Catalyst

Secondary Science Review

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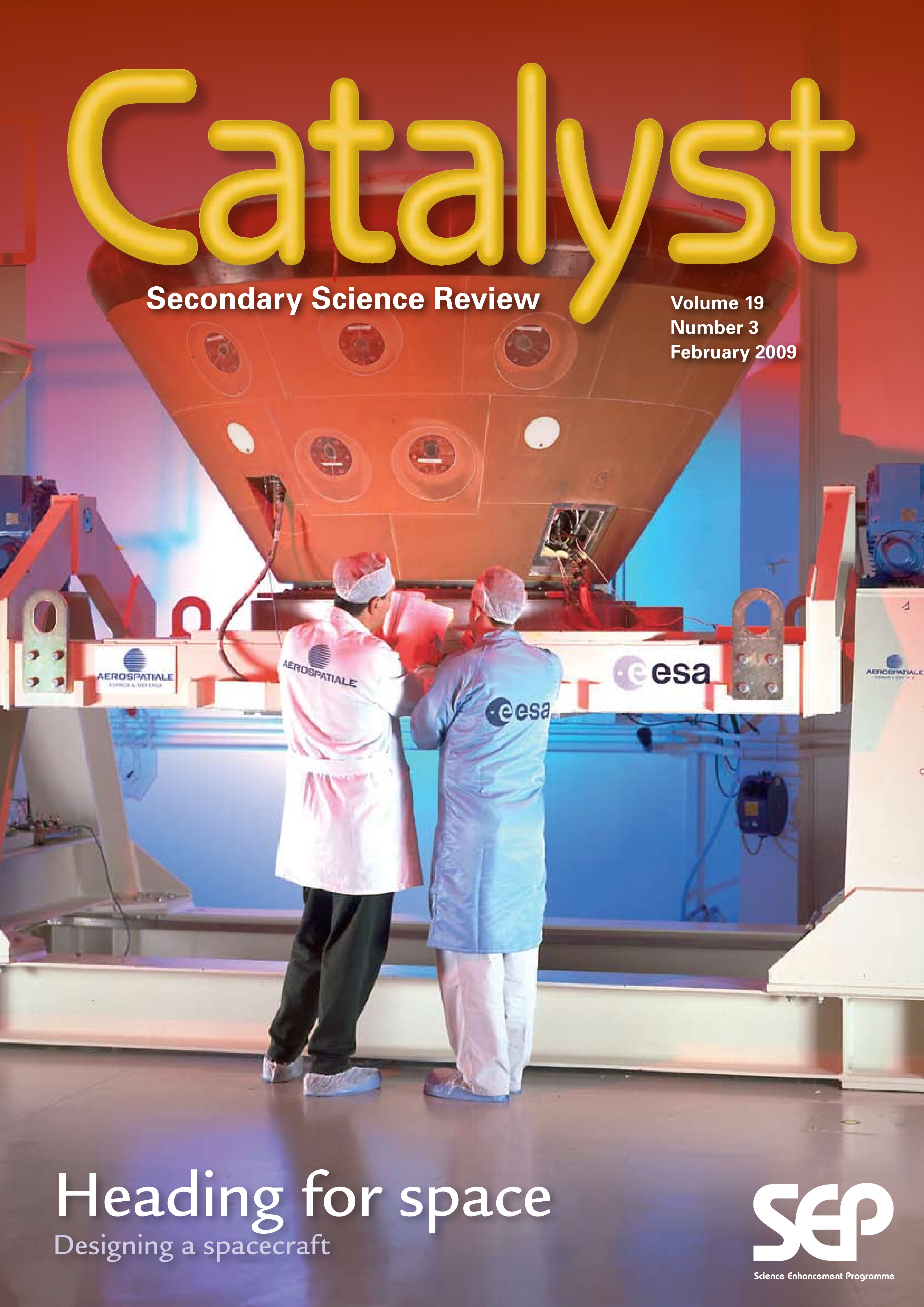

Heading for space

Designing a spacecraft

SEP
Science Enhancement Programme

Catalyst

Volume 19 Number 3 February 2009

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The front cover shows the European Space Agency's Atmospheric Re-entry Demonstrator spacecraft under construction – see the article on pages 20-21. (Aerospatiale/ESA)

From the scientist's pen

In each issue of CATALYST we bring you articles describing some of the frontiers of science and technology. Some are written by expert science writers with an expertise in a particular area of science. However, we also try to bring you articles written by scientists describing the research and development which they themselves are involved in.

- On page 4, Claire Baker describes bioluminescence and how our understanding of this natural phenomenon is leading to valuable technological developments. Claire is lucky – her work takes her into some of the most fascinating parts of Australia's outback and rainforests.
- Peter Cole is a physicist from Manchester University. His article on page 9 describes the work of the radiation protection officer, a vital role when people increasingly work with ionising radiation. Radiation has many uses in, for example, medicine, but it is essential that those who work with it are protected from its hazardous effects.
- Tim Jackson and Suzanne Gildert work on superconductors at Birmingham University. They describe some current and future uses of these extraordinary materials on page 16.
- And on page 20, Victoria Hodge describes the work that goes into designing and building spacecraft. One slight error could ruin a multi-million pound project.

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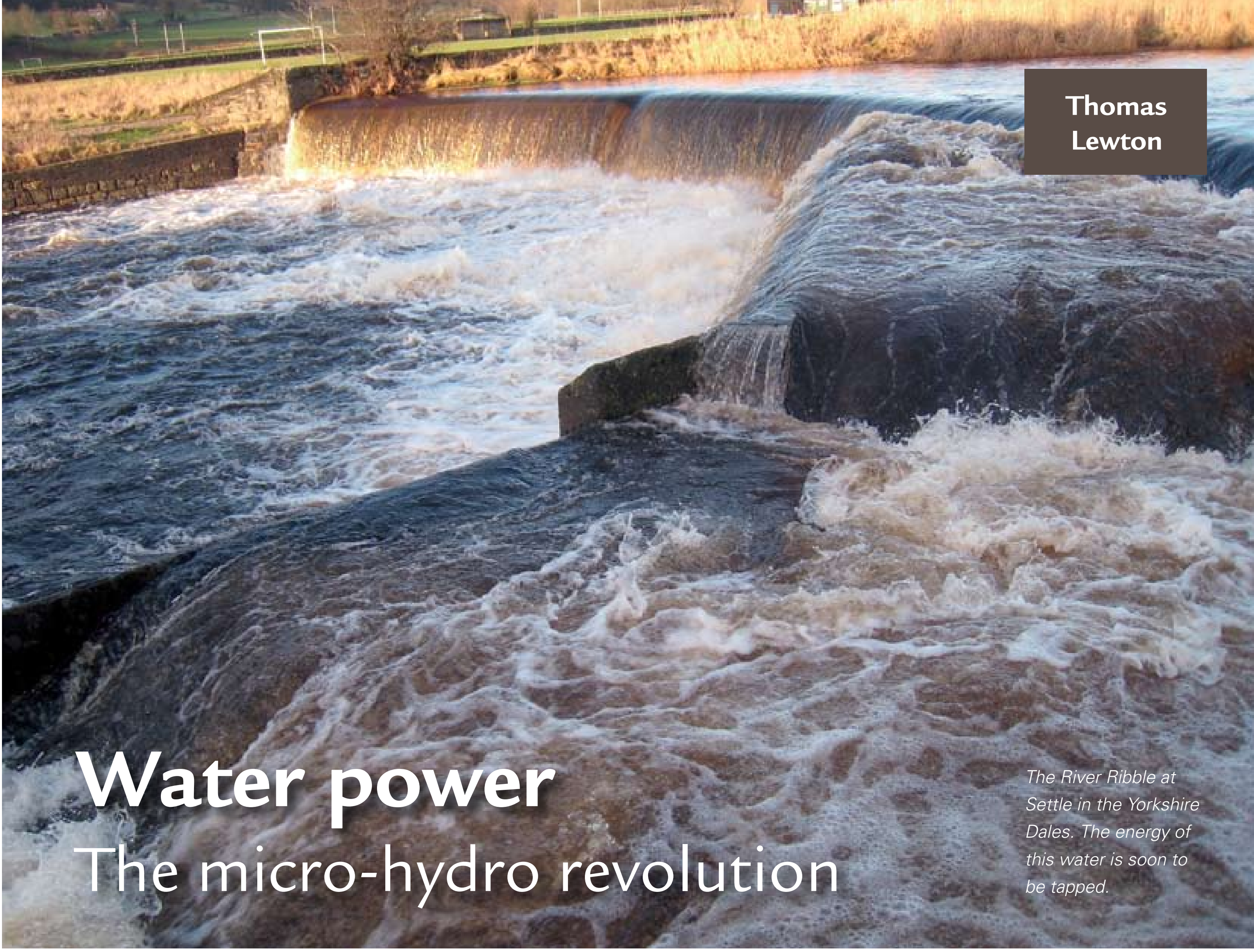


Thomas Lewton

Water power

The micro-hydro revolution

The River Ribble at Settle in the Yorkshire Dales. The energy of this water is soon to be tapped.

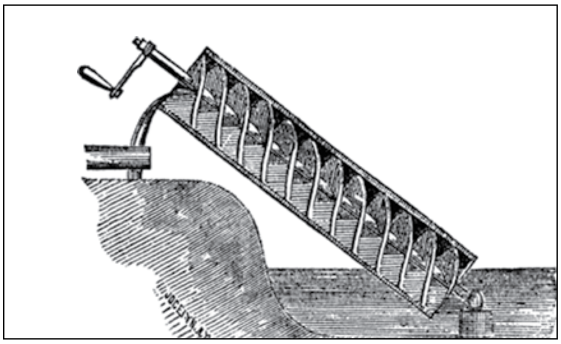
Think hydroelectric, think big. Right? As oil prices soar and global warming threatens, the need for affordable green solutions to the energy crisis is ever increasing. Giant hydroelectric power stations, such as the Three Gorges Dam in China, will help to fulfil this necessity. However, with the benefits of large scale hydro power not so clear cut people are turning back to basics; we are witnessing a new revolution in micro-hydro.

In this article, Thomas Lewton describes one small scale project.

Key words
hydroelectricity
potential energy
electrical power
generator

How does it work?

Micro-hydro is no new phenomenon. Since our agricultural beginnings man has both manipulated and harnessed the energy of our natural water resources. In fact, it is an age old invention, the Archimedean screw, which is currently being put to use around the UK as means of hydroelectric generation.

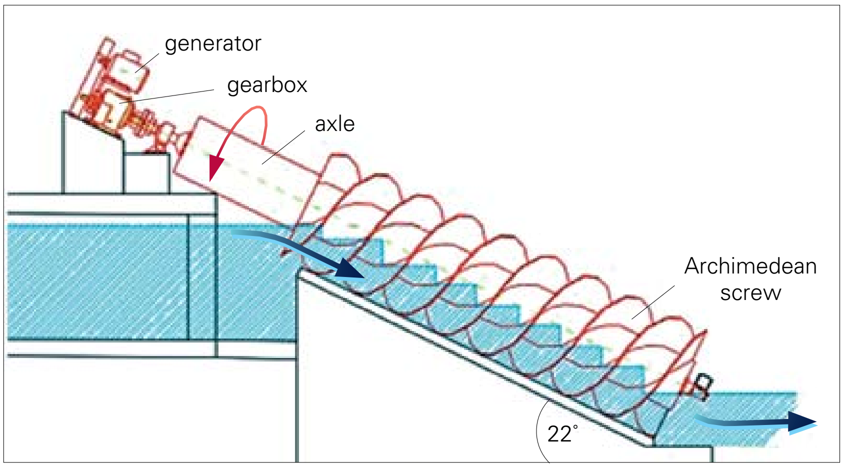


How the Archimedean screw was first used – raising water to a higher level.

The Archimedean screw was invented over 2000 years ago as a means of transferring water uphill from a low-lying body of water and into fields for irrigation. By using the screw in reverse so that water is allowed to flow down it, the weight of the water will turn the screw.

There is an energy difference between two different levels of flowing water, for example at a weir or waterfall. The Archimedean screw harnesses this potential energy and converts it into the mechanical energy of the turning screw which is then further converted into electrical energy using an electric generator.

Micro-hydro is defined to have a generating capacity of less than 0.1 MW. This is roughly enough to power 100 homes and is tiny compared to the Three Gorges Dam's whopping 22 500 MW generating capacity. (1 MW = 1 000 000 W)



The Archimedean screw working in reverse, to generate electricity.

Electrical energy is measured in kilowatt-hours (kWh) where 1 kWh = 3 600 000 J and is the energy supplied by 1 kW working for 1 hour.

Micro-hydro in action

The rural town of Settle in the Yorkshire Dales National Park is the latest community to utilize this innovative technology. An Archimedean screw will be installed at the Bridge End Weir on the River Ribble, close to an original mill waterwheel.

Water will be diverted above the weir down an adjacent steel trough holding the screw at an angle of 22°. As the water descends it will turn the screw on average 28 times a minute.

The mill race, the site chosen for Settle's micro-hydro scheme.

The potential energy available at the site depends on two crucial factors: the vertical fall of the water, known as the head height, and the volume of water passing per second, known as the flow rate. The power available from the system is proportional to the product of head height and flow rate.

- The Ribble has a flow of 2650 litres per second.
- 1 litre of water has a mass of 1kg.
- The Bridge End Weir has a head height of 2.3 m.

Potential energy

= mass x gravitational acceleration × head height

= mgh = 2860 kg × 9.8 m/s^2 × 2.3 m = 64.5 kJ

Each second there is the potential to harness 64.5 kJ of energy from the weir. Power is the energy converted per second, so the potential power rating of the Archimedean screw is 64.5 kW. However, energy is wasted, for example as heat, when converting the potential energy to electrical energy.

The Archimedean screw has a conversion efficiency of 77% and so the maximum power rating of the screw to be installed in Settle is actually:

64.5 kW × 0.77 = 49.7 kW.

The flow of a river varies throughout the year so that the average power rating is less than the 49.7 kW. Even so the screw will still generate 184 000 kWh (units) of electricity every year which is enough for 50 average houses.

A micro-hydro system fully installed. This one is at Ashburton in Devon. The generator is in the wooden hut at the top.

How does it all add up?

The cost of the project at Settle is £300 000. Though minute in comparison to the £15 billion Three Gorges Dam, it is still a significant investment for a small community. The benefit of a hydroelectric project, however, is that it can repay its implementation costs comparatively quickly, making it economically viable. Often loans can be taken out for schemes such as the one at Settle and paid back within a few years of operation.

The Settle hydro project is also implementing a community share initiative. Local investors make a social investment by buying shares in the project, providing the funds so that the project can be realised. Eventual profits from the project will be put into regenerating the local economy and promoting the environmental sustainability of the area.

What's wrong with large scale hydro?

Most large scale hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. However, damming can cause major problems for the surrounding ecosystem. The river is obstructed for aqautic life and the downstream river environment is affected by warmer water with a reduced oxygen content. The harms are not only ecological: population relocation as a direct result of dam construction has affected millions of people worldwide.

Obviously it's not all bad! Hydroelectric power eliminates the need for and hence the cost of fuel providing a more economical alternative to fuel powered plants. Large scale hydroelectric plants are undoubtedly needed as an affordable means of meeting power demands in today's world of

This hydro dam at Pitlochry in the Scottish highlands gives an idea of the scale of traditional hydro schemes.

rising prices and instability in fossil fuel resources. Furthermore, as hydroelectric dams do not burn fossil fuels they do not directly produce carbon dioxide (a greenhouse gas). However, the green credentials of some large scale hydroelectric power stations are beginning to be questioned.

A large reservoir is formed behind the dam wall of a hydroelectric power station. The flooded plant material decays in an anaerobic environment producing methane, a potent greenhouse gas. Though this is an insignificant problem in colder climates, in some tropical environments gas emission from the reservoir is actually higher than the emissions of a fossil fuelled power plant.

The benefits of micro-hydro

Micro-hydro avoids many of the disadvantages of large-scale hydro. The Archimedean screw system requires little alteration to the surrounding environment. A slow moving screw and large passages avoid silting up and allow the free and safe movement of fish through the system. There is no possibility of decaying plants releasing methane into the atmosphere as with large hydro projects. In fact this carbon-free technology will save 80 tonnes of carbon a year from the Settle project alone. What's more, as micro-hydro can be connected directly to the local electricity supply, there is no need for electricity to be sent miles along power cables, a huge source of power loss.

If a river has sufficient flow of water, two Archimedean screws can be installed side-by-side.

A fish swims safely past the rotating Archimedean screw.

Though more environmentally friendly than large-scale hydro, micro-hydro produces a great deal less power. All that is required for a micro-hydro system to be installed is a dependable flow of water with a reasonable height of fall and so it is hoped that by introducing a large number of small projects micro-hydro can make a significant contribution to our energy needs.

China is leading the way in investment in small-hydro projects with over 50% of the world's small-hydro resources. Closer to home, the Scottish government has emphasised the need for small-hydro in meeting its green energy targets and a recent report has shown 650 MW could be produced from hundreds of small projects around Scotland.

In the developing world small-hydro can provide cheap and reliable electricity for lighting, water pumping and small industries. The comparatively easy construction and the simple, small nature of the equipment make DIY micro-hydro projects a possible solution in remote rural and mountainous areas where electrical resources are invaluable to agriculture, powering irrigation and crop processing.

As fossil fuels become scarcer and more expensive, investment in alternative energy sources is a necessity. Though micro-hydro may seem insignificant compared to its vastly larger counterparts, by introducing a large number of these grassroots projects micro-hydro may be one of the most environmentally friendly and economical solutions to the energy crisis. With pioneering projects, such as the Settle Archimedean screw, leading the way, local communities can make a real impact on the pressing issues of today.

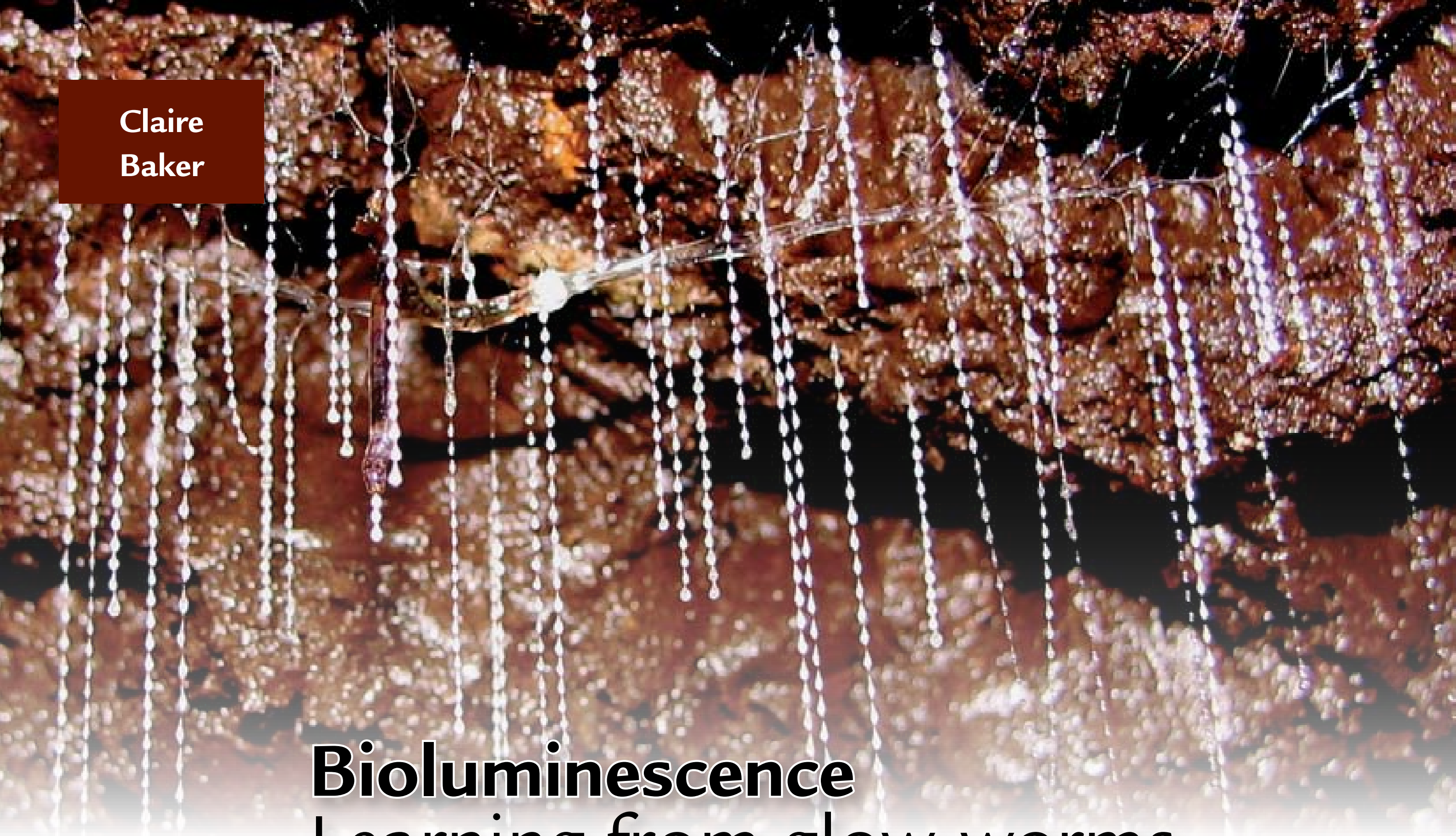
Look here!

Find out some more ways in which Settle is going green: *www.greensettle.org.uk*

Settle's micro-hydro system is built by Mann Power: *www.mannpower-hydro.co.uk;*
look for their movies of micro-hydro systems in action.

The British Hydropower Association has a guide to the science and technology of mini-hydro: *www.british-hydro.org*

Thomas Lewton lives in Settle. He is studying physics at Oxford University. *With thanks to Mann Power for information and photographs.*



Claire Baker

Bioluminescence
Learning from glow-worms

Key words
bioluminescence
rainforest
entomology
biotechnology

All over the world, on land and in the sea, living things have been making light for millions of years. From the glow of the sea on a dark night due to myriads of phytoplankton, to the dance of the male fireflies trying to attract a mate, this phenomenon, bioluminescence, has fascinated people for thousands of years.

In Australia I study insects known as glow-worms which live in our caves and out in the forest, giving a display which entrances tourists and scientists alike. But I am the really lucky one because I get paid to observe and study these fascinating insects in the Australian outback.

What is bioluminescence?

Bioluminescence, or 'living light', is a remarkable phenomenon in the plant and animal kingdoms where light is produced by a chemical reaction inside a living organism. One of the amazing things about bioluminescence is the end product of the reaction is almost 100% light. When this is compared to human light production it is easy to see we have much to learn! When humans create light, we waste enormous amounts of the energy just producing heat. For instance, most incandescent light bulbs give out over 97% heat and only produce 3% light. Fluorescent light bulbs are up to 15% efficient, but this is still not in the same ballpark as bioluminescence.

How does an insect create bioluminescence? The reaction occurs when luciferin (a substrate) is oxidized by luficerase (an enzyme), to make oxy-luciferin, which in turn gives off light photons and carbon dioxide. ATP (adenosine tri-phosphate) powers the reaction.

The stunning bioluminescent display of a colony of glow-worms.

What are glow-worms?

The common name 'glow-worm' is used to describe many different species that use bioluminescence. The glow-worms that I study in Australia and New Zealand are the larvae of a delicate fly. These fascinating insects undergo a holometabolic life cycle, i.e. a transformation from an egg, to a larva, to a pupa, to an adult (see Figure 1) as do many other insect groups such as butterflies and moths (Lepidoptera), beetles (Coleoptera) and all other flies (Diptera) (Box 1).

Figure 1 *The life cycle of a glow-worm: from left to right adult female, adult male, eggs, larva, pupa. (Images Anthony O'Toole, University of Queensland)*

It is only in the larval stage that glow-worms can actively create light, as the chemicals required are produced in their digestive system. However, occasionally adult glow-worms have been observed to give off a very weak light if disturbed in the adult or pupal stage. This light is probably due to residual chemicals being present, as they lose their digestive system when they pupate to become adult flies and are thus unable to physically produce light. The larval stage lasts for between four months to one year, although this is dependent on environmental conditions and prey abundance. The adults are very short lived (females two days, males six days), as they are unable to feed due to the loss of their digestive system. It is during the short adult stage that glow-worms are able to find a mate and reproduce, thus ensuring the success of another generation.

An adult female Arachnocampa flava. *The adult stage is the reproductive stage of this insect's lifecycle. They must mate and lay eggs to ensure the survival of the species.*

Why do animals use bioluminescence?

There are many uses in the plant and animal world for bioluminescence. For instance some species use their lights for mate attraction. For example, adult fireflies (Coleoptera; Lampyridae) use their pulsing light to signal and attract a potential mate. Other organisms use light to communicate, scare off predators, illuminate their habitat and attract potential food. *Arachnocampa* glow-worms glow to attract small insects emerging from the leaf litter and water in and around which they are usually found. The glow-worms construct "snares" made from silk threads and sticky mucous droplets to capture insects so they can be devoured. Their scientific name, *Arachnocampa*, refers to their "spider-like" ability to make a web snare.

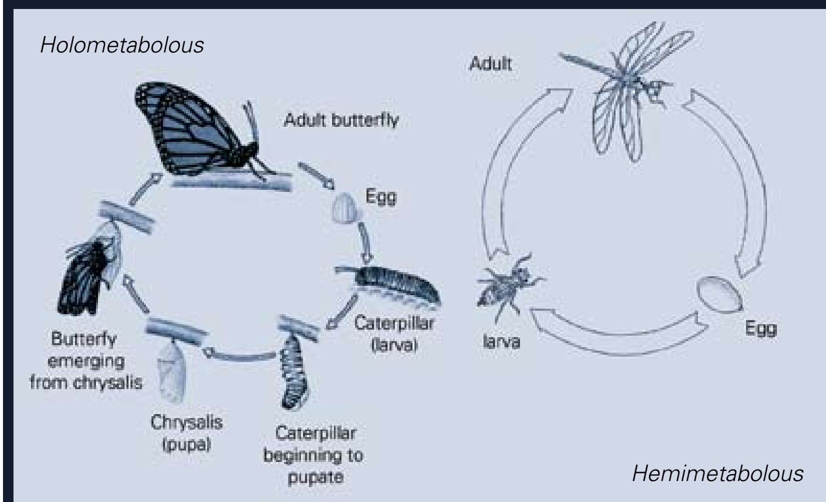
The individual light of one glow-worm is remarkable but easily missed unless specifically looking for it. When glow-worms congregate in large numbers in suitable forest habitat they make breathtaking displays of light that attract human tourists from around the world. These incredible displays serve as powerful lures for drawing insects towards their silken snares. Thus, by working as a team, they attract more insects to their snares.

The silken snare of one glow-worm larva, used for prey capture. Each snare is made from a thread of protein (silk) with sticky droplets of water affixed. The terminal segment of the glow-worm is where the glow is produced.

Box 1

From egg to adult

There are two major ways in which insects develop from egg to adult: Holometabolous and Hemimetabolous.



What other organisms can bioluminesce?

Many organisms glow in our natural world. Bioluminescence evolved separately in different groups including single celled organisms, earth and sea worms (the *real* 'glow-worms'?), insects, centipedes, millipedes, sea sponges, jellyfish, vertebrates like deep-sea fish and even some sharks. Fireflies are major tourist attractors in Asia and North America, where large congregations on trees appear like giant sets of flashing fairy lights in the wild. There a number of beetle familes that have evolved the ability to glow. Railroad worms (Phengodidae) and click beetles (Elateridae) are examples of these. Outside the animal kingdom, a number of fungi and lichen species are known to glow. In a few rare instances, the glowing organisms rely on bacteria to create the glow. However, most organisms create their own glow through a similar enzyme-based reaction to glow-worms.

One tiny firefly larva in the leaf litter. Fireflies uses bioluminescence in the larval stage to attract food and a pulsing light in the adult stage to attract a mate.

Glow-worms and biotechnology

Glow-worm DNA is now synthesized and used in the biotechnology field to 'mark' or 'tag' diseases, infections or other cells being studied Anyone in working in a genetics lab will use these tags as part of everyday work. The very first tag to be used was green fluorescent protein (GFP) from bioluminescent jellyfish.

A tag is a small piece of DNA that can be inserted into any living cell via a bacterial vector. The glowing cells are then monitored using a specialized camera that can read levels of light though up to 6 cm of body tissue. The tag can be spliced with, for instance, embryonic cells to make an entire animal that glows (every cell contains the DNA), or with bacterial or fungal cells to map infections.

Cancer cells are tagged for monitoring during the drug testing phase of drug design. The tagging does not kill the cancer, but it allows scientists to be able to see the direct response of the disease or infection to various drug treatments. The technology is not yet being used on human patients, but by using it in the drug design process, fewer animals are needed for testing (the same individual can be used multiple times as they do not have to be killed and dissected to observe growth or decline of the cancer cells) and it rapidly speeds up the entire process.

Learning more from bioluminescence

Could insects hold the answers to more efficient lighting systems for humans? The glow of a glow-worm is now inspiring scientists to make more efficient lighting systems. Organic light emitting diodes (OLED's) are being used as a more efficient way of lighting up television screens, PDA's, mobile telephones and computer screens. An OLED consists of an organic membrane that is powered by electricity. This type of technology is known as electroluminescence as it still requires an external power source. Phosphorescent technology works through the absorption of light photons that are then slowly released over time. Phosphorescence is used in items like glow in the dark plastics and safety work clothing.

Other products and ideas that have been inspired by or directly use bioluminescence technology include bioluminescent trees along highways to decrease electricity usage, christmas trees that use bioluminescence instead of electricity, agricultural plants that glow when they need water, using bioluminescent markers to assess contamination in food products and novelty pets such as glowing fish.

Glow-worm survival in the future

Glow-worms need very specific rainforest habitat or caves for survival. As our own species continues to expand, some of the more severe threats to glow-worm survival include: habitat loss and fragmentation, increased sedimentation in waterways, climate change, predators, parasites, fungal or bacterial infections, stream degradation and direct human impacts such as insecticides and other chemicals, insect repellants, vandalism, smoking? and soil compaction (shortcutting off walking tracks).

Special projects, like the glow-worm caves on Tamborine Mountain (see links below) and education are the two main ways in which these fascinating animals might be preserved for the future.

Dr Claire Baker is an entomology consultant based in Hervey Bay, Queensland, Australia

Look here!

Bioluminescence web page:
www.lifesci.ucsb.edu/~biolum/

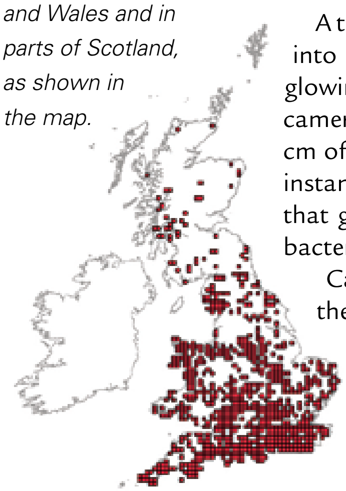
Caliper life sciences – imaging inside living animals using bioluminescent tags:
www.caliperls.com/products/optical-imaging/

Where to see Australian glow-worms:
www.cedarcreekestate.com.au/tmgw/index.html

Studying glow-worms in the UK:
www.uksafari.com/glowworms.htm

Where to see bioluminescence in the UK

Unfortunately Arachnocampa *spp. are not found in the UK, but there is a bioluminescent insect called a glow-worm. This one is a beetle,* Lampyris noctiluca, *which is quite common. It can be found all over England and Wales and in parts of Scotland, as shown in the map.*



What's in a name?

Gary Skinner

Students are often daunted by long 'Latin names' in Biology. After all, why call it Drepanosiphum platanoides *when you could call it a sycamore aphid, or* Troglodytes troglodytes *(the wren)? Are these long names just biologists showing off, or do they have a purpose?*

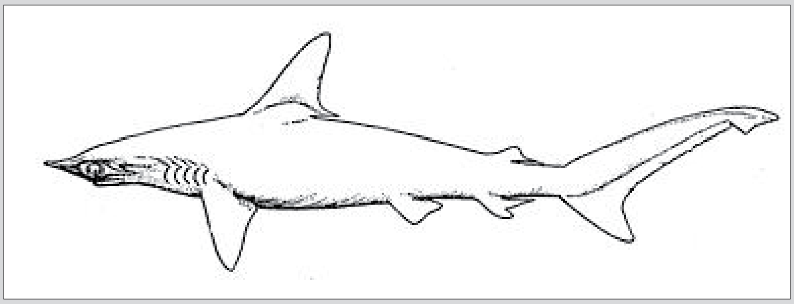
Back in the early '70s, when I was doing a dissertation on the narrow-bordered five-spot burnet moth (*Zygaena lonicerae*), I had to search the literature to find out what was already known about this species. In those days, there were no PCs so it was all done by leafing through some very big books in the library called 'Abstracts'. These were indexes of scientific papers, giving title, author and a brief summary or *abstract* of each paper. This was laborious work and when I found a paper that looked promising, it was a question of tracking it down in the actual journal where it had been published. If the library did not have that journal, I would have to get it traced, photocopied, and sent from another library. This led to some embarrassment on one occasion. Having found a title which looked promising, I ordered it through the inter-library loans department. After a week or so it arrived, but I was only to find it was all about a different *Zygaena*, the smooth hammerhead shark, *Zygaena malleus*!

*Two very different species with similar Latin names: (left) the narrow-bordered five-spot burnet moth '*Zygaena lonicerae*' and (right) the smooth hammerhead shark,* Sphyrna zygaena*, formerly* Zygaena malleus.

So, how had this happened? At some point in the past, the hammerhead shark had been named *Zygaena* but then it was discovered that this name had already been used for the burnet moths. By the rules of naming things, called the International Code of Botanical Nomenclature (for plants) and the International Code of Zoological Nomenclature (for animals), the older use of the name had to stand. So, the moths got *Zygaena* and the shark had to be given a new name. It is now called *Sphyrna zygaena*, but notice the old name lingering on in the so-called specific name, although this animal has had many names, called synonyms, in its past (Box 1).

The benefits of this system are that it is economical (just two words do it, some older systems stretched to sentences long!), it leads to some stability of names and it is usable all over the world, whatever the language (Box 2). Also, it is unambiguous, unlike common names (Box 3).

Box 1 Synonyms

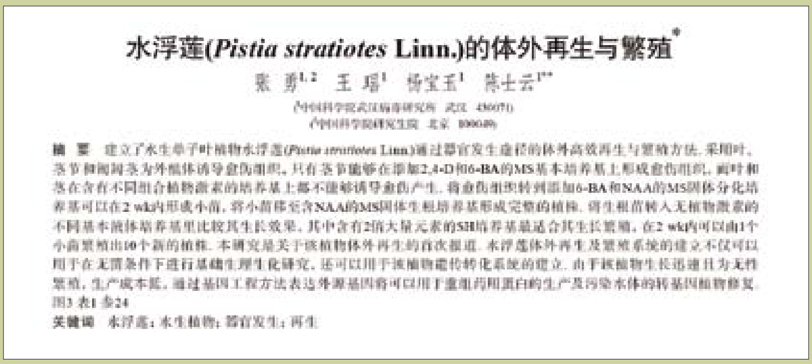


The smooth hammerhead shark (now *Sphyrna zygaena*) has had several different Latin names in the past. These are called synonyms, and each is accompanied by the name of the biologist who gave the name, plus the date. The rules of naming are slowly making sure that no two living species end up with the same Latin name.

Squalis pictus Blainville, 1816
Squalus carolinensis Blainville, 1816
Squalus malleus Valenciennes, 1822
Squalus zygaena Linnaeus, 1758
Zygaena malleus Valenciennes, 1822
Zygaena subarcuata Storer, 1848
Zygaena vulgaris Cloquet, 1830

Box 2 Understanding Chinese

This paper in a Chinese scientific journal is about *Pistia stratiotes*, the water cabbage or water lettuce. If a scientist was doing research on this major weed of water bodies around the world, they would know from the Latin name that this paper might be worth translating.



水浮莲(*Pistia stratiotes* Linn.)的体外再生与繁殖*

Box 3
Common names can be confusing

People have takean an interest in living things for millennia, whether it be because they were potential food, potential predators or poisonous plants or just very attractive or striking. So, many of these things were given a common name. Any red-breasted bird tends to be called, at least by people of British origin, a robin. So the American robin is called for its red-breast although not the same species as the one we find in Britain. The Australian robin red-breast is actually the scarlet robin, which is a warbler with a red-breast.

The Australian robin, Petroica multicolor

The American robin, Turdus migratorius

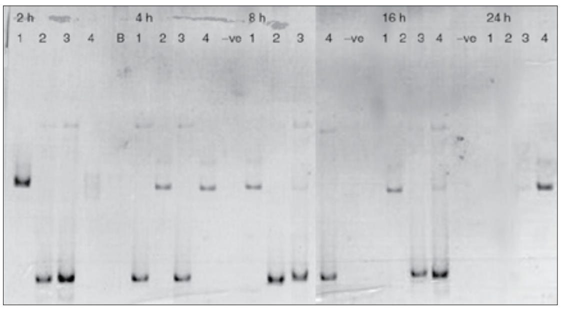
The European Robin, Erithacus rubecula

Why do binomial names change?

Apart from the changes due to the rules mentioned above, why else might the names of living things change? There are many reasons but one that is becoming more common today is that DNA fingerprinting of living things (yes, it works with them too!) is revealing that many species that we thought we knew are turning out to be more complicated than we thought.

Take the example of the humble, and very common, earthworm *Allolobophora chlorotica*. In a recent study, scientists at Cardiff University were trying to find out what food ground beetles survive on when they cannot get their most popular dietary items of slugs and aphids. They thought earthworms might be part of the answer. To check their ideas, they fed beetles with earthworms which they believed to be *A. chlorotica*. They then analysed the DNA fingerprints of the remains of food found inside the gut of the beetles, and got some very surprising results. They found that, instead of the one earthworm species, *A. chlorotica*, there were two different kinds, which were further apart genetically than a human and an orang utan! At this stage the researchers said:

> Interestingly, DNA from the earthworm *A. chlorotica* was detected as one of two alternate and very different bands on the gel. Variation is possible, but there is evidence that *A. chlorotica* comprises two cryptic species and the observed separation into two distinct genotypes would tend to support this.



Banding patterns shown by earthworm DNA from the gut of a beetle. This shows two sorts of banding pattern where only one would be expected.

So, there *had* been a suspicion that this so-called species was in fact two. A scientist called John Satchell wrote a paper in 1967 in which he had hinted at this possibility, based on the appearance of the worms, some of which are pinkish, others greenish.

Two earthworms - but are they one species or two?

However, the Cardiff group went further than this and found that there are in fact *three* different British species of this worm, which was thought to be one, as well as yet another in the rest of Europe, four species in all!

So, with the names of living things it is a question of 'watch this space', but at least we know we have a worldwide system for giving a name, once we know what it should be!

Gary Skinner is biology editor of Catalyst.

Look here!

National Earthworm Survey, starting in Spring 2009:
www.nhm.ac.uk/nature-online/science-of-natural-history/science-at-the-museum/earthworm-survey/

One of many links about Linnaeus:
www.nhm.ac.uk/research-curation/research/projects/linnaeus-link/

Working in radiation protection

Routine measurement of radiation levels close to Heysham nuclear power station, Lancashire, UK.

Radiation protection is a specialised area of health and safety. It deals with the protection of workers, patients, the general public, organisations and the environment. It is concerned with the use of two types of radiation:

- **ionising radiation** (e.g. X-ray machines, radioactive materials)
- **non-ionising radiation** (e.g. lasers, ultraviolet light and electromagnetic fields).

Radiation Protection Practitioners, often known as health physicists, give advice, provide guidance and offer a wide variety of support services including:

- Measuring levels of radiation in the workplace or the environment.
- Investigating incidents or accidents.
- Managing the disposal of radioactive waste.
- Advising of the safety of facilities and work practices.
- Assessing radiation doses to people.
- Handling the security and safe transport of radioactive materials.
- Ensuring organisations and people comply with all the radiation laws.
- Specialist training.
- Liaising with, or acting as, Government radiation inspectors or regulators producing legislation.

Radiation check

The Big Picture on pages 10-11 of this issue of CATALYST shows three French scientists checking for environmental contamination by radioactive materials which may escape in small quantities from nuclear power stations, through escapes of gas from the reactors or leaks of contaminated cooling water. Fortunately, ionising radiation can be detected at very low levels. Each click of a Geiger counter indicates that a single radioactive atom has undergone decay, emitting either alpha or beta radiation, along with a gamma ray.

In the photograph ...

- The scientist on the left is using a meter to check the conductivity of the river water. The meter's sensor has two electrodes which pass an electric current through the water. Ionising radiation increases the number of charged particles in the water, so that its conductivity increases.
- The researcher on the right has collected samples of a dark-coloured moss and is about to check them with a Geiger counter. Some plants take up radioactive substances and accumulate them in their leaves.
- The third scientist is using a pipette to collect a precise volume of river water for analysis back in the lab.

This type of radiation detector can tell which radioactive elements are present by measuring the exact energy of the gamma rays they emit.

It isn't only nuclear radiation that needs monitoring. This detector measures the levels of electromagnetic fields near an electricity sub-station.

See the previous issue of CATALYST for Peter Cole's article comparing the radiation effects of mobile phones and sunbeds.

Researchers check for possible radioactive contamination along the banks of the Tinée river in SE France.


Catalyst
www.sep.org.uk/catalyst
Pascal Goetgheluck / Science Photo Library

The traditional radiation hazard warning sign (top) has 3 black 'blades' (representing radiation spreading out from a source) on a yellow background. You may also come across the alternative sign (lower) which has been designed to be more comprehensible to the general public.

Potential employers

Many health physicists work in the health service e.g. in the NHS for diagnosis and radiotherapy, or in related industries such as pharmaceuticals and radioisotope manufacture. Others work in the nuclear power industry for firms such as British Energy, or for the Nuclear Decommissioning Agency, the body responsible for the decommissioning of nuclear reactors when they reach the end of their useful lives.

There is also potential employment in the public sector, including regulatory bodies such as the Health and Safety Executive and the Nuclear Installations Inspectorate, and in universities and research establishments such as CERN.

A technician manipulates radioactive materials using remote handling tools; he is protected by lead glass.

Qualifications and training

You can commence a career in radiation protection with GCSE and A-level qualifications in scientific (or numerate) subjects, but in all cases you will require additional specialist training. Courses are run at a number Further Education colleges and universities.

At the full professional level you will normally require a degree in a science subject, most commonly physics, chemistry or biology. There is a structured training programme for graduate trainees entering the radiation protection profession, for example, in the medical field and the nuclear industry.

A film badge, worn by radiation workers, records their exposure to ionising radiation.

All of the major employers have a good career structure and most are keen to support your studies, if necessary up to degree level or beyond. Job responsibility can come at an early stage in your career, with consequent promotion opportunities. There is a fair degree of interchange between major employers. Some people choose to specialise in one field, such as dosimetry, instrumentation, environmental management or radiochemical analysis. In other cases promotion from radiation protection managerial posts to higher general managerial posts is also possible. Formal appointment as a Radiation Protection Adviser, as required by the Ionising Radiations Regulations, is a likely target for those involved in operational radiation protection.

Controlling a hospital X-ray machine from a safe distance.

Careers in radiation protection are extremely stimulating, and offer tremendous opportunities for varied and flexible work. The rewards, both financial and intellectual, can be significant. There is always a high demand for well-trained people with radiation protection skills. It is worth noting that as the current crop of nuclear reactors is being decommissioned and the UK gears up for a new phase of nuclear power a career in radiation protection is likely to offer you the security of a job for life.

The Society for Radiological Protection (SRP)

The SRP is the professional body for anyone concerned with radiation protection. Its membership exceeds 1400, comprising Fellows, Members, Graduates, Associates, Students and Affiliates. It is a Chartered Society and its objective is to promote the science and art of radiation protection and allied fields for the public benefit. It achieves this by means of meetings, conferences, lectures and publications.

The Society has an official publication, *The Journal of Radiological Protection,* which is published quarterly. The SRP members communicate with each other through a newsletter, networking and email discussion groups.

Peter Cole is the Radiation Protection Adviser in the Physics department, Liverpool University.

Joe Sullivan

Jules Prosser

What is chemistry?

Chemistry has close links to Biology, Physics, Geology and many other subjects. In this article, Jules Prosser explores what chemistry is about and what makes it distinctive from the other sciences and looks at some of the areas in which chemists work.

Key words
chemistry
blast furnace
polymer
recycling
drug

Chemistry is what chemists do. It's the study of the nature, properties and composition of matter, and as such links together biology, physics and maths. Chemistry is roughly split into fields of *organic*, which is the chemistry of carbon containing compounds, *inorganic*, looking at the other elements of the periodic table and their compounds and *physical* chemistry which investigates reactions for their precise atomic changes. These have their own specialist areas including *biochemistry* (study of molecules and their interactions in living systems), *synthetic organic* (making molecules – which my job relies on), *analytical* (determining exactly what is present in a sample and in what amounts), *computational, polymer,* and many, many more. Chemistry is constantly evolving and as new discoveries are made, new areas of work open up.

Working as a chemist involves using carefully measured quantities of chemicals.

What use is chemistry?

Plastics and metals clearly shape the world around us, and chemistry is at the heart of their development. Around 1000 BC iron and copper working started in Europe. Chemists developed the refining process, which today produces 1800 million tonnes of pig iron a year (see Box 1).

Box 1
Obtaining iron: the blast furnace

A workman at a blast furnace in the Czech Republic

Iron ore comprises haematite and magnetite, both iron oxides. These are fed into a blast furnace which is heated by a hot air stream. Carbon in the form of coke is added, which reacts with oxygen from the heated air to form carbon monoxide. The carbon monoxide in turn reacts with the iron oxides to give carbon dioxide and iron.

$$C + O_2 \rightarrow CO_2$$
$$C + CO_2 \rightarrow 2\ CO$$
$$3\ CO + Fe_2O_3 \rightarrow 3\ CO_2 + 2\ Fe$$

The iron formed this way contains about 4–5 % carbon with other impurities such as magnesium and phosphorus. It is relatively brittle and is used to cast items such as lamp posts. Modern construction needs steel, which is an iron / carbon alloy containing between 0.4–2 % carbon. Carbon prevents weakening movements in the iron crystal lattice, and so varying the carbon content allows chemists to produce a metal with the required properties, such as strength or ductility.

Plastics are polymers that come from the joining of many small reactive molecules. Natural polymers such as latex have been traditionally used by native tribes in South America, but the first example of a commercially exploited synthetic plastic was Bakelite, patented in 1909 and designed for mechanical parts and as an electrical insulating material. It was quickly found that additives (see Box 2) changed the properties of the plastic and allowed additional uses. Cheap, strong and easy to manufacture, it started a wave of experimentation that resulted in the large variety of plastics we use today.

Synthetic plastics have a wide range of everyday uses.

Chemistry starts at the sub-atomic scale. Medical imaging, from X-rays to the latest 3D scanning techniques, make use of radiation and so require a deep chemical understanding of both the radioactive materials and their effects on living organisms.

Atomic knowledge can also be used offensively; in 1945, 2 atomic bombs were dropped on Japan to end the Second World War. These bombs worked through nuclear fission, which is the splitting of atoms to release huge amounts of energy. Whilst nuclear research for weapons continues, nuclear power now makes up around 20% of the UK's energy production. Nuclear power generation relies on chemists being able to initiate and then control the rate of the reaction.

What of chemistry now and when I want a job?

Chemistry and medicine are very strongly linked. From the first healers who used natural remedies, chemistry has developed into a huge pharmaceuticals industry (see Box 3). This is where I work as a synthetic organic chemist, making molecules to be tested against a disease. My job has changed since I graduated, with more automation coming in, but there is still a high demand for chemists in this industry. We also need to continue to explore molecules from nature looking for new therapeutics (active ingredients in a drug or medicine) and to synthesise these to prove the structure and to provide enough material for testing.

This boy uses a 'puffer' to ensure that he receives the correct dose from his asthma inhaler.

Currently many drugs are tested on animals. This is controversial in itself, but also far from ideal for biological reasons – tests on animals may not provide a reliable model when applied to humans. Testing on isolated human cells does not provide information on the effects on other parts of the body. Computational chemists are currently attempting to make a 'virtual human' which can model drug effects on all parts of a body, and even allow for existing complaints (for example a heart condition).

Box 2 Additives in plastics

Different types of plastics are formed from different materials. The same plastic can be made to have different properties by controlling the reaction conditions (temperature, pressure, time) used to make them and by use of additives, including plasticisers, flame retardants, pigments, and conductive additives. Antibacterials such as triclosan can be added to plastics that contact food.

Nanotechnology is another rapidly expanding area of chemistry. Working on a nanoscale (10^{-9} m or millionths of a millimetre) requires new diagnostic and imaging tools. Scanning Electron Microscopy uses a carbon nanotube attached to a very fine tip to pass electrical current over the surface of a material, giving its topography on a nanoscale. Many other techniques are being developed.

Our population is growing and the pressure on the Earth for raw materials and space is increasing. Environmental chemists need to ways to satisfy rising energy demands, develop alternative fuels, and protect existing populations from their waste. Recycling is twofold; there is the drive to recycle current waste, and here chemistry is needed to help solve the economic problems of recycling; and there is the reclamation of materials dumped in landfill at a time when recycling was economically unviable. Currently, most councils in the UK recycle four types of plastics; large amounts of potentially useful hydrocarbons are still buried in landfill or incinerated.

Useful resources are increasingly being extracted from landfill sites.

Box 3
How do you make a drug?

People in the Philippines take the drug albendazole as part of a public health campaign. This drug provides protection against the infectious disease filariasis which is carried by parasitic worms.

Often drugs start from existing treatments or naturally occurring molecules with the desired biological effect. Chemists then make a large number of similar molecules, looking for the correct pharmacokinetic properties – strength of the biological effect, take-up in the blood stream (bioavailability) and how long the effects last (half life). When a molecule is discovered that shows the desired properties a synthetic route to make many kilos of it is needed, usually differing from the original route used to make small amounts for initial testing. Assuming it gets this far, the molecule then goes into healthy volunteers for safety checks, into patients to prove it works, and finally (hopefully) is approved for sale as a medicine.

Chemistry is a subject with deep roots in all the sciences, constantly evolving to meet new needs in society, healthcare, materials sciences, fuels and food. For me, it's a day to day struggle to find a new drug, often frustrating but with potentially huge rewards.

__Jules Prosser__ graduated 6 years ago from Warwick University and now works for Pfizer as a research organic chemist making molecules to be tested for antiviral activity.

Look here!

This website has information about how nuclear power is generated:
www.eon-uk.com/EnergyExperience/343.htm

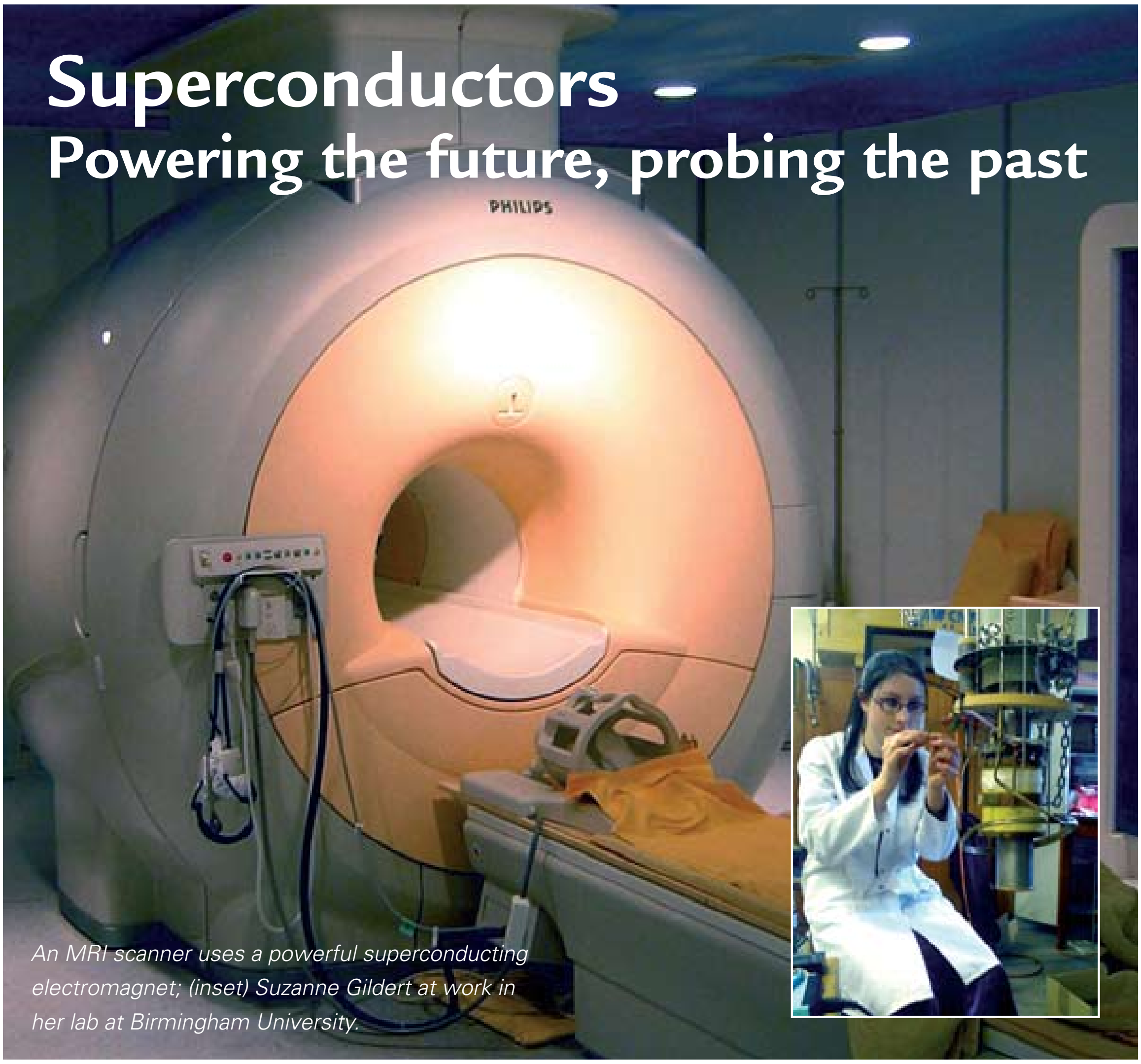
A previous issue of Catalyst had more information about making new medicines:
www.sep.org.uk/catalyst/articles catalyst_19_1_363.pdf

The Royal Society of Chemistry website has further details about careers in chemistry, help with revision and games:
http://rsc.org/Education/SchoolStudents/index.asp

Tim Jackson

Suzanne Gildert

Superconductors – Powering the future, probing the past



An MRI scanner uses a powerful superconducting electromagnet; (inset) Suzanne Gildert at work in her lab at Birmingham University.

Key words

resistance

electrical conductor

current

electromagnet

What do the 1700 magnets at the Large Hadron Collider and power cables in Detroit have in common? The answer is both use amazing materials called superconductors - materials which, when cooled below a certain temperature, lose all their electrical resistance, and display some other remarkable physical properties. Tim Jackson and Suzanne Gildert of Birmingham University explain.

Cool Physics

Each superconductor works at a different temperature. Commonly-used superconductors include metals such as tin, lead and niobium and alloys such as niobium-tin. These materials do not become superconducting until they are cooled close to the temperature of liquid helium (4 K, which is -269°C). Some ceramic compounds such as yttrium-barium-copper-oxide, commonly known as YBCO, become superconducting at higher temperatures, around 100 degrees above absolute zero. For this reason they are known as 'high temperature superconductors' and only require cooling by liquid nitrogen, which is much less expensive. Hot and cold are relative terms – see Box 1.

Box 1 Low temperatures

Nitrogen boils at -196°C. It can be produced from nitrogen in the air and also stored and used cheaply and easily. Helium gas is much more scarce. It boils at -269°C and is expensive to produce, store and use.

While -196°C sounds cold to us, in absolute terms it is hot. Hotter still are the temperatures we describe as 'cold'. The lowest winter temperature ever recorded in Britain is -27°C. The lowest recorded temperature on earth is -89°C, in Antarctica.

Superconductors rely on the unusual and somewhat 'spooky' properties of quantum physics, which describes how the world operates on the very small scale. In the microscopic 'quantum' world, an electron behaves both as a wave and as a particle, and can be in two places at the same time. In a metal these effects are never normally seen, as the electrons are jiggling around too much. However, electrons inside a superconductor are much better behaved and work together, allowing them to flow smoothly, and transport current without generating any heat – see Box 2.

Superconductors also react to magnetic fields in an interesting way. When a magnet is placed close to a superconductor, the magnet will levitate. In addition, by placing two pieces of superconductor close together, you can also make a transistor-like 'switch', which has many applications in electronic circuits. The rather unconventional electrical and magnetic properties of superconductors mean that they can be used in cutting edge technologies.

A small magnet levitates above a superconducting electromagnet. Liquid nitrogen is used to cool the superconductor.

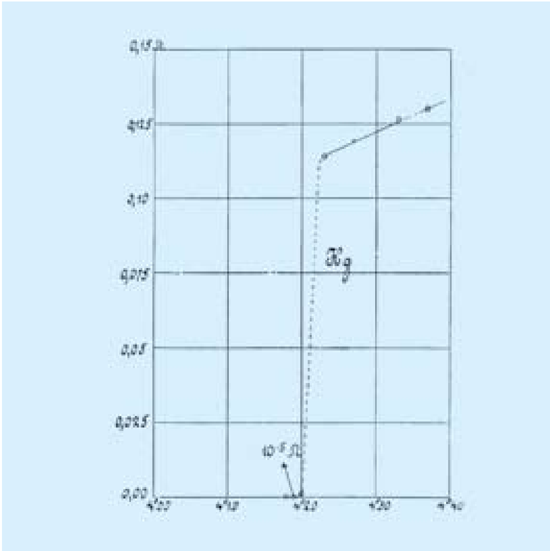
Box 2
How superconductors work

Electrical current is defined as the rate of flow of electric charge. In a metal it is negatively-charged electrons that flow to make a current. However the electrons cannot move totally freely through the metal. They collide with impurity atoms and with the vibrating atoms of the metal. This is what gives a metal its electrical resistance, and it has the effect of dissipating electrical energy as heat.

In a superconductor cooled to below its transition temperature, the electrons can move without any impediment and so an electrical current can be carried without generation of heat. The processes which enable this to happen are delicate and are sufficiently strong in only a few materials. Too large a current though, or too large a magnetic field around the superconductor, and superconductivity breaks down resulting in the material becoming resistive again. The weakness of the interaction led many to believe superconductivity would never be possible at temperatures as 'high' as the boiling point of liquid nitrogen. This is the reason why 76 years elapsed between the discovery of superconductivity in mercury and its discovery in YBCO. In fact, elucidation of the mechanism which allows superconductivity at such temperatures is one of the greatest challenges in modern physics.

Discovery

The first observation of superconductivity was made in 1911, in measurements of the resistance of mercury. At first the scientists thought that something had gone wrong with the experiment when they observed the resistance of the metal suddenly and unexpectedly drop to zero!

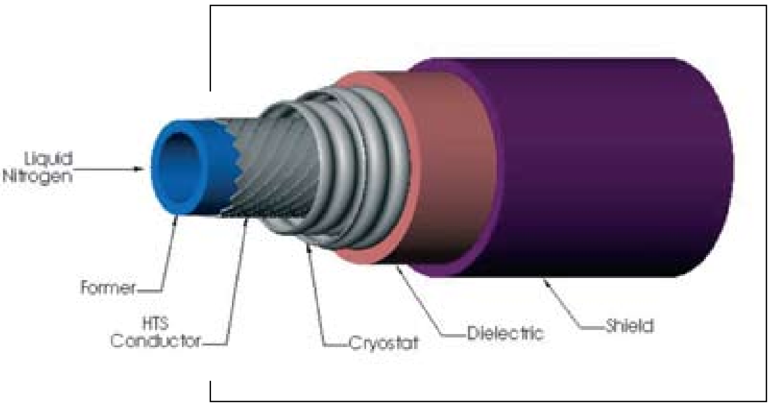


The graph obtained by Kamerlingh Onnes, the discoverer of superconductivity, when he and his student Gilles Holst investigated the resistance of mercury cooled below 4 K using liquid helium.

After they had checked the result, the phenomenon was found to occur in many different materials. Niobium-tin and niobium-titanium alloys were found to be superconducting in the 1960s. Being metals, they can be relatively easily drawn into wires. However the need for cooling with liquid helium and the cost of the metals made it too expensive for large scale commercial applications. The ceramic superconductors were discovered in the late 1980s. Ceramics are much less ductile than metals – making reliable and practical wires has been challenging engineers and scientist for the last twenty years. However, meeting the challenge is worth the effort : Cheaper and easier cooling with liquid nitrogen or liquid hydrogen makes large-scale applications of superconductors much more feasible.

The ultimate energy saver

At first sight the most obvious applications of superconductors would seem to be in power transmission. Electric power is transmitted over long distances at high AC voltages (in the UK, at 440 kV or 275 kV) and low current to reduce the losses associated with cable resistance. The voltage is stepped down by transformers to 110 kV for local distribution and further to 230 V for the domestic supply. About 8 % of the power is lost along the way. Superconductors don't just save energy – they lose literally NO power at all along the way. High temperature superconducting cables can efficiently carry three times the current of conventional cables. In fact, if the familiar electrical cables which span the country were replaced with superconducting ones, the benefit to the environment over the years would be substantial.



The construction of a superconducting cable. HTS is the high-temperature superconducting material; the cryostat contains liquid nitrogen to cool the superconductor below its transition temperature.

So why don't we replace the old power cables? Replacing the whole system with superconducting cables straight away would simply not be economical. However, as we look to the future it is clear that the electricity distribution system that has served us well for thirty years will need to adapt to increasing demand and changing sources of power. In densely populated cities there is little space for adding new cabling.

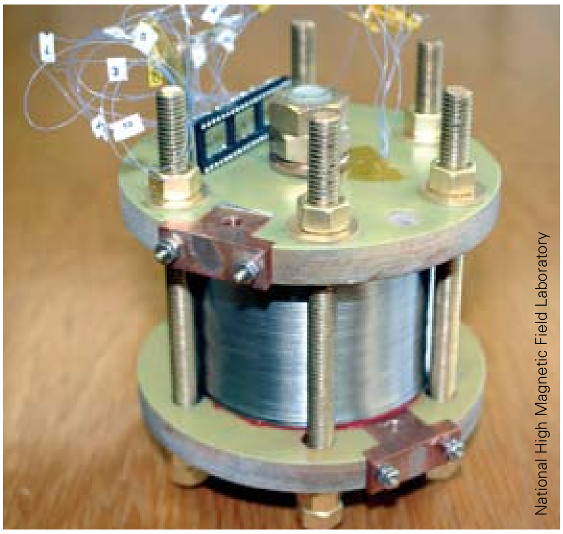
Trials of cables cooled with liquid nitrogen in the USA, China, Japan and Denmark are developing the technology and showing promising results. There are still challenges to overcome but the technology is improving all the time. Soon, superconducting cables may be coming to a home near you.

Superconducting cables may be even better adapted to heavy industrial factories, which consume vast amounts of power. By operating the cables at lower voltages, they may be safer too. Prof Bartek Glowacki, at the University of Cambridge, has described this engineering with superconductors as 'where quantum physics blends with heavy industry'.

Superconductors are everywhere!

Because superconductors can carry large currents, they are ideal for making magnets. By making the superconducting material into a wire, coils can be formed. The resulting electromagnets can generate fields of up to 40 tesla, 1000 times stronger than a fridge magnet!

The Large Hadron Collider at CERN, designed to test theories of particle physics and the nature of the Universe, uses over 1700 electromagnets made of niobium-tin superconducting wire to steer the beams of protons which will be smashed together. Neither the strongest magnets (such as neodymium iron boron) nor electromagnets made from copper wire are capable of providing the magnetic fields required. 96 tonnes of liquid helium are needed to keep the magnets cooled to just 1.9 degrees above absolute zero.



The world's most powerful electromagnet – its wires are made of the superconducting ceramic known as YBCO. It produces a field one million times the strength of the Earth's field.

One of the 1700 superconducting electromagnets of the Large Hadron Collider at CERN being lowered into position.

The cost and difficulties of engineering with liquid helium, and the cost of the niobium-tin wire, is one reason why superconducting power cables were never feasible until after the discovery of ceramic superconductors in 1986. Low temperature superconductors are however widely and successfully used in magnets in magnetic resonance imaging (MRI) systems. They are also used in the world's fastest train, in Japan. This train uses a combination of superconducting and conventional electromagnets to levitate 10 cm above its track. With this electromagnetic suspension system eradicating rolling resistance it can travel at speeds up to 500 km/h. Levitating trains might one day compete with short haul air travel, offering similar journey times e.g. one hour between Edinburgh and London without the air pollution associated with take-off and landing. The smooth ride would also be good news for nervous flyers.

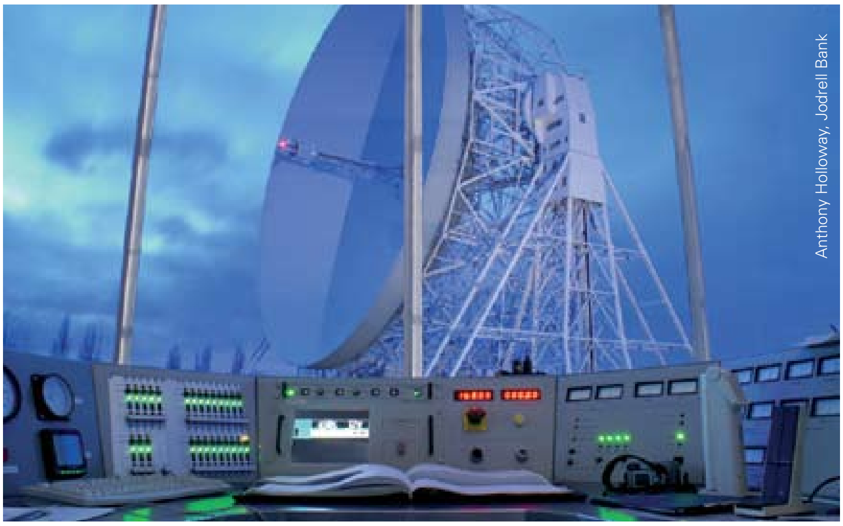
Superconductors crop up in the most unusual places. Some engineers are considering all electric aeroplanes, powered by hydrogen and thus free of carbon emissions in take-off, flight and landing. Hydrogen would be burned to rotate turbines that would drive superconducting electricity generators. These turbines would be much lighter than conventional jet engines. Hydrogen is cleaner and cheaper than current jet fuels.


Yosemite

Trains of the experimental Japanese Yamanashi rail link use superconducting electromagnets to levitate them above the track.

Forward into the past

Another way in which superconductors may be used to probe the physics of the Universe is in radio astronomy. Under the direction of Prof Mike Lancaster, our research group at Birmingham University is leading the design of superconducting circuits fitted to the first stage of electronics behind the dishes of radio telescopes. These telescopes are used to study radiation from distant astronomical objects such as pulsars. Such studies have provided sensitive tests of Einstein's theory of General Relativity and may yield insights into the evolution of the Universe from the Big Bang to the present day. The radio signals which we use on Earth to communicate with each other mask the faint signals. The superconducting circuits act like the bouncer at the door of a nightclub: the signals on the astronomers' list are allowed through, the radio signals are excluded.


Anthony Holloway, Jodrell Bank

The radio telescope at Jodrell Bank observatory, seen from inside the control room. Superconducting circuits will help to separate out the radio signals coming from space from man-made electromagnetic pollution.

The future

In the future, superconductors may even find their way into your iPod, mobile phone and laptop. New types of transistors are being developed which use superconductors instead of conventional silicon chips. The quantum mechanical properties of superconducting materials will allow engineers to make smaller, faster, and much more energy efficient components - an entirely new generation of processors.

A more exotic application of superconductors – quantum computing – may be on the horizon too. A quantum computer would use the uncertainty of the quantum world to greatly speed up calculations. Because the electrons in a superconductor can be in two places at the same time, they can also be used to perform two calculations in parallel. Current interest in superconducting electronics is driven by the (conflicting!) desires for greater security and privacy in communications and for the ability to crack any code. For us, this research, which draws together physicists, materials scientists, electronic engineers and computer scientists, is one of the most exciting aspects of physics today.

Tim Jackson and Suzanne Gildert are in the School of Electrical, Electronic and Computer Engineering at the University of Birmingham.

Look here!

There's much more about superconductors and their uses at: *www.superconductors.org*

Dr Suzanne Gildert's blog is at: *physicsandcake.wordpress.com/*

An introduction to quantum computing: *www.cs.caltech.edu/~westside/quantum-intro.html*

Victoria Hodges

The Skynet 5 satellite blasts off into space on board an Ariane 5 rocket in November 2007.

Designs on space

The lifecycle of a satellite

There are thousands of man-made satellites orbiting the Earth. Some are only a few hundred kilometres above us and complete one orbit roughly every 90 minutes. Geostationary satellites are located around 40 000 kilometres from the surface of the Earth, completing an orbit of the Earth every 24 hours. Other spacecraft are exploring the solar system. With so many spacecraft out there, have you ever wondered how a satellite is made? Victoria Hodges, a satellite engineer, explains.

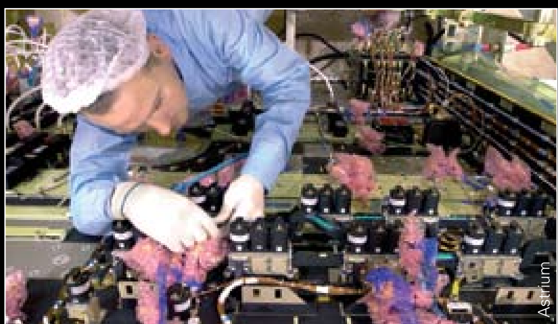
Key words
satellite
orbit
design
construction

From concept to design

Typically there are four main stages in the lifecycle of a satellite. At the end of each stage and before the next can commence the project will go through a series of technical reviews in order to ensure that the stage has been properly completed and that the project team are ready to move on.

The first stage is the Concept Exploration. During this phase the initial mission concept feasibility will be studied and a preliminary design will be produced. The preliminary design must take into account the requirements provided by the customer.

The second stage is the Detailed Design Phase. At this point, the customer may provide more detailed requirements as the design of the mission and the satellite becomes more advanced. By the end of this phase a "baseline" solution for the mission will have been produced. This provides the starting point for the next stage. However, before the next stage can start, the design must pass through another series of reviews.



An engineer assembles part of the payload on a satellite

Box 1: Satellite Systems

Power – for Earth-orbiting satellites the power is generated by large solar panels and then distributed around the satellite via the power distribution system. Power is also stored on board the satellite in rechargeable batteries, enabling the satellite to draw extra power when required and providing power when the satellite enters eclipse (when the satellite travels behind the Earth so that the Earth blocks the satellite's view of the Sun).

Thermal – the thermal control system controls the temperature of the satellite systems, so that they can continue to operate normally. The electronics used on board a satellite generally work around room temperature, but the temperature in space is much less than this. Looking out into deep space and in eclipse the temperature can be as low as -270°C; however, in view of the Sun the temperature can be up to 180°C. Insulation is provided by thermal blankets (made up of many layers of a polymer called Mylar interspersed with layers of netting) wrapped around parts inside the satellite and around the outside. Other methods of controlling the temperature of a satellite include paints and surface coatings, heat pipes (a bit like central heating) and radiators used to release excess heat out into space.

Attitude and Orbit Control – this system is responsible for controlling the attitude (orientation) of the satellite and maintaining its orbit. This is vitally important. For example, in order to communicate with the ground stations on Earth, the satellite antennas must be pointing at the Earth and in order to generate power, the solar arrays must be pointing toward the Sun. Star trackers provide information on where the satellite is pointing and actuators such as small thrusters and wheels then provide a torque in order to rotate the satellite when necessary.

Communications – the communications system allows two way communications between the satellite and the ground station on Earth. The satellite receives messages from the ground called telecommands and sends back information and data called telemetry. Communications are sent using Radio Frequency electromagnetic waves via the communications antennas mounted on the outside of the spacecraft.

On-Board Computer – the on-board computer is the brain of the satellite. It processes all of the information received from both the ground stations and the satellite itself. The computer sorts the information into different categories and then in the case of commands received from the ground, it communicates the commands to the appropriate systems. The computer also collects telemetry from the different systems and groups it into packets to be sent via the communications system to the ground station.

Manufacture

In the third stage, Manufacture and Test, the overall satellite design is finalised and the manufacture begins. The different parts of a satellite are often supplied by a number of suppliers. The role of the satellite manufacturer is to bring all of the pieces of the jigsaw together in the correct way in order to build the satellite. We call this work the Satellite Assembly and Integration.

Satellites must be assembled in clean environments called "clean rooms". Engineers working in the clean rooms wear overcoats, hats and gloves in order to prevent any dust or particles from getting inside the satellite as this can cause damage to the electronics and other satellite systems. So how clean are the clean rooms? Well, in a Class 100 clean room, there can be up to 100 particles >0.5μm in diameter (that is 1000 times smaller than 1mm!) for every cubic ft. The air outside contains roughly 3 million particles like this for every cubic ft, so it's very clean!

A satellite is comprised of systems. Each system has a different function and generally they fall into one of two categories: Satellite Bus Systems and Payload Systems.

The **Satellite Bus** is the part of the satellite that provides all of the essential functions required by the satellite in order to stay in orbit and support the Payload. The Bus systems comprise the Power Generation and Distribution, Thermal Control, Satellite Communications, the Attitude and Orbit Control, the On Board Computer and many others. Some of these systems are described in more detail in Box 1.

The **Payload** is the mission-specific part of the satellite. For example the payload on a scientific satellite might be a telescope and the associated detectors and processors to collect the scientific data. Payloads often have their own dedicated on board computers in addition to the one provided by the satellite bus. This is usually due to the high volume of data that needs to be collected and stored before being communicated to the ground.

Testing, testing

The satellite must undergo a rigorous set of tests to ensure that it can survive both the launch and the harsh space environment – see Box 2.

Satellite integration into launcher fairing

Once the satellite has passed each of the tests, it will be transported to the launch site to be integrated into the launcher fairing. Final tests will be carried out to check the health of all of the satellite systems and the satellite's own fuel tanks will be filled and tested for any leaks. The satellite and launcher will then be made ready for launch.

Into space

The final stage is Launch and Operations. 3,2,1, zero – we have lift off... finally the satellite will blast off from the launch site and be propelled into space. Once the satellite has been released from the launcher, it will manoeuvre itself into the desired orbit and, after a few months of initial in-orbit testing, it will begin its nominal mission. At the end of its mission the satellite must be disposed of. Satellites in a low-Earth orbit are de-orbited and burn up in the atmosphere, satellites in the Geostationary orbit are manoeuvred out into graveyard orbits further away from the Earth.

Astrium is dedicated to providing civil and defence space systems and services. In 2007, Astrium had 12 000 employees in France, Germany, the United Kingdom, Spain and the Netherlands, and achieved a turnover of €3.5 billion.

Victoria Hodges is an AOCS Systems Engineer at Astrium Ltd in Stevenage, UK.

Box 2 Testing

Thermal Vacuum Test

This test is to show that the satellite can cope with the temperature and pressure variations in space and that the systems will still operate normally. The satellite is sealed into a Thermal Vacuum Chamber. The conditions inside the chamber are then varied so that the satellite experiences the extremes of temperature and pressure that it may encounter in space. During this time the systems on board the satellite will be monitored. Thermal testing can take many weeks to complete.

Electromagnetic Compatibility (EMC) Test

Electromagnetic interference generated by the spacecraft systems can be propagated along the power lines and even radiated outwards by the units. EMC testing is carried out first to measure these interference levels and to ensure that the spacecraft systems can operate normally in the presence of these and slightly higher interference levels.

Vibration Test

The vibration test is designed to simulate the conditions that the satellite will encounter during launch. The satellite is mounted to a "Shaker Table" which then begins to shake at different frequencies, simulating the launch conditions.

1. The Inmarsat 4 satellite enters the thermal vacuum chamber

2. Testing a satellite's electrical systems (EMC test).

3. A satellite undergoes vibration testing

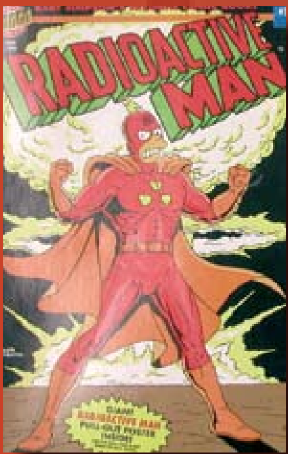
RADIATION AND HEALTH

Radioactive materials are hazardous because they give out ionising radiation. However, like many scientific discoveries, radioactivity provoked a mixed reaction. Some people sought to commercialise it – would you eat uranium flavoured ice cream? At the same time, films and comic books emphasised its harmful effects.

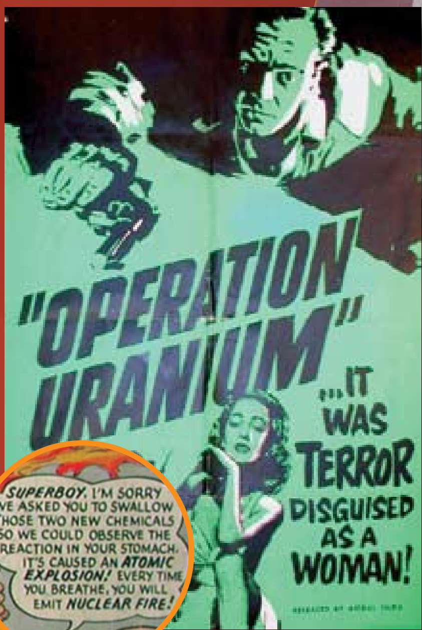
Take the medicine ...

Radium chocolate
Uranium ice cream
Radioactive face cream
Radium water – to be taken twice a day
Energy tablets

Just for fun ...



◀ **Radioactive Man –**
he glows in the dark



◀ Something wrong with the science here..

▲ Uranium – even more frightening than a woman


You'll be SURPRISED

SNOWFLAKE HAS STRUCK IT TOO ! !

YES—

'URANIUM'

The New Rich Ice Cream Discovery.

SNOWFLAKE

"A WEST COAST PRODUCTION"

URANIUM ICE CREAM

NOW ON SALE.

Talking sense

Two health physics posters giving advice to workers in the 1940s.