in the sea than on solid ground, simply because 70% of the Earth's surface is ocean.

- **Spaceguard UK is the British arm of a worldwide network of astronomers concerned with the hazards posed by NEOs. Go to www.spaceguarduk.com/sguk.htm to find out more.**

Food technology

TopFoto

The food and drink industries are part of a chain linking farming and growing through to food processing, manufacture and finally to the sale of food in supermarkets and restaurants. Dr Ken Spears tells us about some of the many career areas in food technology.

Every part of this chain offers exciting prospects for a career, from food research and developing new products, to packaging design or production engineering. There is also plenty of room for entrepreneurs in the food industry so you could set up your own food company — supermarkets, restaurants and cafés are always demanding new and innovative food and drink products.

There are some 30 000 businesses in the UK involved in food and drink, not including shops and supermarkets.

Be what you want to be...

New product development

This is the 'lifeblood' of the industry. Product development is a team-based activity involving developmental chefs, food scientists, nutritionists, marketing people to conduct consumer research, technologists to design the production lines, and packaging designers.

Quality management

Quality managers monitor the quality and safety of food ingredients and food products while they are made and transported. They include laboratory staff, microbiologists, hygiene managers and quality controllers.

Environmental health

Environmental health officers (EHOs) are employed by local councils to inspect food factories, shops, restaurants and catering outlets to ensure that food standards and hygiene are maintained. Local councils usually recruit trainee EHOs with A-levels. Look up environmental health on your local council website.

Buying

Supermarket chains employ buyers to visit food producers as part of their quality control. Buyers have experience in a particular area of food technology and work closely with food producers to develop new products and new food ranges. Some buyers get to travel, perhaps visiting salmon producers in Canada or spice manufacturers in the Far East.

Nutrition

Nutritionists are usually graduates with a wide knowledge of healthy eating and diet-related issues, such as obesity, heart disease and coeliac disease. Many are employed by health authorities, clinics and

Box 1 Did you know?

- The food and drink industry buys two-thirds of all fresh produce grown in the UK.
- As well as shops, there are over 30 000 UK businesses involved in food and drink.
- The food and drink industry employs over 650 000 people in the UK; 200 000 extra employees will be needed by 2012 to fill vacancies.
- The food and drink production industry has an annual turnover of £69 billion — 6% of the UK economy.
- Young people can expect starting salaries of £15–£18K, and graduates can expect to start on £20–£25K. Senior food scientists can earn £65K or more.

Box 2 A case study

The Institute of Food Science and Technology (IFST) is the professional body of food scientists and technologists. Its website (www.ifst.org) has a section on careers and training where you can find out what people like Cath Harris do.

Cath studied food quality, product development and nutrition at the University of Plymouth. After her degree she became a senior purchaser. Her job includes product quality, pricing, delivery deadlines and maintaining good supplier relationships.

> I find it challenging to experiment with food groups and flavours. To make them blend well in taste and texture is very satisfying but the result can be hideous if you get it wrong! My interest in experimentation is related to product development within the food industry and is probably the most proactive and exciting part of the sector.
>
> It is essential to understand the bacteria in food substances and the effects they can have in food preparation, final serving and the shelf life of a finished product. My interest was stimulated by the microbiological part of my degree course.
>
> During my work placement I joined my current company as a member of the quality assurance team. The company creates fine frozen seafood and vegetable-based products for the foodservice industry. I worked within the factory environment and learnt about production and people management, and gained a vast amount of technical knowledge.

Cath Harris

government agencies, but companies also employ their own nutritionists to give advice on healthy food production and to their customers.

Food research

Government research agencies carry out research to ensure good nutrition and food safety, and as part of a European team monitoring food quality. Careers in food research require scientific knowledge and skills at all levels, including laboratory assistants and technical officers. The research agencies have libraries and so also need librarians and information researchers.

Brian Bell/SPL

Left: *Researcher developing food with high mineral, vitamin and protein content*

Qualifications

The above examples should convince you that there is more to a career in food than putting cherries on the top of cakes. So how do you start your career? Your GCSEs and A-levels provide the basis for a range of higher qualifications, skills and work-based learning. An interest and enthusiasm for science and practical technology are useful.

National Vocational Qualifications (NVQs)

Some areas of the industry require NVQs. You can study for these while you are at work, but you also need to spend some time in a college of further education.

National Diploma

You can complete a National Diploma by part-time or full-time study. This can be combined with work-based learning and is intended for people interested in management. National Diplomas may be accepted for entry to degree programmes.

Degrees

These involve full-time study at a university. Some universities offer 'sandwich' courses where you spend a year on an industrial placement with an employer, like Cath Harris did (see Box 2.)

Box 3 Useful websites

Improve Ltd is the Sector Skills Council for the modern food and drink industries: www.improveltd.co.uk

The *Grocer* magazine website has a careers supplement: www.careersinfoodanddrink.co.uk

The trade journal *Food Manufacture* also has a useful website: www.foodmanufacture.co.uk

Other useful websites include:

- Food and Drink Federation: www.fdf.org.uk
- The British Retail Consortium (BRC): www.brc.org.uk
- Meat and Livestock Commission: www.mlc.org.uk
- The Biscuit Cake Chocolate and Confectionery Alliance (BCCCA): www.bccca.org.uk

Marks and Spencer reformulates each of its thousands of different food products every 3 years.

__Dr Ken Spears__ is a food technologist who has industry experience. He has taught food technology in schools and at South Bank University.

Jane Taylor

Testing new medicines

Hemera Technologies

GCSE key words
Testing medicines

New medicines cannot be prescribed until they have been tested to see if they are safe for people to take. This article outlines the processes involved, from laboratory tests to clinical trials.

Animals benefit from testing involving other animals in the development of veterinary medicines.

New medicines might replace a defective enzyme product, change a biochemical reaction, help substances to move in or out of cells, kill some cells or encourage other cells to grow.

TopFoto

Right: *The short life and plentiful reproduction of mice allow scientists to monitor impacts on life span and the next generation*

Diseases happen when things go wrong in the body. Once scientists begin to understand the problem they can search for medicines that will help sufferers. They investigate any potential medicine to show how effective it is and to find out if it is likely to have any harmful or unpleasant side effects.

Laboratory tests

The effects on cells of a potential new drug are investigated using tissue cultures of human or animal cells. Some tissue cultures use fresh tissue samples, but most come from well-established laboratory cell strains. The cell cultures receive various doses of the test substance and its effects are monitored. If a substance harms abnormal cells, such as cultured cancer cells, or stops viruses infecting cells, it could be useful. At the same time, scientists check that the drug does not affect normal cells.

Computer modelling

Scientists use what we know about the complex interactions of the human body's biochemistry to make computer models of body systems. New drugs are tested in these systems to see how they affect the natural variations of body chemistry in the human population.

These systems can show unanticipated side effects and interactions between the new substance being tested and other drugs that people might be taking, as well as with substances such as alcohol and coffee. Undesirable interactions can be 'designed out' by manipulating the structure of the new drug molecule. Computer modelling can even produce detailed information that cannot be generated by existing experiments.

Testing on animals

Once a new drug's potential for working on diseased tissues has been tested on cells it is time to see if it works in a whole organism. Laboratory cell cultures have a carefully controlled environment with constant supplies of nutrients. This is different from the environment in a human body with its varying levels of nutrients, wastes, hormones and other important biochemicals.

Animal tests tell scientists if a drug affects organs other than the target diseased tissue, what the effective dose and harmful doses are, and if there are likely to be side effects. Data are collected on how the new drug is absorbed, spread round the body, changed or broken down by the body's enzyme systems and excreted, as well as how toxic it is.

Two species of animals, including one which is not a rodent, must be used for such tests. Mice are often used. Some strains of laboratory animals suffer some of the same diseases as humans so some new drugs can be tested for their effects on the actual disease, rather than on healthy animals.

Clinical trials

Once a drug is shown to be safe and to work in tissue cultures and animals it has to undergo clinical trials on humans. The physiology of other mammals is very similar to our own, but there are important differences. It is only when the drug is in the whole human system that scientists can see its true effects. Some complications are seen for the first time when real people use the drug. Some drugs are given to healthy volunteers first, but they are usually tried on patients.

In more economically developed countries there are ethical guidelines about which patients can be asked to take an experimental drug, and they must agree to being treated with it. The drug's use should be carefully monitored and any side effects recorded. The drug must have a good record in clinical trials if it is to gain a licence for use.

Box 1 Useful websites

- Log on to www.abpi-careers.org.uk to explore more about the processes involved in developing and testing new medicines, as well as about the scientists involved.
- You can find out about a number of different clinical trials by logging on to www.bctu.bham.ac.uk and clicking on 'Current trials'.

Drugs must be tried out on real patients before scientists can be sure they work safely

Tek Image/SPL

Blind and double blind trials

Sometimes we really want our experiments to work and unconsciously interpret our results to fit our expectations. If scientists expect a new drug to relieve symptoms they will tend to view what it does in a favourable light.

Data gathered from trials must be assessed objectively so potential new drugs are tested using double blind trials. The doctors who are administering a drug under trial do not know if the medicine they are giving contains the new drug, the usual medicine or a harmless substitute (a placebo). Doctors assessing the patients' symptoms after the course of treatment do not know what medicine the patients received. Who had what medicine is only revealed when the full results are analysed.

People may report fewer symptoms, or less pain, after they have been taking what they thought was a medicine, even if it did not contain any active ingredients. This is known as the placebo effect.

- **Use the internet to investigate the latest position on the building of the new research laboratory at Oxford University.**

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

John Tucker

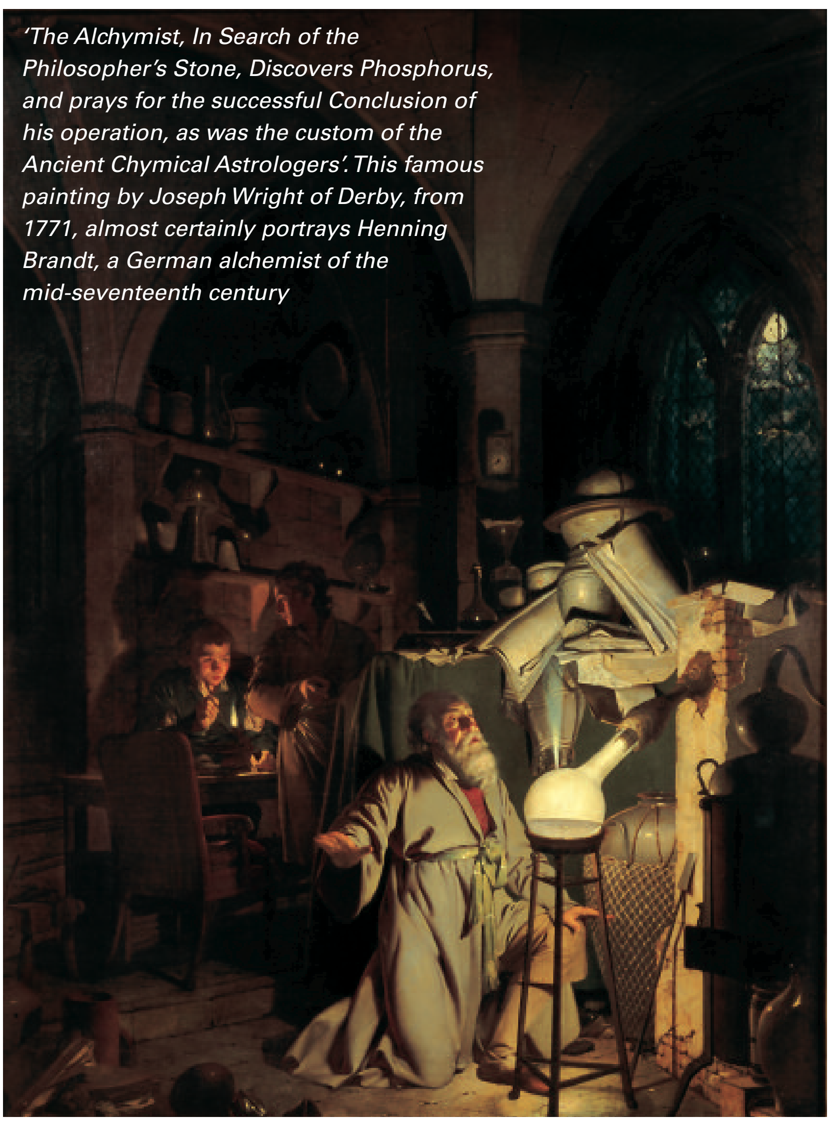
Alchemy

GCSE key words
Distillation
Scientific method
Acids
Corrosion

Alchemy is the study of eternal life, salvation, and the answers to the ultimate questions about life, the universe and everything. It flourished for more than 1500 years until, in the late 1600s, the beginnings of modern, scientific chemistry edged it aside. But what was alchemy and who were the alchemists?

One of the aims of the alchemists was to discover and use the magical **Philosopher's Stone**, which was supposed to change worthless metals into gold. The alchemists thought that this was possible because they believed that every substance was a combination of the four elements: earth, air, fire and water.

We still use the expression 'the acid test' to mean an especially critical test of genuineness.



'The Alchymist, In Search of the Philosopher's Stone, Discovers Phosphorus, and prays for the successful Conclusion of his operation, as was the custom of the Ancient Chymical Astrologers'. This famous painting by Joseph Wright of Derby, from 1771, almost certainly portrays Henning Brandt, a German alchemist of the mid-seventeenth century

Gold

Gold was a key material in alchemy. Its colour suggested the Sun, and its complete resistance to corrosion marked it out as something special. Gold was the only metal that could not be dissolved away by ordinary acids. It even resisted concentrated nitric acid. Thus, acids could be used to distinguish between real gold and a mere yellow alloy such as brass.

Gold also had symbolic significance as the metal of kings, princes and emperors because it represented their nobility — their supposed immunity from the baser concerns of the common people. Alchemists thought that turning the base metal lead into the noble metal gold was simply a matter of dissolving away the unwanted qualities and nourishing the 'seed' of gold. Like all metals, gold was thought to be somehow born from Mother Earth. This process was believed to be like the normal plant cycle of life and death followed by regeneration.

The ideas behind alchemy

The complex ideas underlying alchemy were a mixture of detailed practical knowledge and ancient religious and mystical beliefs, as well as the thoughts of Greek philosophers.

The planets played an important part in this, and many substances, especially metals, had astrological links (see Table 1). Unsurprisingly, the Sun represented gold, and the Moon silver. According to alchemical theory these two metals also represented complementary opposite 'masculine' and 'feminine' characteristics, like the 'Yang' and 'Yin' of Taoism, which are linked to day and night, Sun and Moon and so on.

Box 1 Henning Brandt

Henning Brandt was a German alchemist of the mid-seventeenth century. Brandt discovered phosphorus accidentally, about 100 years before Joseph Wright's famous picture of him was painted. It seems that he had an idea that gold and the yellow colour of urine were connected in some mysterious way.

While heating the solid residues he had got from evaporating several buckets of stale urine with powdered charcoal he found that phosphorus, glowing and burning, distilled from the flask. He believed that he was on the threshold of discovering the Philosopher's Stone. He wasn't, of course, and eventually he sold the recipe, which he had kept secret for some years, to cover his debts.

TopFoto

Left: Two early sixteenth-century alchemists standing behind alchemical apparatus designed to distil liquids

Mercury, a liquid metal, was named 'hydrargyrum', 'water-silver'; hence the symbol Hg.

Ben Jonson, a contemporary of Shakespeare, wrote his play *The Alchemist* in 1610. Its plot involved fake alchemists.

Practical chemists

Alchemists were the chemists of their time. They used the same methods of extraction and purification as you will have encountered in the laboratory: filtration, distillation and crystallisation, for example. Like you, they heated and mixed substances to see what would happen. They used acids and alkalis, dissolved things in water, and ground solids up into powders to make them react more efficiently. Their pieces of apparatus may look rather odd, but the alembic (see Figure 1), for example, was basically for distillation.

Alchemists did thousands of experiments and then recorded their observations. However, the language they used was often deliberately obscure so it is difficult for us to understand.

Their desire to get at the **essence** of things led alchemists to distil plant and animal products. The essences they produced might be oils, perfumes, or liquids with medicinal properties known as **elixirs**. One such liquid was **alcohol**, which was thought to be in some way a **spirit**. Hence the modern use of the word 'spirits' to indicate a drink with a high alcohol content, like whisky or brandy.

Alchemists invented furnaces for heating mixtures strongly and melting metals, and the water bath, or **bain-marie** (named after a famous female alchemist, Mary the Jewess), for gentle heating over a long period. They invented pieces of apparatus which were the forerunners of modern laboratory glassware, and they discovered many useful chemicals, like the three mineral acids.

Robert Boyle and Isaac Newton were alchemists as well as scientists.

Table 1 *Astrological symbols for metals*

Substance	Planet	Symbol
Gold	Sun	☉
Copper	Venus	♀
Mercury	Mercury	☿
Iron	Mars	♂

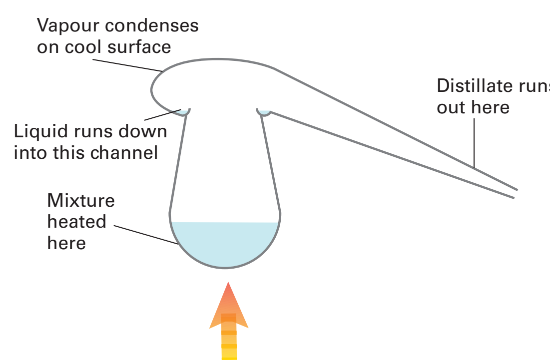


Figure 1 *An alembic*

Key substances discovered or refined by the alchemists include glass, the three mineral acids (hydrochloric, nitric and sulphuric), 'sal ammoniac' (ammonium chloride), alcohol, alum, phosphorus and alkalis.

Victoria & Albert Museum, London, UK/Bridgeman Art Library

Above: *'The Alchemist' by William Fettes Douglas*

During the Second World War, the top secret Los Alamos project built the USA's first atomic bombs.

In Britain, it was not unusual for a clergyman to be a secret alchemist. Very likely he would have inherited wealth and could subcontract curates to do his parish duties, leaving him with plenty of time to pursue the 'Divine Art', as it was known.

Alchemy was not a science

Alchemy was not a science with a rational set of theories tested against the experimental evidence. Alchemists certainly had theories, but they tended to try to make the experimental facts fit them rather than the other way round. They made little progress because they stuck to a pre-existing set of theoretical ideas and were reluctant to communicate their findings publicly. These two failings, as we would see them, were to them the whole point of alchemy.

Alchemical authorities

Alchemy looked backward to the ideas of 'authorities': learned men and women who, it was thought, had possessed a knowledge lost long ago. This could only be recovered by devotion to their ideas and attempts to rediscover their 'secret'. Present-day expressions like, 'The secret of successful revision is...' hark back to this attitude of mind. By 'secret' or 'art' we mean a technique passed on by word of mouth, or perhaps by apprenticeship to a more experienced and wiser person.

Box 2 The lure of gold

Being an alchemist was expensive: there were all those unusual pieces of glassware to be paid for as well as rare, highly priced chemicals from the Orient. To be one, you needed either a wealthy patron or a private income. The famous painting by William Fettes Douglas shows an old man explaining the significance of a flask of gold-coloured liquid to a rich nobleman or merchant.

The lure of unlimited quantities of gold allowed conmen to swindle greedy people by a variety of simple tricks. One scam was to coat a small piece of gold in black wax so that it resembled an ordinary metal. During a long ritual, this black lump was put into a crucible in the furnace, along with the last few drops of the all-important elixir. The wax would melt, of course, and burn away, leaving the 'miraculous' piece of gold. Such charlatans gave alchemy a bad name; although it did not help matters that genuine alchemists sometimes resorted to similar frauds.

Box 3 Alchemy websites

Look up the following websites to find out more about alchemy:

http://en.wikipedia.org/wiki/Alchemy
www.levity.com/alchemy/index.html
www.pbs.org/wgbh/nova/newton/legacy.html

Alchemical secrets

Alchemists thought there was a bright and wonderful secret at the heart of alchemy. This secret was not to be revealed to ordinary people who might not have the strength of character or nobility to stop them from abusing that knowledge.

It is worth noting that in the twentieth century many of the scientists who worked on the Los Alamos project were worried about the potential evil uses of atomic energy. Today, we are concerned about the potential misuses of genetic engineering. The difference is that these are, more or less, openly debated and that publication and peer review allow scientists to share knowledge and keep each other up to the mark. Thousands of alchemical experiments were needlessly repeated time and again.

Alchemy and chemistry

Was alchemy the beginning of chemistry? Opinions vary, but although alchemy contributed nothing to the all-important theoretical basis of modern science, it did produce or isolate a number of key substances for the first time. Alchemists also developed practical techniques which are still being used in the twenty-first century.

John Tucker *teaches chemistry at St Edward's, Oxford and is an examiner.*

Evaluating websites

Improve your grade

The internet can be useful for all sorts of reasons during your GCSE science course, but should be used with caution.

Textbooks and magazines, like CATALYST, are checked by their authors, editors and technical reviewers to ensure that they are accurate. They explain when an ethical or controversial issue is being considered, rather than stating it as hard fact, and give you some of the differing points of view.

Some websites are also rigorously checked (we check the ones we recommend to you), but anyone can set up a website. For example, a site you visit after searching for a scientific term on Google could be based in a university or could be your next door neighbour's. You cannot assume that anything on it is accurate or even halfway correct unless you have thoroughly checked its credentials. Here are some strategies to adopt when looking at a website.

(1) Visit the home page

- When was it created and last updated? Science changes fast.
- Whose site is it? Are they experts? Are they biased? Are they a pressure group, a business or do they have a vested interest? Pressure groups may only present one side of an argument or sensationalise their viewpoint. On the other hand, such sites can be useful for exploring controversial issues, such as those raised by animal experimentation.
- Do the links work? If not, the site is old and is not being maintained.
- Is it at the right level? You want more accuracy on nutrients, for example, than a health food supplier needs but not a university course. Some company websites can be informative, but most are too general. If they can't spell the terms correctly they are not for you.

(2) Look at the web address

Websites that you can trust include libraries and websites ending:

- **ac.uk** — a UK university or government-funded research organisation
- **edu.au** — an Australian university
- **edu** — a US university
- **org** — a website ending with this is a reputable organisation and should be factually correct

For example, the web address of The Royal Society is **www.royalsoc.ac.uk** and the British Trust for Ornithology is **www.bto.org**. Many of these sites have links to other reputable sites that you can follow.

A great resource

In summary, the internet is a wonderful resource, but always look critically at anything that you summon up on screen.

Box 1 Links

It is worth looking at whether other sites have made links to the site you have found. You can check this out in Google by entering 'link:*webaddress*' in the search box. If the linked sites are reliable ones, it is unlikely that they will make links with sites with poor credentials.

Box 2 Exam board websites

The internet provides access to examination board websites (see below), where you can find the specifications for your course, past examination papers and mark schemes. These examination board sites may offer useful support materials with coursework. You can also read examiners' reports, which include what people tended to get *wrong* in recent examinations — check that you know and understand these things!

- England: www.aqa.org.uk, www.edexcel.org.uk, www.ocr.org.uk
- Wales: www.wjec.co.uk
- Scotland: www.sqa.org.uk
- Northern Ireland: www.ccea.org.uk

Box 3 Science in the news

The internet provides an extraordinary window into the wider world of science and offers an excellent way to gain access to a wide range of topical information and breaking science news. This could come in especially handy for those of you doing the new GCSE science courses.

You could:

- download the latest images from the satellite orbiting Venus (www.esa.int/esaMI/Venus_Express)
- download and listen to lectures delivered recently by famous scientists (www.royalsoc.ac.uk)
- catch up on the latest information about bird flu from the World Health Organization (www.who.int)

www.quick.org.uk/menu.htm is an excellent website offering comprehensive advice on how to evaluate websites.

Read 'A life in science' on pages 12–13 to find out about the origins of the World Wide Web.

A life in science

Hank Morgan/SPL

TBL@WWW

Today, most readers of CATALYST *have easy access to the World Wide Web. Ten years ago, that was not the case. Tim Berners-Lee, a British scientist, came up with the idea of the Web in the late 1980s and set up the first server for it in December 1990.*

In the late 1980s Tim Berners-Lee was working at CERN, a large, international particle physics lab in Geneva where thousands of scientists and technicians work collaboratively. As in many branches of science, experiments in particle physics generate large amounts of data in very short spaces of time, and these have to be stored and analysed on computers. Tim devised the Web to allow his colleagues to access data at the click of a mouse, but he could also see the advantages of such a system for people in many different walks of life.

The internet already existed when Tim invented the Web (see Box 1). Tim realised the need for standard approaches for identifying resources on the Web, and for sending information from one computer to another (see Box 2).

Early days

Tim Berners-Lee grew up in southwest London. His parents were involved in developing early computers. He wasn't sporty; he preferred toy trains, and later the electronic systems that control them. He went to Oxford University to study physics. He and a friend were banned from the university computer after they were caught hacking.

After graduating with a BSc degree, he worked in industry before moving to CERN in 1984. There, he devised computer systems for controlling experiments

The UK is one of the world's top ten countries for internet usage. In January 2006, there were an estimated 37 800 000 internet users in the UK, 63% of the population.

Box 1 The internet and the Web

The internet existed before the World Wide Web – they are two different things. The internet is the system which allows two computers to communicate when they may be on opposite sides of the world. The Web is a system for locating and transferring information (text, data, images etc.) over the internet. E-mail is an example of another system for transferring information over the internet.

Box 2 WWW essentials

What does it take to make a web linking computer users around the world?

Hypertext Uses links to allow the user to jump around within a document, or from one document to another. (You can create links in a document using a word-processing program such as Microsoft Word.)

HTML Hypertext mark-up language – the code used to send the words, pictures, sounds etc. which make up a page of hypertext.

Resource identifiers The addresses which tell the system where to find the pages you are looking for.

Clients and servers Your computer is a client; it sends out requests to the network of server computers via your internet service provider, and they send back the pages you require (Figure 1).

and handling data. This led him to see the need for the Web. He came up with the idea of giving every 'document' a universal document identifier (UDI). A document might be text, data, an image or whatever. Today, these identifiers are known as universal resource identifiers (URI); they are the filenames that start www. and end .html, .pdf, .doc and so on.

Today and tomorrow

Tim is now professor of computing at both Southampton University and MIT in Boston. He is also director of the World Wide Web Consortium, an organisation guiding the development of the Web.

Perhaps the most impressive aspect of Tim's inventiveness was that he could see the great use the Web would come to have for millions and even billions of people. He chose not to patent his idea, so that it is freely available for all to use.

The Web is often criticised because it allows people to download violent or obscene images, or even bomb-making recipes. What does Tim say to this?

> People also say how their lives have been saved because they found out about the disease they had on the Web, and figured out how to cure it.

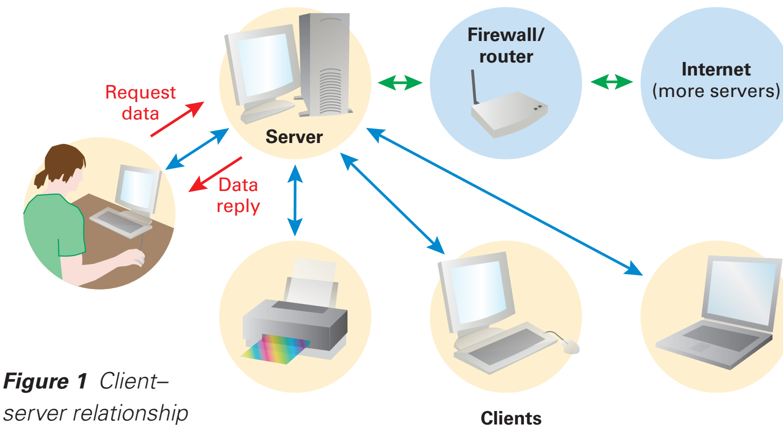


Figure 1 *Client–server relationship*

> I think the main thing to remember is that any really powerful thing can be used for good or evil. Dynamite can be used to build tunnels or to make missiles. Engines can be put in ambulances or tanks. Nuclear power can be used for bombs or for electrical power.
>
> The Web is a tool for communicating. With the Web, you can find out what other people mean. You can find out where they are coming from. Let's use the Web to help people understand each other.

Tim Berners-Lee's homepage (www.w3.org/People/Berners-Lee) includes a link to his blog.

***Weaving the Web* by Tim Berners-Lee is his account of the invention of the Web.**

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

Alchemical wordsearch

Puzzle

D	I	V	A	N	E	L	I	X	I	R	A	N
Z	L	I	O	R	C	E	L	E	M	E	N	T
O	A	O	I	P	N	C	I	B	M	E	L	A
U	M	F	G	R	E	L	O	H	O	C	L	A
T	O	U	C	H	S	T	O	N	E	C	H	E
R	E	H	P	O	S	O	L	I	H	P	I	H
O	H	T	R	A	E	Q	R	E	T	A	W	A
N	O	I	T	A	T	U	M	S	N	A	R	T
S	N	G	I	B	N	Y	E	N	O	T	S	N
R	U	R	B	A	I	N	M	A	R	I	E	O
A	S	O	Y	R	U	C	R	E	M	O	O	R
M	U	L	L	I	Q	U	I	D	I	T	Y	I

How many of the following words can you find in the grid? Words can run in any direction. Which of the words listed below is not in the grid?

air	alchemy
alcohol	alembic
bainmarie	earth
element	elixir
fire	gold
iron	liquidity
mars	mercury
moon	philosopher
quintessence	spirit
stone	sun
touchstone	transmutation
water	

Answer on page 19.

Nigel Collins

Biofuels

Photo Provider Network/Alamy

GCSE key words
Energy
Ethanol
Fuel
Global warming

Burning fossil fuels releases extra carbon dioxide into the atmosphere, which contributes to global warming. However, burning renewable biofuels is part of the normal carbon cycle and does not contribute to an increase in atmospheric carbon dioxide. This article looks at the ways in which the energy stored in biofuels can be released.

Using vegetable oil as fuel in diesel engines is not a new idea. Rudolf Diesel's first engines were built to run on peanut oil in countries which had no petrochemicals industry.

Plants use water from the soil, carbon dioxide from the air, and mineral nutrients such as nitrate, sulphate and phosphate ions, also from the soil, to make carbohydrates, proteins and lipids (fats). Photosynthesis is effectively a type of chemical process called **reduction**. Plants release oxygen as part of this process; they also use hydrogen atoms from the water to make sugar.

The materials made by a plant form its **biomass**. Plant biomass is the immediate source of energy for all living things, not just animals but also the plant itself. Respiration releases the energy from carbohydrates. This process is the converse of photosynthesis and can be thought of as an **oxidation** process. It requires oxygen and releases carbon dioxide gas to the atmosphere; hydrogen atoms are also transferred back into the other by-product, water.

Combustion is also an oxidation process — to release the energy from a fuel, oxygen is needed as well as the fuel. Carbon dioxide and water are produced. Combustion therefore has the same starting materials and end-products as respiration:

organic matter + oxygen → carbon dioxide + water

Biofuel basics

When fossil fuels, such as oil, natural gas and coal, are burned, the carbon dioxide released has been out of circulation for a very long time, so any which is released in this way is in addition to that maintained by normal carbon cycling (see Figure 1).

When fresh biomass, such as wood or the residue of crops, is burned, the carbon dioxide that is released was in the atmosphere recently and is now returned to it. Other plants grown for harvesting as fuel then utilise this carbon dioxide.

Some crops grow very quickly, producing a lot of biomass in a short time (Table 1), and a number of crops are grown deliberately for energy production, rather than to provide food. Table 2 lists some examples.

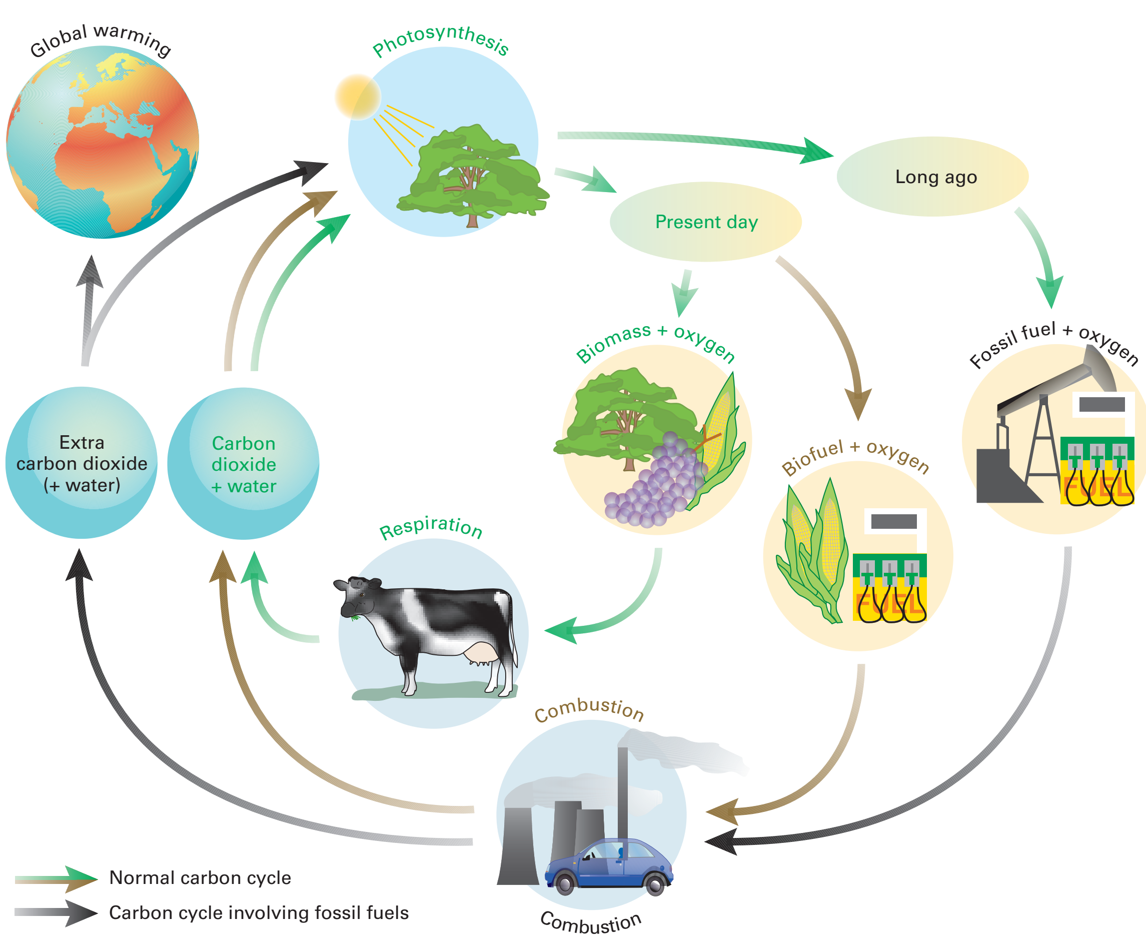


Figure 1 *The carbon cycle and fuels*

Another way to make a biofuel is to use bacteria to decompose organic materials under anaerobic conditions and release methane, an inflammable gas. This biogas, produced by microbial respiration, can be used as a fuel to power the generation of electricity in sewage works, for example.

Although many diesel cars can run on biodiesel, some with particular makes of injector pump cannot — so don't try putting biodiesel in the family car without thorough research!

Table 1 *Fast-growing biomass crops*

Type of plant	Annual yield of dry matter (tonnes per hectare)
Wood produced by short rotation coppicing of willow or poplar	10
Giant grasses, such as *Miscanthus*, reed canary grass or switchgrass	60

Biofuel for cars

Each of the energy crops in Table 2 can be converted to a liquid fuel that can be used to power vehicles. The main way in which this is produced is by fermentation, followed by distillation, to produce **ethanol**. The crops contain sugar, either as individual sugar molecules or in the polymers, starch or cellulose. Sugar and starch are used in most instances:

- stage 1: starch/cellulose is broken down to sugar, involving the use of acid
- stage 2: sugar → ethanol + carbon dioxide, using yeast

- **Log on to http://bioenergy.ornl.gov/papers/miscanthus/miscanthus.html to find out more about a fast-growing biomass crop.**

Table 2 *Energy crops*

Energy crop	Examples	Fuel use	Alternative uses
Cellulose/lignin crops	Wood, straw	Combust directly as heating fuel	Digest cellulose to sugar and use this to make ethanol, which can be blended with petrol
Starch crops	Barley, wheat, maize and rice seeds, potatoes	Use to produce ethanol, which can be blended with petrol	Straw from cereals can be burned
Sugar crops	Sugar cane, sugar beet	Use to produce ethanol, which can be blended with petrol	
Whole plants	Maize, *Miscanthus*, reed canary grass, coppiced willow, poplar	Combust directly as heating fuel	Convert to methanol or ethanol, which can be blended with petrol
Oil crops	Sunflower, olive, palm, oilseed rape	Combust directly as heating fuel	Add to transport fuel to make biodiesel

Box 1 Biodiesel: a case study

Was that a whiff of doughnuts when that car went past? Maybe the driver was someone like Steve Dewar. Although Steve has an ordinary diesel-engined car it can also use biodiesel. Steve uses waste cooking oil from a local café to make biodiesel. Chip shop and curry restaurant oils are not suitable, but filtered doughnut frying oil is fine.

Waste cooking oil is normally sent to landfill sites or put down drains. It was used for pet food, but since there is a risk that it could contain animal products it can no longer be used for this. So, as well as helping his pocket, biodiesel also reduces the waste problem — something that Steve cares deeply about.

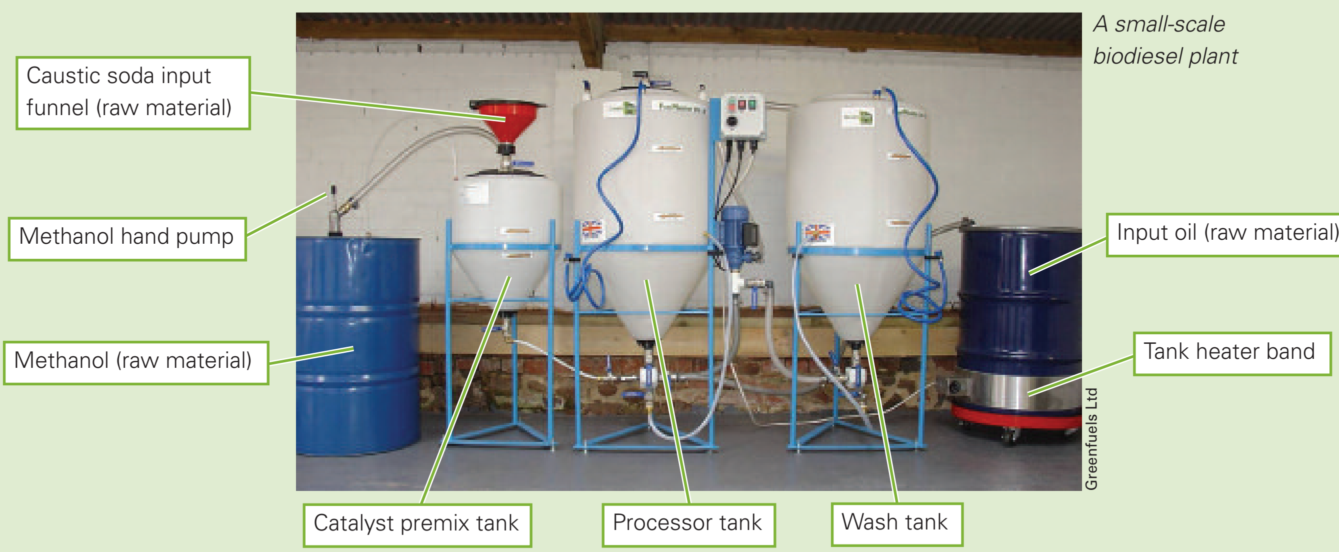
Steve learned about biodiesel from a friend and researched how to make it on the internet. One big advantage of biodiesel in the past was that it cost less than conventional diesel. It also has a higher cetane rating (a measure of how easily it ignites), produces cleaner emissions — no oxides of nitrogen, sulphur dioxide or particulates — and makes car engines run better.

The price advantage has almost disappeared because home biodiesel makers now have to pay more fuel tax on their oil — 47p per litre. Commercial companies which can prove their biodiesel meets European standards pay less fuel tax, but there aren't many commercial producers yet. Biodiesel is popular in Germany and there is a growing band of backyard biodiesel producers in the UK.

Making biofuel

The science of making biodiesel

Waste cooking oil consists mainly of triglycerides. The process uses methanol and sodium hydroxide to split the triglyceride molecules into glycerol and fatty acids. The fatty acid products are the fuel element. Glycerol can be composted, recycled and used to make other products.



Greenfuels Ltd

A small-scale biodiesel plant

- **Log on to www.greenfuels.co.uk and click on biodiesel. Look at both sections. You can download a PDF that describes the process of making biodiesel in detail.**

The ethanol can then be blended with petrol (usually between 5% and 22% ethanol). Brazil has over 300 distilleries, and the fuel derived from sugar cane there is called gasohol. In the USA, Spain and France, maize and other cereal crops are used as the feed-stock. The organism involved in ethanol production is often a variety of yeast; experiments are also being conducted in Canada and Scandinavia with other microbes that can digest woody material, releasing sugar from lignin and cellulose.

The other plant product that can be used as a fuel is the oil produced by plants within their seeds or fruits. The seeds, such as those of sunflower, rape or palm, or fruits, such as the olive, are crushed to release the oils. The oils can be used in two ways. They can be added directly to diesel fuel as a supplement or they can be converted to **biodiesel** (see Box 1).

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

Blood pressure

Jane Taylor

Steve Gschmeissner/SPL

Above: *A capillary in the liver. Its small diameter (note the size of the red blood cells) creates a high resistance to blood flow*

Have you ever fainted? Fainting can be the result of a sudden drop in your blood pressure, which is often part of a shock reaction. Read on to find out more about how and why your blood pressure may vary.

GCSE key words
Heart
Circulation
Blood pressure

Maintaining your blood pressure is an important part of keeping your body in balance. Blood is put under pressure when it passes through your heart. The main function of the **left ventricle** when it contracts is to pressurise blood so that it is forced through the blood vessels which serve the organs of your body (Figure 1). The tiny capillaries that distribute blood through your tissues and organs have a very small diameter and so offer a high resistance to the flow of blood through them. Your heart needs to work hard to provide enough pressure to push blood through the miles and miles of capillary beds.

Inside a capillary bed in an organ, blood pressure is part of the mechanism that causes water to leave the blood and enter the tissues carrying nutrients,

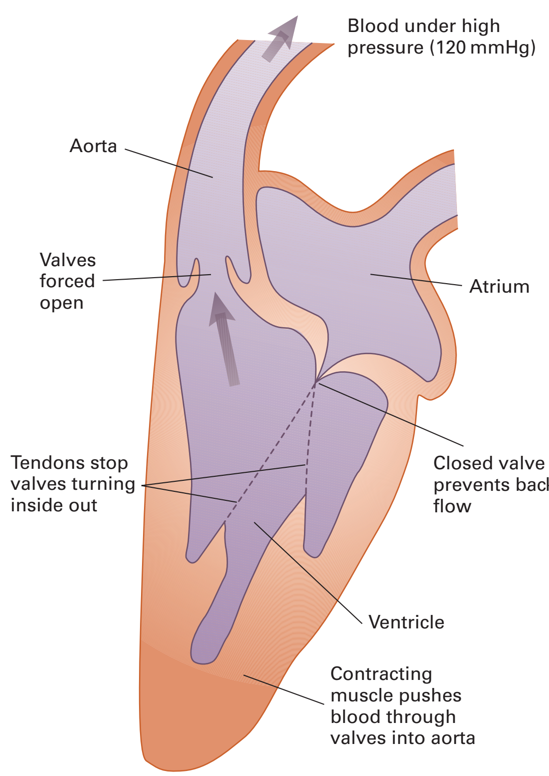
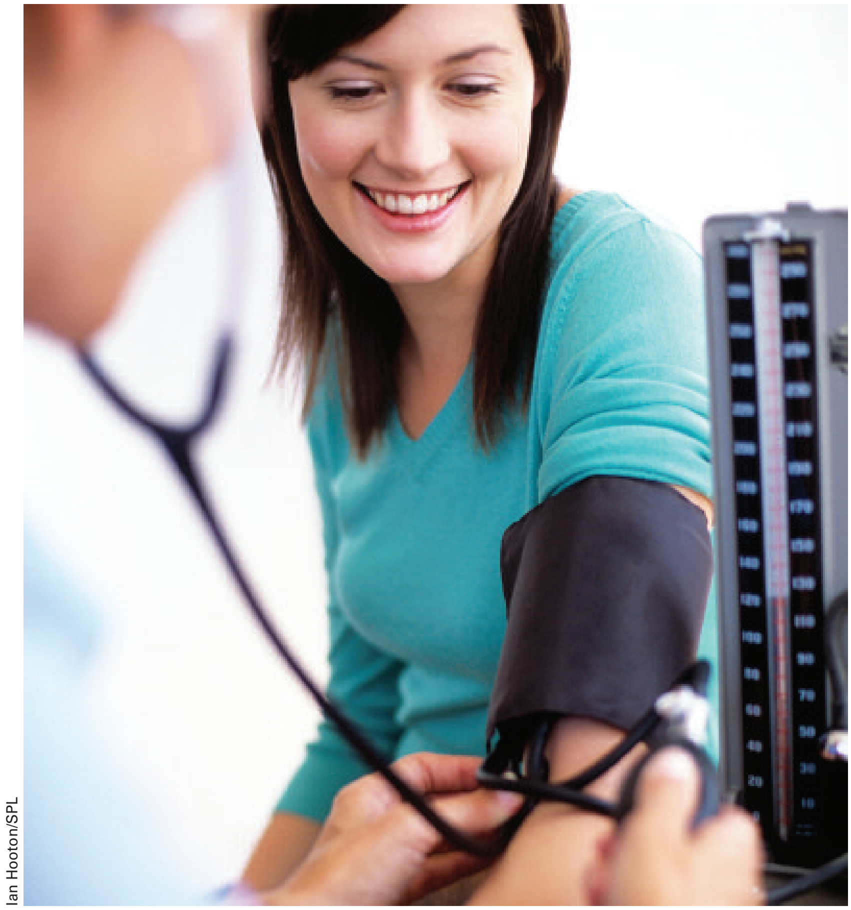


Figure 1 *One half of a heart during ventricular contraction*



Above: *A doctor measuring a patient's blood pressure*

Osmosis is an important part of the exchange mechanism in capillary beds.

hormones and other useful substances (Figure 2). By the time blood has travelled to the end of a capillary bed it has lost much of its volume and pressure. The pressure of fluid in the tissues is now higher than blood pressure, so water can return to the blood from the tissues by **osmosis**.

Measuring blood pressure

Your blood pressure is given as two figures, for example 120 over 80 **mm of mercury (mmHg)**. Although we should use pascals to measure pressure (the reading above would be 16 over 10 kPa), the general public is more familiar with the older units.

A doctor or nurse measures your blood pressure using a **sphygmomanometer**. Usually a cuff is wrapped round your upper arm to measure the pressure in the main artery supplying your arm. This artery is one of the first branches from the aorta so the pressure is high.

As the cuff is inflated the pressure of the air inside it pushes on the artery and stops blood flow through it. The air pressure is then reduced slowly. When the air pressure is low enough for blood pressure to force blood through again the nurse can hear the blood flow. The pressure can be read off the scale. This gives the higher figure (120 in the example above). It represents the pressure of the blood as the left ventricle contracts to push blood out of the heart. This is the **systolic** pressure.

The lower figure (80 in the example above) is when the nurse can no longer hear the flow. It is the blood pressure in the arteries while the heart is relaxed and filling with blood. This is the **diastolic** pressure. Many hospitals now use digital blood pressure meters which are thought to be more accurate than a nurse's judgement of the flow.

Normal blood pressure

Healthy people have blood pressures around the figures given above (120/80 mmHg). If you need to have your blood pressure taken you may be asked to sit quietly for a while beforehand because when you are active your blood pressure rises slightly. During activity your body produces a hormone called **adrenaline** that causes you to tense your muscles and increases your heart rate. When you are relaxed your blood pressure drops slightly. Figures of 140/90 mmHg or more indicate you could have a problem with your blood pressure.

Blood pressure and the kidneys

Your blood pressure is not just due to heart action. Several different mechanisms are involved, including your kidneys. The water content of the blood is regulated in your kidneys. If you expel a lot of water

The amount of fluid that can flow through a pipe is proportional to the radius^4. A pipe can carry only 1/16th of the volume of a pipe twice as wide.

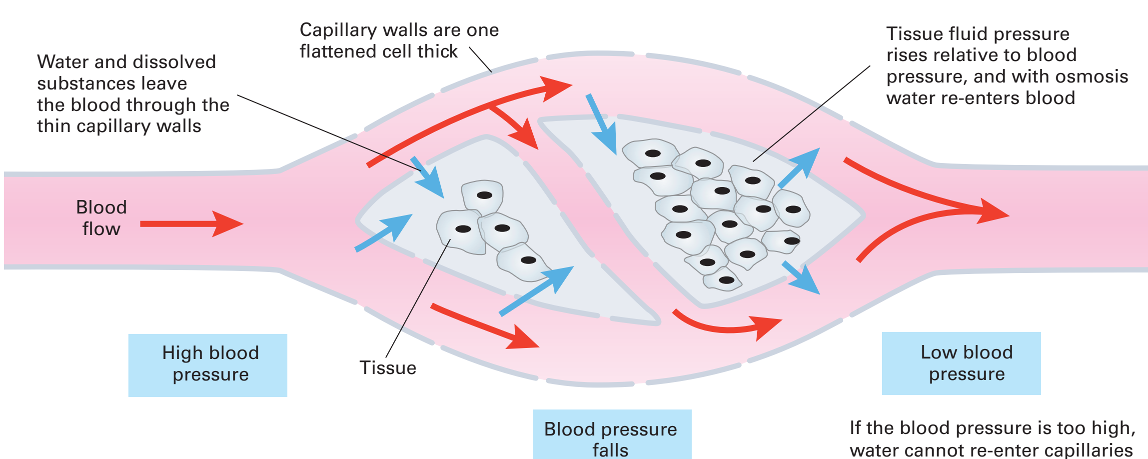


Figure 2 *What happens in a capillary bed*

Susumu Nishinaga/SPL

Above: *The tiny capillaries that make up the glomerulus in a kidney tubule are a filter for the blood. High blood pressure or very low blood pressure can lead to kidney failure*

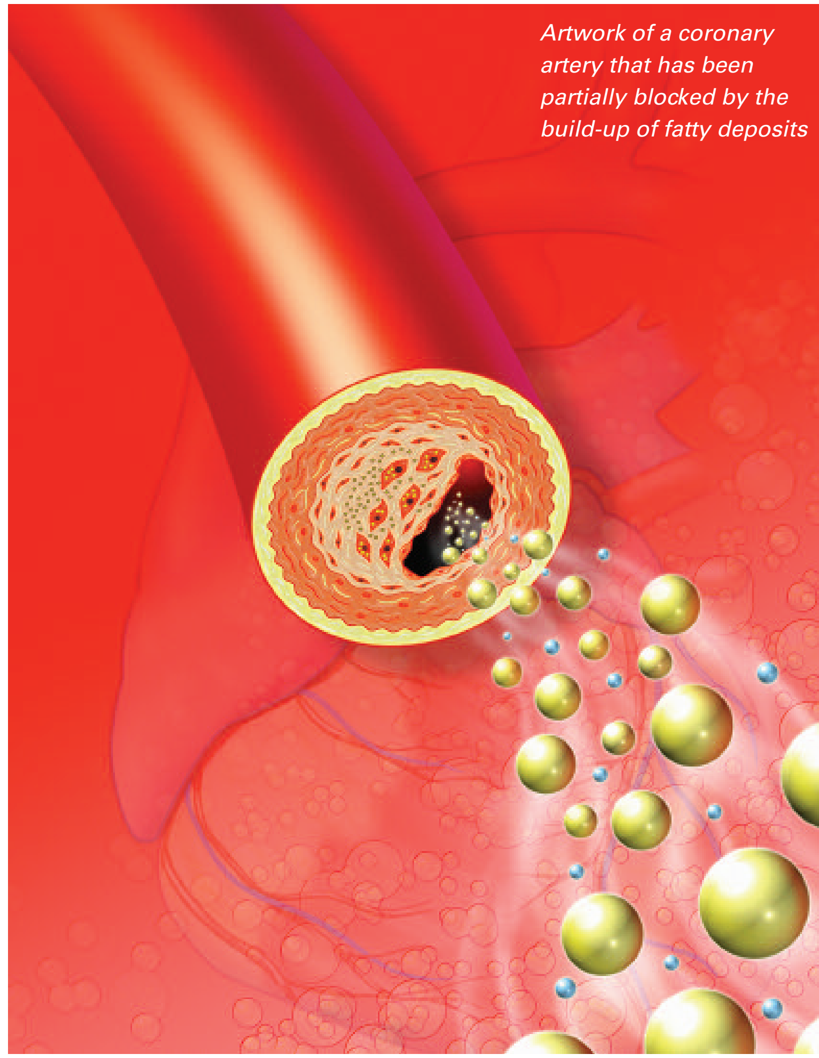
from blood into urine then the blood volume, and hence pressure, will be lower. When you are short of water a chemical is produced in the body called angiotensin II which causes your arteries to constrict. The pressure of blood inside these narrower arteries rises. Angiotensin also makes you feel thirsty.

Hypertension

Some people have high blood pressure. This is known as **hypertension**. Their blood pressure is greater than 140/90 mmHg. There are several causes, but a common one is fatty deposits in the arteries around the heart. These reduce the internal diameter of the blood vessels so much that less fluid can pass through. This raises the pressure and puts a strain on the heart.

If someone's blood pressure is too high, the pressure will not have dropped enough by the end of the capillary bed to allow fluid to return to the blood. Instead it stays in the tissues and makes them swollen and puffy. People with high blood pressure may develop swollen ankles and feet.

High blood pressure also damages some of the very tiny capillaries serving important organs such as the kidneys and brain. If blood vessels are damaged, or their lining is roughened by fatty deposits, there is a greater risk of a blood clot forming in the blood vessel – a condition know as thrombosis. Blood clots can cause local problems where they form, or they may be dislodged, to block blood flow elsewhere in the circulatory system.



Artwork of a coronary artery that has been partially blocked by the build-up of fatty deposits

David Gifford/SPL

Living with high blood pressure

People with high blood pressure are encouraged to make some changes to their lifestyle. Taking more exercise and eating a balanced diet help to reduce the 'furring up' of their arteries by reducing the amount of fats in the blood. Reducing salt intake helps the kidneys regulate the water concentration in blood. Stress and anxiety release adrenaline and nor-adrenalin that raise blood pressure, so managing stress also becomes important.

Some people need treatment to reduce their blood pressure. Drugs called **beta-blockers** reduce the rate at which the heart beats and the force of the ventricular contractions. As a consequence, blood pressure is reduced. **ACE-inhibitors** reduce the effects of angiotensin and dilate the arteries and veins so that blood flows more easily.

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

Over 10 million people in the UK have hypertension.

The right ventricle pumping blood to the lungs generates only 25 mmHg (3.3 kpa).

Answer to Alchemical wordsearch, page 13

The word not in the grid is **spirit**.

Medical museums in London

You can find out more about these museums and many others by logging on to www.medicalmuseums.org.

London is famous for two particular museums when it comes to science — the Science Museum and the Natural History Museum, both in South Kensington. But a great many other smaller museums and places of scientific interest are scattered around London. Here we focus on one group of museums — those associated with various aspects of medicine.

Alexander Fleming Laboratory Museum

The effect of penicillin on bacteria was first observed by Alexander Fleming, working in a small laboratory at St Mary's Hospital in 1928. An in-situ reconstruction of the laboratory, displays and a video uncover the remarkable story of how a chance discovery became a lifesaving drug destined to revolutionise medicine.

Visiting information

The Alexander Fleming Laboratory Museum is in St Mary's Hospital, on Praed Street, in Paddington.

- Open Monday to Thursday, 10.00–13.00
- Closed on public holidays
- Admission: adults £2, students £1

Find out more at www.st-marys.nhs.uk/about/fleming_museum.htm

Alexander Fleming Laboratory Museum

Alexander Fleming's laboratory

The Hunterian Museum at the Royal College of Surgeons

If you are interested in the science and art of surgery, the Hunterian Museum, housed in the Royal College of Surgeons, is worth a visit. The collections have been brought together over four centuries by a cast of colourful characters, including the surgeon and anatomist John Hunter (1728–93). There is a fascinating mix of human and animal anatomy and pathology specimens, wax teaching models, surgical and dental instruments as well as paintings, drawings and sculptures.

Recently reopened after a £3.2 million refurbishment, there are various permanent displays and a changing programme of temporary exhibitions. Check the website for the current programme.

Visiting information

The Hunterian Museum at the Royal College of Surgeons is at 35–43 Lincoln's Inn Fields.

- Open Tuesday to Saturday, 10.00–17.00
- Closed 23 December to 2 January, Good Friday and Easter Saturday
- Admission free, donations welcome
- Disabled access (see museum website for details)

Find out more at www.rcseng.ac.uk/museums

Below: *The Crystal Gallery at the Hunterian Museum*

Royal College of Surgeons of England

Old Operating Theatre Museum

The nintеenth-century operating theatre at the Old Operating Theatre Museum

Old Operating Theatre Museum and Herb Garret

This fascinating museum is located in Southwark, just south of London Bridge, and opposite Guy's Hospital. Hidden in the roof of a church, a 300-year-old herb garret houses the only surviving nineteenth-century operating theatre, complete with wooden operating table and observation stands, from which spectators witnessed surgery performed without anaesthesia or antiseptics. The oak-beamed garret was also used for the storage and curing of medicinal herbs.

Visiting information

The Old Operating Threatre Museum is only 2 minutes' walk from London Bridge Underground and Mainline Station, at 9a St Thomas's Street.

- Open daily, 10.30–17.00
- Closed 15 December to 5 January
- Admission charge
- Disabled access is limited

Find out more at www.thegarret.org.uk

British Dental Association Museum

Interested in dentistry? This museum has recently been refurbished and offers modern displays alongside historic film footage and a CD-ROM *Oral Histories*. The BDAM's collections include dental instruments and equipment, furniture, archives, photographs, fine art and new inventions.

Visiting information

The British Dental Association Museum is located at the British Dental Association's Headquarters at 64 Wimpole Street, London W1G 8YS.

- Open Tuesdays and Thursdays, 13.00–16.00; other times by appointment
- Admission free
- Disabled access

Find out more at www.bda.org/museum

- **Try to identify the other medical museums indicated by the symbol 'M' on the map.**

Filip Gierlinski/Courtesy of the BDA Dental Museum

Left: *Exhibits at the British Dental Association Museum*

Science Museum

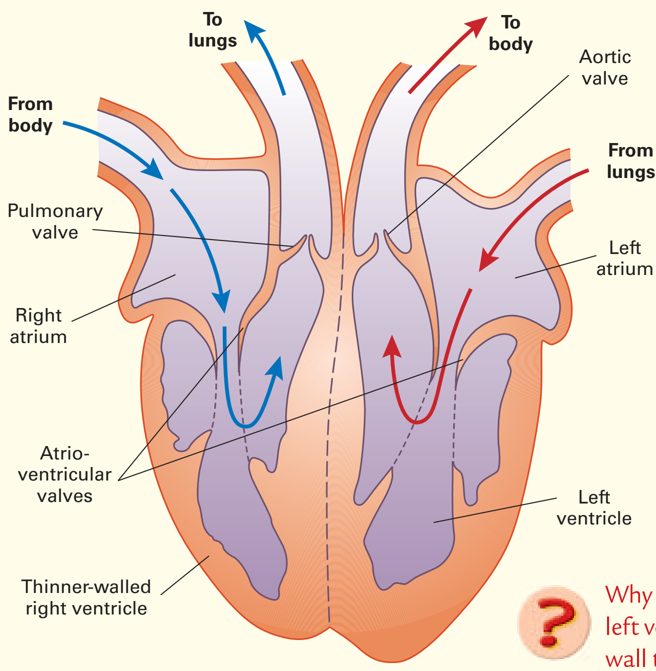
The Science Museum has a lot related to biomedicine in its main galleries — but high up, on the fourth floor, is a section called 'Glimpses of Medical History', where there is a series of historical dioramas. 'The Science and Art of Medicine' and 'Veterinary History' are on the floor above. To find out more, log on to **www.sciencemuseum.org.uk** and click on 'Visiting' and then on 'Gallery guide'.

The human heart

Human heart statistics

Your heart:

- is the most active muscle in your body
- can beat at up to 160 beats per minute when you exercise hard
- beats over 100 000 times a day
- pumps up to 6 litres of blood through 20 000 km of blood vessels
- started beating well before you were born



Why is the left ventricle wall thicker?

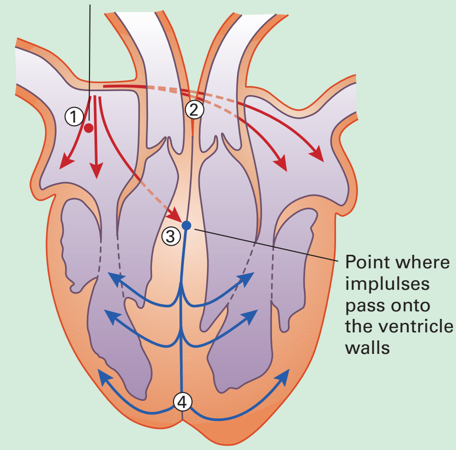
Healthy heart valves

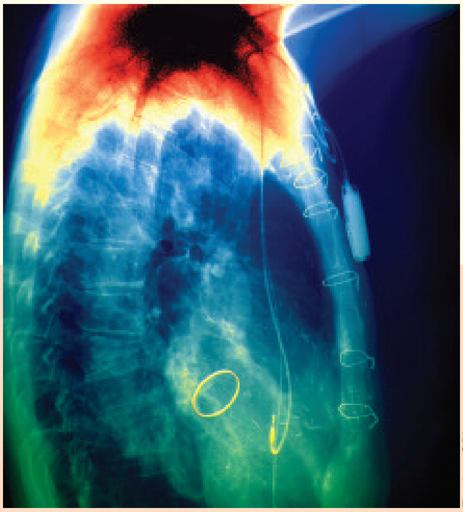
The four major heart valves stop blood flowing backwards — back out of the heart, backwards within the heart or back into the heart. Their positions are indicated in the two-dimensional diagram above, in which the heart is drawn to describe its function, rather than to represent its three-dimensional structure accurately.

A heart with faulty valves will be unable to pump blood efficiently. As a result, oxygen and carbon dioxide are not moved from and to the lungs as efficiently as they should be. A person with faulty valves may be short of breath, have a higher pulse rate and be generally tired. The damaged valve and its surrounding ring can be removed and replaced with an artificial valve.

Heart beat

The heart has an in-built rhythm. The electrical impulses which travel through the heart muscle, causing it to contract, start at the natural 'pacemaker' in the wall of the left atrium (1). Initially, the impulses and contractions spread across the two atria (2). The impulses can only head on to the ventricles via a narrow pathway (3) down the middle of the heart, towards the bottom (confusingly called the apex) (4). Impulses travel fastest to the apex and slower to the rest of the ventricle walls. If you think about it, this pattern makes sense. Blood has to be forced upwards into the aorta or the pulmonary artery. If the natural pacemaking of the heart fails, an artificial pacemaker can be implanted to overcome the problem.





Zephyr/SPL

An artificial valve and a pacemaker in place

Coloured X-ray of a side-view of a 72-year-old woman's chest. She has an artificial heart valve (the yellow ring surrounds the valve itself) and a pacemaker (white oblong, upper right). You can follow the lead from the pacemaker to its termination in the heart. It supplies electrical impulses to the heart to keep it beating regularly. You can also see the wire stitches (rings, right) used to pin the bones of the chest together, after they were cut to allow open heart surgery