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Arctic coral reefs

Kerby, T

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Catalyst: Secondary Science Review

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Catalyst

Secondary Science Review

Volume 18

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Surfactants at work

Helping babies to breathe

SEP
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Catalyst

The front cover shows a premature baby in an incubator (see the article on pages 4-6). (AJ Photo / Science Photo Library)

Volume 18 Number 2 November 2007

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Seeing is believing

Welcome to second issue of Volume 18 of CATALYST. Ever since Galileo turned the recently-invented telescope towards the night sky, scientists have been devising new ways of making observations which can take us beyond the realm of simple naked eye observations. In this issue, three articles focus on fascinating findings which have come from specialised techniques of observation.

- Elizabeth Hirst uses a scanning electron microscope to produce dramatic images of tiny pollen grains, the cause of hay fever.
- Tina Kerby and Jason Hall-Spencer have used a submersible to reveal the unsuspected world of cold-water coral reefs.
- Lucie Green describes how, over the last fifty years, space telescopes have revolutionised our understanding of the Sun and its effects on the Earth.

As scientific instrumentation develops, there is no shortage of new and surprising discoveries to be made.



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The Catalyst archive

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Benjamin Drew



Would you be a CLEVER driver?

As more and more people want to get about within cities and towns, the problems of congestion and pollution are increasing. Motorcycles and bicycles take up less space and produce fewer emissions than conventional cars, but they are unsafe in an accident and don't offer much in the way of comfort or protection from bad weather. Benjamin Drew of Bath University describes an alternative solution – the CLEVER vehicle.

A CLEVER idea

The objective of the CLEVER Project was to design and develop a vehicle that could fill the gap in the market between cars and motorcycles, providing a safe and comfortable vehicle that produces less harmful emissions and takes up less room on the road than a conventional car.

CLEVER is a three-wheeled two-seater car; the passenger sits behind the driver.

CLEVER is the result of a three year long research

project funded by the European Commission. The project comprised four academic institutions and five industrial partners from the UK, France, Germany and Austria who worked together to develop the vehicle. Each institution focused on a specific aspect of the work, with the goal of producing two fully functional prototypes and three crash test vehicles.

The design of CLEVER is an enclosed narrow vehicle that is three metres long and one metre wide. This gives efficient use of road and parking space, reduced fuel consumption and a reduction in harmful emissions. Table 1 compares the CLEVER car with the Mercedes Smart car which can be seen on the roads today.

| | CLEVER | Smart Diesel |
|---------------------------|--------------------|--------------------|
| engine power | 15 kW | 30 kW |
| kerb weight | 400 kg | 800 kg |
| front-end area | 1.0 m ² | 2.2 m ² |
| CO ₂ emissions | 60 g/km | 100 g/km |

Table 1: Comparing CLEVER and Smart; a small front-end area reduces air resistance

Key words
car safety
energy efficiency
unbalanced forces
acceleration

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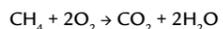
Subscription information

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CNG is mainly methane, CH₄. In the CLEVER engine, it burns with oxygen to produce carbon dioxide and water.



Is it green?

CLEVER has an engine that runs on compressed natural gas (CNG) which produces less carbon dioxide and other harmful emissions than an equivalent petrol or diesel engine. CLEVER has two lightweight carbon-fibre tanks, each holding 6 litres, giving a range of approximately 125 miles. CNG is similar to the gas used in homes for heating and cooking, so in the future it may even be possible to fill your car up at home!

CLEVER's small size, light weight and narrow shape also mean that it is more fuel efficient, further reducing fuel consumption and harmful emissions. CLEVER's emissions are 60 grams of carbon dioxide per kilometre, which is less than half the target set by the European Union, and its fuel consumption is equivalent to 108 miles per gallon. Despite the engine being small, CLEVER's design means that it can reach 60 mph and accelerate from 0 to 40 mph in seven seconds, which is adequate for a vehicle designed specifically for cities.

Acceleration:
CLEVER accelerates from 0 to 40 mph (= 17.8 m/s) in 7 s. That's an acceleration of $17.8 / 7 = 2.5 \text{ m/s}^2$.

What about safety?

The structure of CLEVER uses a lightweight aluminium frame with plastic body panels. The frame was developed with crash safety in mind, with specifically designed crumple zones and energy absorbing structures at the front and sides



CLEVER undergoes a standard impact test in the EuroNCAP trials.

to make sure that the occupants of CLEVER would be protected in an accident. Inside, CLEVER has an airbag and seatbelts, and the interior surfaces are constructed from energy absorbing materials to reduce serious injury to occupants. Three prototypes were assembled specifically for crash testing: a frontal impact, a side impact and a 'compatibility' impact, where CLEVER crashes into the side of a car. The results of these three tests suggest that CLEVER would score 3 stars in the standard EuroNCAP tests. (Conventional cars currently on the market usually score 4 or 5 stars, so 3 stars for a first prototype is an excellent result.)

Why does CLEVER tilt?

One of the most unusual features of CLEVER is its narrow width. Being only one metre wide, two CLEVER vehicles could fit side-by-side in the space occupied by one car, which leads to reduced congestion and easier parking. The problem with narrow vehicles is that they tend to roll outwards in corners, and can topple over if cornering too quickly. When a bicycle or motorcycle goes round a corner, it tilts into the corner. An automatic tilting mechanism was designed for CLEVER to make cornering possible. This was the focus of our work at the University of Bath.



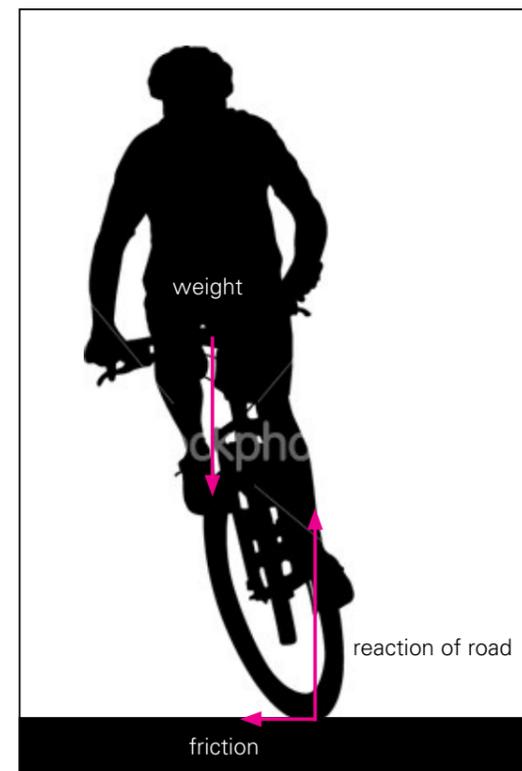
As the CLEVER vehicle corners, the front wheel and the passenger compartment tilt into the corner by up to 45°. This test vehicle also shows the aluminium frame which protects the occupants.

When a car goes round a corner it has to accelerate towards the centre of corner – this happens by the car's tyres creating a sideways force into the corner. The tighter the corner and the faster the car is moving, the greater the acceleration required. But if this acceleration is too great, the car will roll over. One way to avoid rolling over is to have a very low centre of gravity – that's why racing cars are low and wide – but this would mean that the occupants would have to sit very low down in the vehicle: getting in and out would be difficult, and the driver would have greatly reduced visibility.

To solve this problem, a mechanism was developed to tilt the body of the vehicle as it corners, up to an angle of 45°. An electronic control unit measures

the driver's inputs and the vehicle's current tilt position, and two hydraulic pistons tilt the cabin to the required angle to balance the vehicle. This shifts the centre of gravity sideways and pushes the weight on to the inside wheel, thus avoiding roll-over.

In an ordinary, non-tilting car cornering at speed, you may have felt yourself being flung sideways; in a tilting car, the occupants don't feel these side forces. The system is computer-controlled and fully automatic, so the driver doesn't have to balance the vehicle like on a motorcycle. This system not only makes CLEVER stable in corners, it also makes it good fun to drive!



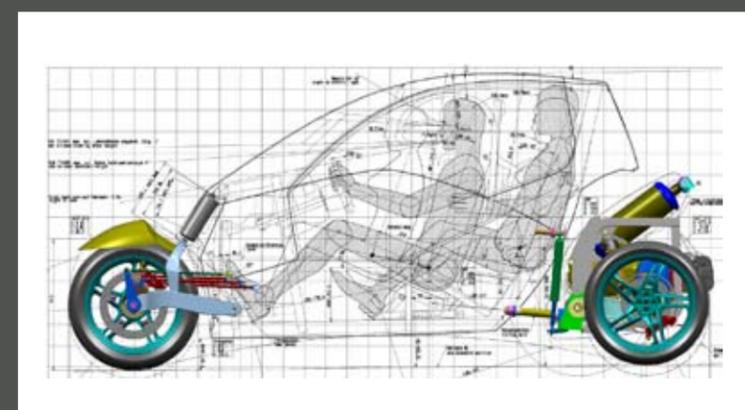
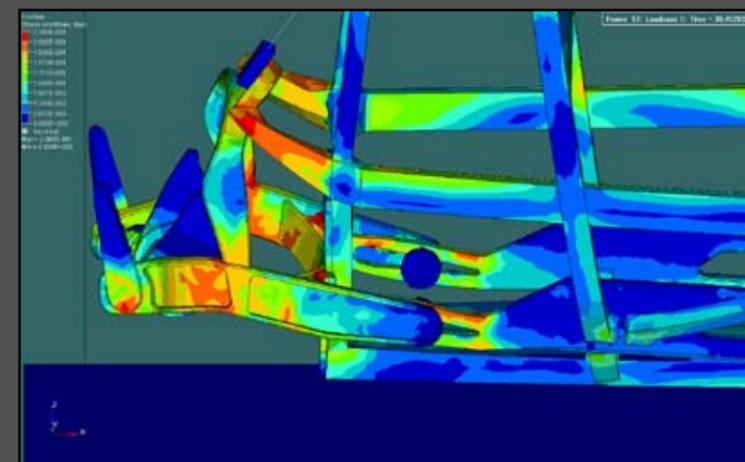
A cyclist cornering: the sideways frictional force of the ground on the tyre provides the force needed to follow a curved path.

When can I buy one?

CLEVER will never go on sale in its current form, but it is envisaged that some of the technologies demonstrated on CLEVER such as the tilting system and compressed natural gas engine could be on the market in a few years time. Many car manufacturers are actively researching alternative vehicles, like CLEVER. The main reason is that the European Union will start to impose fines if a manufacturer's fleet of cars has an average carbon dioxide output above 140 grams per kilometre. For manufacturers of large premium cars like BMW or Mercedes-Benz, a vehicle like CLEVER included in their range that produces only 60 grams of carbon dioxide per kilometre will significantly reduce this fleet average, thus avoiding the fines.

BOX 1 Working together

The CAD drawing of the CLEVER vehicle with the front and rear chassis parts shown in 3D.



Powerful computer-aided design (CAD) software was used to design and construct a virtual CLEVER. This meant that, while different teams worked on their own individual aspects of the design, the different systems within the car (the transmission, chassis etc) could be integrated effectively. The virtual model was also used in virtual crash simulations.

Dr Benjamin Drew is a research officer in the Department of Mechanical Engineering at the University of Bath.

Look here!

The CLEVER Project website is at www.clever-project.net.
The CLEVER Research Team webpage is at www.bath.ac.uk/projects/clever.htm.
You can see photos and movies of CLEVER undergoing crash tests at http://www.clever-project.net/gb/gb_crashtest.htm.
This BBC News item about the CLEVER vehicle includes a movie showing Ben Drew test-driving the car: <http://news.bbc.co.uk/2/hi/technology/4930794.stm>

Studying lung surfactant

This baby was born prematurely and is being supported in an incubator. It breathes oxygen-enriched air until its lungs are fully functional.

Our lungs have a specially designed coating on the inside and without it breathing would be impossible. This coating is called *Natural Lung Surfactant* and it reduces the work required to breathe. When babies are born very prematurely they can lack this surfactant, and this can make it very difficult for them to breathe. This is called *Respiratory Distress Syndrome (RDS)*. This article looks at the background science of lung function, the development of treatments for RDS and future research directions.

Breathing is something that each of us does on average more than 20 000 times per day, every day of our lives. The breathing rate is even higher, more like 70 000 per day, for newborns. This is something that takes place without us having to think about it; in fact it is impossible for a healthy person to stop themselves breathing. The structure of the lungs is crucial to this process but so too is the surface which separates the lung tissue from the air breathed in.

The structure of the lungs

The internal surface of the lung is coated with a thin layer of liquid. It is the surface of this liquid which is in contact with the air and which the oxygen must cross to get from the lung sacs into the bloodstream. The composition of this liquid is vital because if it does not have the right properties then breathing cannot take place. One of the crucial factors is the **surface tension** of the liquid surface. The surface tension of water arises because water molecules attract each other strongly – more strongly than they attract molecules of the air. So molecules at the surface of water are pulled inwards, into the bulk of the liquid. This makes it

much harder for any substances to cross into the water – see Box 1.

You can see the effect of surface tension if you look at water droplets. They adopt a shape which gives the minimum possible surface area, so drops of water and bubbles of air in water are spherical. This surface tension effect can also be seen when water is placed on a surface it doesn't like, such as a car that has been waxed or the outer surface of a tent.

Box 1 The surface tension of water

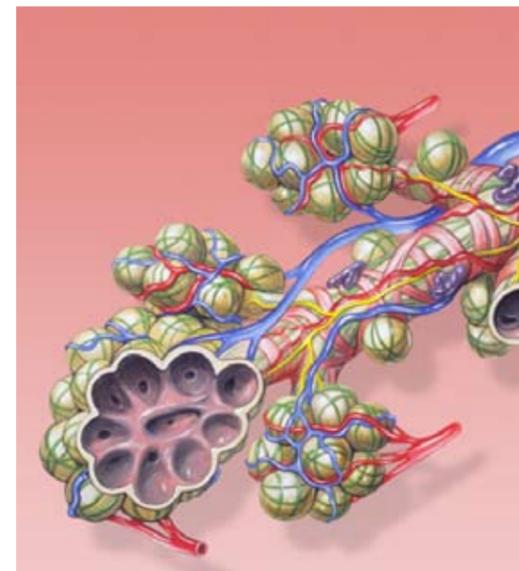
Here's how to observe how the surface tension of water prevents transfer across the water air barrier. Take a small bowl or cup of water and float a pin on it. It is easy to do as the surface tension of the water is strong enough to prevent the pin from crossing the surface. This is the force that the lungs would have to overcome if they did not have lung surfactant. If a single drop of detergent is added to the water, the pin sinks straight away. Likewise, lung surfactant reduces the force required for the oxygen to pass from the air in the lungs into the blood.



The surface tension of water pulls inwards on each droplet, preventing the water from wetting the entire surface.

The lungs are not two large empty chambers but consist of large numbers of bunches of alveoli. There are about 600 million of these very small circular chambers. It is these which are lined with liquid and which change their size during breathing. The strength of the surface tension over all the alveoli is so high that if they were lined with pure water breathing would be almost impossible. This is where Lung Surfactant (LS) comes in; one of its main roles is to reduce the surface tension of the lungs to enable breathing.

Respiratory Distress Syndrome (RDS), suffered by some premature babies, is a condition in which the lungs do not have sufficient LS. In a normal 9 month pregnancy, the lungs start to produce surfactants about 2 months prior to birth; babies born earlier than this are likely to have RDS because the strength of the surface tension forces makes it impossible for them to breathe. Prior to the development of treatments, RDS was a significant cause of death in premature babies.



When you breathe in, air enters the internal space in the alveoli; oxygen diffuses across into the blood vessels, while carbon dioxide diffuses in the opposite direction.

Box 2 How big are your lungs?

The total volume of air in your lungs is about 6 litres. However, the structure of the alveoli means that they have a large surface area.

Using the following information, you can calculate the surface area of a single alveolus and then the total surface area of the lungs.

600 million alveoli in lungs
Radius of one alveolus = 0.1 mm
Area = $4 \times \pi \times r^2$
1000 mm = 1 m

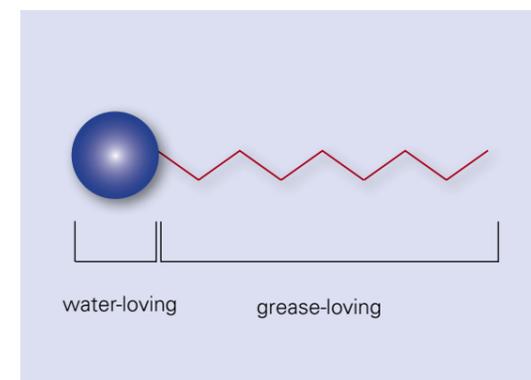
Is the total area closest to ...?

- a A football pitch (about 4500 m²)
- b A squash court (about 65 m²)
- c A double bed (about 4 m²)

Answers on page 21.

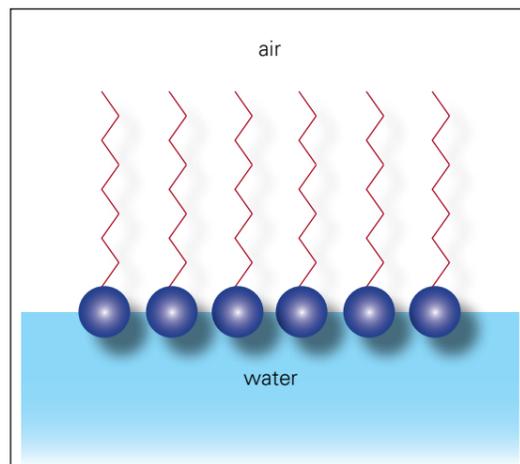
Surfactants

Surfactants, an abbreviation of SURFace ACTIVE AgeNTs, are molecules that stabilise the surface between water and oil or water and air by lowering the surface tension. One part of the surfactant molecule likes water (hydrophilic) while the other does not (hydrophobic.) Because of this surfactants congregate at water/oil or water/air surfaces reducing the surface tension. Surfactants are key components of many everyday products such as detergents, fabric softeners, emulsions and foods like mayonnaise. In applications using these products the surfactant stabilises the surface where the oil and the water meet. In a detergent, one part of the molecule (the hydrophilic part) will interact with the water while the hydrophobic part interacts with an oily stain to help remove it from the item being cleaned.



A surfactant molecule: the long thin 'tail' is hydrophobic and will not dissolve in water. The spherical 'head' end is hydrophilic and so will dissolve.

Key words
breathing
lungs
surface tension
hydrophobic
hydrophilic



On the surface of water, surfactant molecules have their hydrophilic 'heads' in the water and their hydrophobic 'tails' in the air.

Lung surfactant

LS is a very complex mixture of many components with the majority being phospholipids. Phospholipids are the molecules that make up most of the body's cell membranes and they can act as surfactants because they contain hydrophilic and hydrophobic regions. There are at least six different types of phospholipids in the LS mixture. There are also four different proteins which are a part of LS.

The behaviour of phospholipids has been extensively studied as they are a crucial component of every cell in the body. The Lung Surfactant Proteins have proved to be more difficult to study as purifying them from the lungs is a long process. Scientists have conducted experiments on the proteins to try to understand their size and shape at an air water surface and how this is affected by phospholipids. This is a difficult system to study so experiments started with protein and have progressed to simple mixtures of protein with one or two of the main phospholipids. These experiments are not carried out on people or animals but in a lab using a Langmuir trough (see Box 3) which provides a good model system for the fluid layer in the lungs.

The Langmuir trough provides a way of controlling the amount of area at the air/water surface so we can simulate or model the difference between breathing in (large surface area) and breathing out (small area). Scientists then use a range of methods to study the different components as the area is changed to try to understand the location and possible role of each in the breathing process. As a result of experiments carried out over the years a number of treatments for infant RDS have been developed. These have resulted in a dramatic drop in the number of infant deaths from RDS.

A baby with RDS is usually helped to breathe in some way and given oxygen. If necessary, lung surfactant can be sprayed into the baby's lungs along with the oxygen. Most babies who develop RDS now make a full recovery.

Make your own Langmuir trough and use it to measure surface tension - see Try this on page 21.

Box 3 The Langmuir trough

A Langmuir trough consists of a reservoir and two barriers made of Teflon. The trough is filled with water and surfactant molecules or proteins can be placed on top of the water surface. The distance between the two Teflon barriers can be changed thereby changing the area of the water surface; this simulates the breathing process. This either squeezes the surfactant molecules together or gives them more room. The photo shows the drop of solution containing the LS molecules about to be placed on the surface and the device used for "weighing" the surface to determine the surface tension.



The author dropping solution on to the surface of water in a Langmuir trough.

Stephen Kill, STFC

Research goals

The proteins used in these treatments come from animal sources (mainly cows) and this can lead to problems. The goal of current research is to improve our understanding of the role of the main components of LS so that the simplest possible treatment mixture may be used until the premature baby's body can produce its own LS. The second aim is to work out how to synthesise the essential protein components, giving safer treatments which will be more widely available, particularly in the developing world.

Stephen Holt is a research scientist who works for the government funded Science & Technology Facilities Council. His own studies are aimed at understanding the behaviour of surfactants and proteins at surfaces.

Look here!

Visit this Canadian website to see animations and to learn more about premature babies, RDS and lung surfactant.

<http://tinyurl.com/yswwt4>



Handling drums of low-activity radioactive waste in an underground store.

Jill Sutcliffe

Radioactive waste decisions – having your say

Would you want a radioactive waste disposal site in your neighbourhood? Before you say, "No thanks," have a think – there might be benefits. Job opportunities, better roads, improved health facilities ... But how does a government decide where to put such a dump? And how can citizens affect the decision-making process? Jill Sutcliffe discusses how governments try to involve their citizens in decision-making.

Making policy in a democracy

The UK government has increasingly emphasised the importance of finding out the views of members of the public and there has been a steady flow of consultations on different policies – energy, planning and, in the summer of 2007, how to implement policy for managing radioactive waste safely. These are areas where science has an important part to play in decision-making.

Our nuclear power stations supply about 20% of the UK's electricity. Their spent fuel and other wastes contain highly-radioactive substances – see CATALYST Vol 14 issue 4. This **nuclear legacy** has to be managed and disposed of safely. But how, and where?

In 2003, the government set up an **independent committee**, the Committee on Radioactive Waste

Management (CoRWM), to recommend what should happen. CoRWM consulted a wide range of people and this aspect of their work was highly thought of.

CoRWM encouraged people to give their views on:

- the "inventory" (types and amounts) of existing radioactive wastes;
- the options for dealing with different types of waste.

In October 2006 the government accepted the following recommendations from CoRWM:

- Geological (underground) disposal should be adopted as the end point for long-term management of the most radioactive wastes.
- Robust storage in the interim will be needed.

The recommendations also emphasised that a repository should not be forced on a local community, but that "volunteers" would be sought to host it.

A wider consultation

In June 2007, the Government launched a consultation on its proposals for siting an underground waste repository. It published a document which posed a series of questions; groups and individuals were invited to send in their responses by a specified deadline.

Although an independent committee like CoRWM works independently of the government, its membership and terms of reference are decided by ministers.

One of CoRWM's recommendations was that there should be more education in schools on the issue of radioactive waste. They ran a specific project with 15 schools in Bedfordshire. Students were introduced to the basics of the issue and then had to research answers to some questions. They then suggested how other pupils could be involved which enabled over 1300 young people aged 11-18 to take part.

Box 1 outlines two other ways in which the views of citizens have been gathered to inform policy-making where science is involved. The aim is to encourage people to engage with the issues and to study the evidence before they give their opinions.

Box 1 Informed opinion

Where scientific issues are involved, governments want to hear informed opinions rather than prejudices. Here are two ways in which they have tried to do this.

Citizens' Panels (also known as **Citizens' Juries**) involve a random selection of citizens who spend several days cross-questioning experts and coming to a shared conclusion. For CoRWM, four panels of 12-16 citizens met three times each to contribute to the process of deciding how to handle the nuclear waste legacy.

In **Joint Fact-Finding**, different interest groups set up a working party representing all sides of an issue. The working party tries to find shared answers to the most important questions, although they do not have to agree on every issue. Once people have worked together like this, they are more likely to reach an agreement on the remaining areas of dispute.

Another way for citizens to make their views known – the *Climate Camp at Heathrow Airport in August 2007*. The campers were highlighting the role of air travel in climate change. Their banner says: *WE ARE ARMED ... ONLY WITH PEER-REVIEWED SCIENCE*



Each of these approaches has its pros and cons. The members of a **citizens' panel**, for example, need to be supported by staff who help them to question expert witnesses. The staff, known as facilitators, must not try to push the panel to reach a particular conclusion.

One of the most important things about consultation is that decision-makers need to be genuinely prepared to change their proposals in the light of what people have to say, and make it clear how they took these views into account.

Dr Jill Sutcliffe is Project Officer with NuLeAF (Nuclear Legacy Advisory Forum), an organisation which aims to identify and promote a common, local government viewpoint on nuclear waste clean-up issues. Local authorities have a key role to play in enabling communities to decide on these issues.

Box 2 Informed opinion

Governments don't always get things their own way. In February 2007, the campaigning environmental group Greenpeace won a Court case concerning the conduct of the government's consultation on its proposed Energy policy, including how radioactive waste would be handled. The judge, Mr Justice Sullivan, stated that "something has gone clearly and radically wrong" with the consultation process. In his opinion, the review was "seriously flawed" and the process was "unfair" because insufficient and "misleading" information had been made available by the government.



The photographs on pages 10-11 show pollen grains from several different plant species. They were made using a scanning electron microscope. This technique provides apparent 3-dimensional images of specimens, giving a better understanding of spatial relationships and revealing unsuspected detail at much greater magnifications than can be obtained with an optical (light) microscope.

When viewed with a dissecting microscope, pollen looks like a fine yellow or white dust, but when magnified many thousands of times in a Scanning Electron Microscope (SEM) each plant pollen species reveals a unique set of characteristics. They can be distinguished by shape, size and ornamentation. Grains come in a variety of shapes but are usually spherical, ovoid or disc-like and between 15 to 100 μm in length.

How the images were made

The images are called micrographs and were taken in a scanning electron microscope (see page 13). An SEM uses electrons instead of light as a source of illumination. Electrons have a much shorter wavelength than visible light and so much

higher real magnification can be achieved ranging from $\times 20$ to a practical maximum of $\times 50\,000$ for biological specimens. It can resolve structural details as small as 5-10 nanometres (nm).

(The long wavelength of light compared to electrons limits any light microscope from $\times 10$ to an absolute maximum $\times 1500$ and revealing structural details limited to 300 nm.)

Micrographs from an SEM are black and white because the short electron wavelength is outside the visible spectrum. However "pseudo-colour" can be produced by electronically assigning different levels of grey to a particular colour during image processing.

What to look for:

The micrographs show architectural detail of pollens from seven different species of British wild flowers and a crop (oil-seed rape).

The tough outer coat is made of sporopollenin and has hard features that may include pores and furrows. The surface may be meshed, grooved, spiny, striated or smooth.

Each image is marked with the voltage used in the SEM (10 kV), the magnification, a code number, and a bar which represents 1 μm (written as 1.0 μ), or 10 μm (10.0 μ). 'NIMR' stands for National Institute for Medical Research, where the images were made.

Pollen grains are small, so their sizes are measured in micrometres (thousandths of a millimetre).

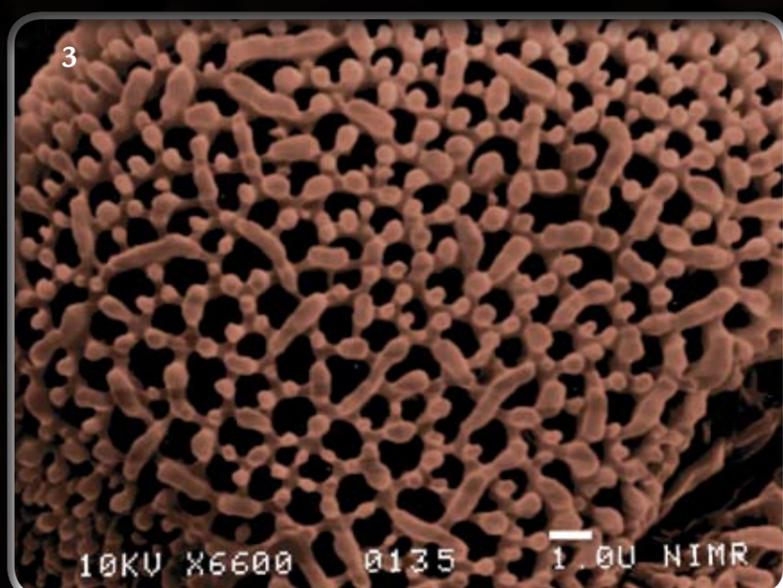
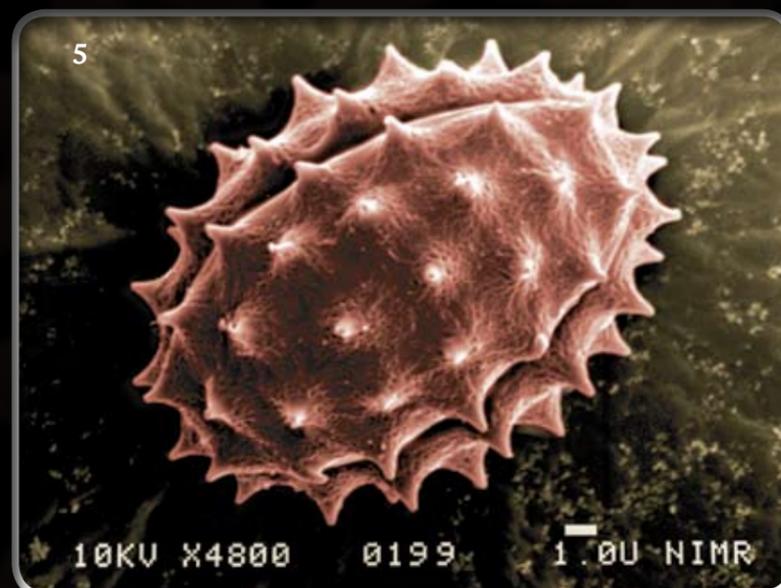
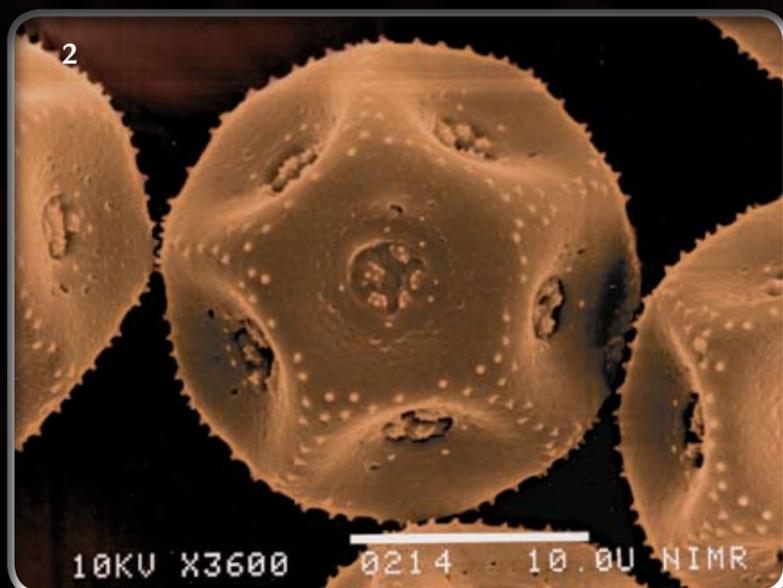
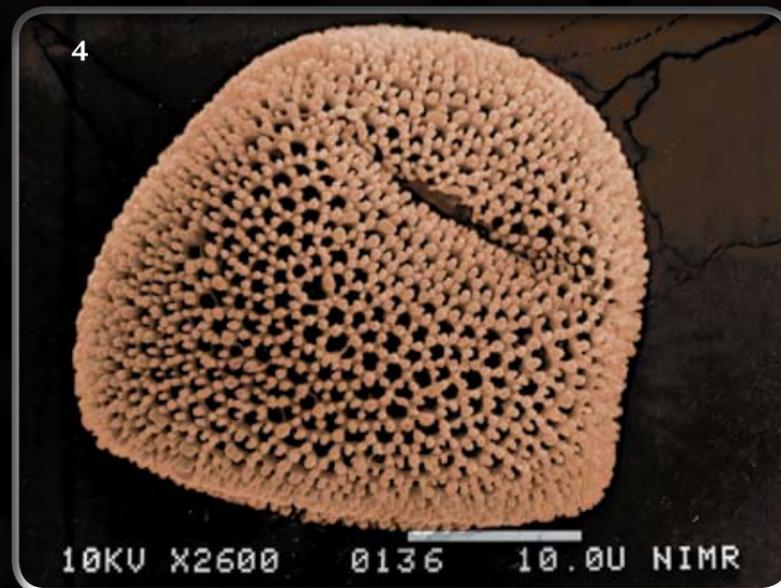
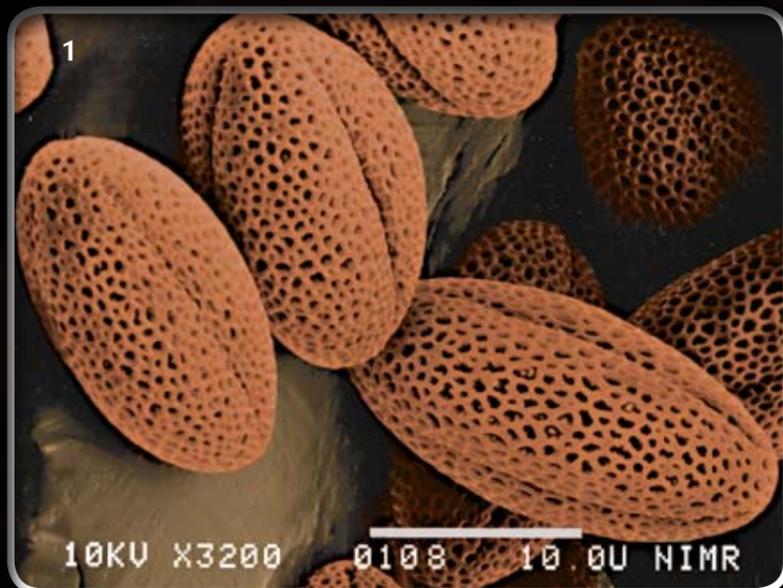
1 μm = 1 micrometre = 10^{-6} m

1 nm = 1 nanometre = 10^{-9} m

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Scanning electron microscopy shows up the shapes and sizes of pollen grains from some British plants.



- 1 Oil seed rape
- 2 Greater stitchwort
- 3 Herb robert
- 4 Herb robert
- 5 Ragweed
- 6 Dandelion
- 7 Blackberry
- 8 Deadly nightshade
- 9 Tree mallow

Right: Extracting a soil core; different layers contain pollen grains from different plant species, revealing how the local vegetation has changed over the last few thousand years.



Pollen was used in evidence against Ian Huntley, the Soham murderer.

Why are images of pollen useful?

Forensic science: Pollen and other plant material is used in criminal investigations to link the perpetrator to the crime scene. It may be possible to show that pollen found on clothing or in a car has come from a specific place, because some plants have limited geographical locations, some places have unusual or specific combinations of plant species, and some plants only produce pollen at very specific times. Analysis of any pollen grain evidence is highly time-consuming it is only used in serious crimes such as rape and murder.

The scientific study of pollen is known as palynology.

Palaeontology: Pollen and spores preserved under anaerobic conditions, such as in peat sediments and lake beds, can illustrate the effect of human impact over time and trends in biotic history such as vegetation cover or sequence of climatic changes.

Archaeology: Identification of pollen and plant remains on archaeological artefacts can be used to determine their place of origin.

Pollen allergies: Allergies to pollen are known as hay fevers. Hay fever is a modern disease which has only become common (or perhaps only recorded?) in the last 100 years. However it is known that pollution, diet and chemicals can worsen hay fever symptoms and that allergies are an increasing problem in medicine.

Pollens that commonly cause hay fever usually come from plants with tiny insignificant greeny-yellow flowers; grass and plantain pollens account for 95% of hay fevers in the UK. (Two very notable exceptions are ragweed and the crop oil seed rape which have showy flowers.) Most highly-allergenic pollens come from plants that rely upon the wind for dispersion. This means that millions of very small lightweight grains are released simultaneously to ensure that at least some will reach the female. The air is filled with them so they are impossible

“Pollen counts” are now a regular feature of the weather forecast because so many people are affected.

for hay fever sufferers to avoid. (One giant ragweed can release 8 000 000 000 grains in 5 hours!)

Hay fever symptoms include sneezing, blocked or runny nose, itching watering eyes, itching throat, nose mouth and ears. The symptoms are caused when the body’s immune system over-reacts to a normally harmless substance by producing huge amounts of Immunoglobulin-E to attack the pollen and releasing histamines which cause itching. Symptoms often begin in early teens, peak in twenties and subside by forty. It has been estimated school hay fever sufferers drop at least one exam grade because symptoms are worst in spring and summer.



A hay fever sufferer learns from her doctor about the effects of ragweed pollen on her lungs.

Health claims for pollen

A variety of ‘health food’ producers have begun selling pollen for human consumption, claiming various health benefits. As yet, there is no scientific basis for the claims made – and a possibility of allergic reactions!

Elizabeth MA Hirst is employed at the National Institute for Medical Research, London.

Scanning electron microscope

Elizabeth Hirst explains more about how the images on pages 10 and 11 were obtained.

Specimen preparation

Pollen is a hard, dry biological specimen and therefore relatively easy to prepare (compared to other wet biological materials). Pollen is collected directly from the plant stamens using double sided sticky carbon tape which is then mounted on a metal stub. A thin film of gold metal is then condensed onto the specimen surface to a thickness of around 10 nm.

Although expensive, gold has the ideal metallic properties to prevent build up of electrical charge on the specimen surface (this would ruin the image).

The specimen is then inserted into the SEM vacuum via an airlock and the electronic image of it is viewed on a TV monitor.



The tall microscope has controls to allow the operator to position the specimen in the electron beam. Images appear on the monitor screen.



This bee has been coated with gold before being examined in an SEM.

How an SEM works

cathode –

a tungsten filament, heated to 2300°C, releases electrons

anode –

high voltage attracts electrons to form beam

magnetic lens –

focuses electron beam to a fine point

scanning coils –

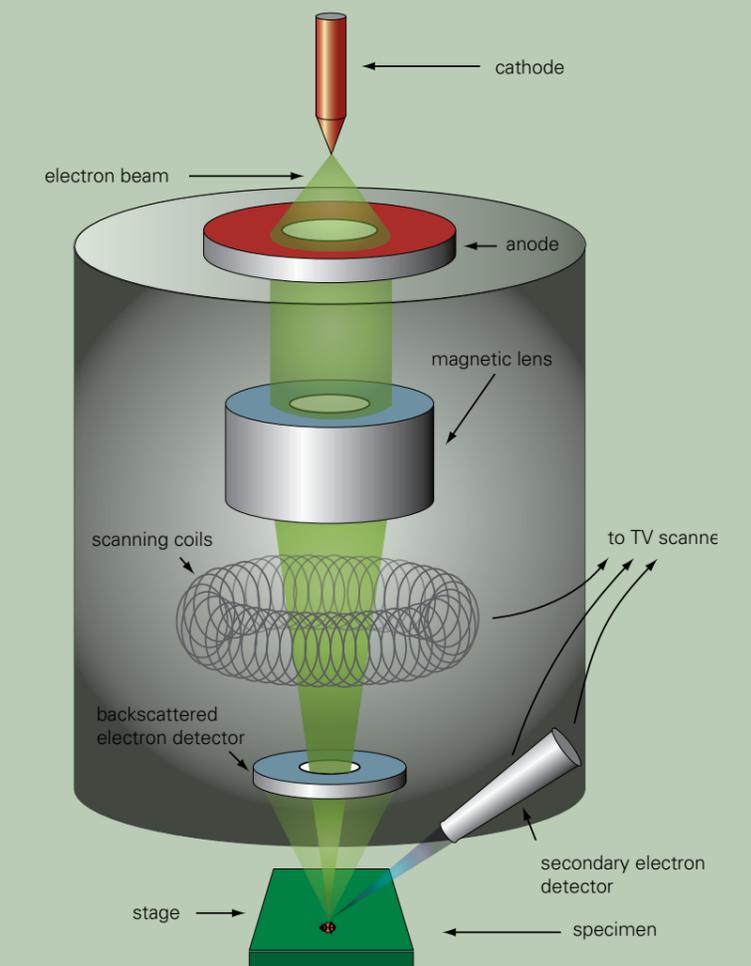
make the beam ‘raster’ back and forth across the specimen

detector –

collects electrons reflected from specimen

specimen –

scanned by beam of diameter 10 nm



Tina Kerby
Jason
Hall-Spencer



Arctic coral reefs An undiscovered environment

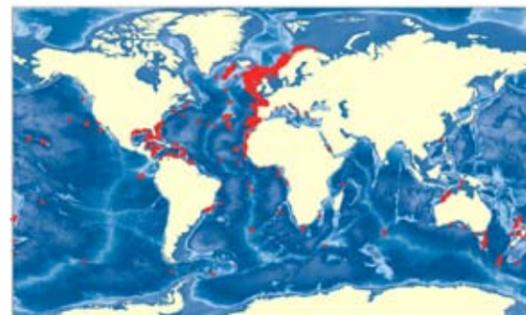
Bubble-gum coral,
Paragorgia arborea

Key words
environment
human impact
greenhouse effect
coral bleaching
climate change

Recent expeditions to the cold, northern waters of the Arctic have revealed giant deep-sea coral reefs. In this article, Tina Kerby and Jason Hall-Spencer describe the latest findings from a project to study these surprising environments.

“Coral reefs in the Arctic? That can’t be right...”, you might think, as all the text books say that coral reefs are restricted to the sunlit warm waters of tropical and subtropical regions. But the text books are wrong, and this just shows that major scientific discoveries still await those who, like us, are lucky enough to get to see unexplored regions of the planet!

We now know that coral reefs are not confined to warm, shallow waters. They are also found in great depths and at low temperatures, where they were not expected.



Map showing the areas where cold-water coral reefs are known to form.

Cold-water corals have actually been known about for centuries, since fishermen first brought up coral fragments entangled in their nets from deep-sea areas. But we didn’t know they formed giant reefs. It is only in the last few years that scientists have been able to investigate the oceans with more and more sophisticated technology, using the latest underwater cameras mounted on robotic or manned submersibles, giving them the chance to explore deep-water environments.

It has turned out that cold-water coral reefs can be found in deep waters throughout the world’s oceans. These cold water coral reefs are now known from depths of just 40 metres in the sheltered fjords of Norway right down to hundreds or even thousands of metres along the edges of continental shelves, around offshore submarine banks and on submerged volcanoes, termed ‘seamounts’.

We all lived in a yellow submarine

In July 2007, we joined scientists from various European countries on a month-long expedition aboard “RV Polarstern”, a research vessel run by the Alfred Wegener Institute for Polar and Marine Research in Germany. This expedition provided an opportunity to investigate cold-water reef ecosystems. The ship had a hull that was strong enough to break through polar ice and was equipped with a two-man submersible called Jago, on loan from the Leibniz Institute of Marine Sciences at the University of Kiel (Germany). This provided the opportunity to undertake the first manned submersible observations of Røst Reef,

the largest reef so far found in cold-water regions of the planet. Equipped with a grabber, sampling container, digital-camera and a high definition video camera, we were able to sample very precisely within this fragile habitat.



Jason Hall-Spencer gets ready to go down in the Jago submersible.

A boyhood dream came true when Jason was able to use a little yellow submarine! Stunning close-up footage of Røst Reef was captured with digital and video cameras mounted on Jago, and samples were carefully taken at depths of 300-380 metres.

Back in Plymouth, the research team have begun studying and analysing the data and samples collected on this expedition. The samples brought to the surface demonstrated the rich diversity and abundance of species living in this habitat and illustrate that cold-water coral reefs are hot-spots of biodiversity in the deep waters of the Arctic.

Not only marine biologists were interested in this complex ecosystem; geoscientists were also onboard to study the area with sonar systems to visualise the sea bed. Compilation and processing of the sonar data with special computer software delivered insights into the reef structure and its surrounding sea bed. During the whole cruise, oceanographers took consecutive water samples to measure temperature, salinity, oxygen and pH with a so-called CTD-sensor (Conductivity-Temperature-Depth). The resulting values help to evaluate the precise characteristics of the waters that support cold-water coral development.



Jago’s probe measures oxygen levels in a coral bed.

Living together

In shallow tropical waters, reef-forming corals possess single-celled symbiotic algae (zooxanthellae) which produce oxygen and nutrients through photosynthesis. The coral polyps use waste products from these algae for food, and in return the corals provide shelter due to their hard skeleton and also provide materials (e.g. carbon dioxide) that are needed by the zooxanthellae for photosynthesis.

Zooxanthellae belong to the phylum Dinoflagellata. They are unicellular algae living in symbiosis within the tissue of many marine animals, like giant clams, nudibranchs and jellyfish and play a highly important role living within tropical coral polyps. Up to 90% of tropical coral’s energy requirements can be delivered by Zooxanthellae. The death of these Zooxanthellae, or a reduction in their chlorophyll content, can arise due to pollution or sea temperature changes. This is the basis of coral bleaching. Such events have become more common over the last 20 years, possibly due to global warming.



The coral on the right has a healthy population of Zooxanthellae; on the left, the coral appears bleached because these organisms have died.

Cold-water corals, living in the dark, do not have light-dependent symbiotic algae like their shallow warm-water cousins. They are dependent on particulate organic matter (POM) and zooplankton for their food and energy resource. Corals belong to the phylum Cnidaria, as do anemones and jellyfish, and extend their stinging tentacles into the water current and retract them when they capture food.

Organic matter (e.g. dead algae, faeces, dead animals) produced in the sunlit zone, sinks in the water column and transports carbon and other biogenic material downwards. This POM (Particulate Organic Matter) serves as a food-source for bacteria and more complex organisms living in the water column and on the sea bed. Biological, chemical and physical processes change the size and composition of the particles as they sink and they can aggregate and accumulate to form what looks like a floating blizzard of what is termed *marine snow*.

Brandon Cole/nature.com



An abandoned length of fishing line has become entangled with this coral; in the background you can see flakes of 'marine snow' drifting down.

Coral cities

Corals, whether tropical or cold-water, can build hard calcium carbonate skeletons as they grow, forming giant and complex reefs. The reefs build-up slowly over thousands of years since the corals only grow a few millimetres or centimetres per year. In comparison to the hundreds of reef-building tropical coral species, there are only two reef-building species known in the cold waters around Britain, namely *Lophelia pertusa* and *Madrepora oculata*. These two species are widespread in deep waters of the north-east Atlantic and were the main interest of our pioneering expedition to the Arctic in 2007.

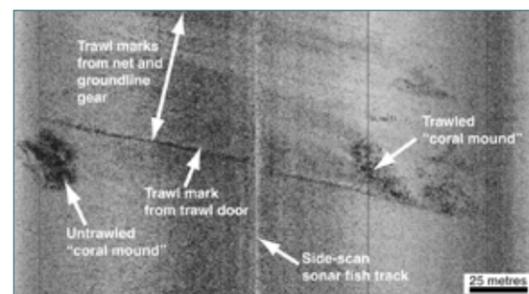
Cold-water coral reefs are important biodiversity hotspots. They are located in nutrient rich zones and provide a habitat for a variety of marine invertebrates, like sponges, polychaete worms, molluscs (e.g. mussels), echinoderms (e.g. brittle stars, sea urchins) and crustaceans (e.g. crabs, squat lobsters). They represent a spatially confined ecosystem and supply shelter and food to organisms living in, on and around the coral reef. They are also important nursery areas for various fish species in the deep-sea.

Reading the history books of the sea

Due to their banded skeletal structure, cold-water corals are good environmental archives (rather like tree rings) preserving archives of past weather conditions within their growth bands. The gathered samples and data will provide scientists with clues to the development of the reef from the last glacial period (8000 BC) onwards. As scientists begin to discover and explore cold-water coral reefs they are recognising how important these ecosystems are and the threats posed by human activities. Film footage and photos provide evidence of the disruptive impact of fishing using towed trawls

across the sea-bed which smashes the coral reefs to pieces. Once damaged, corals need hundreds or thousands of years to recover; many may well never recover.

Another threat to these habitats is that of increased acidity of the oceans due to rising atmospheric CO₂ levels which have been brought about by the burning of fossil fuels such as coal, oil and gas. This leads to higher CO₂ levels in seawater, resulting in a drop in alkalinity and calcium carbonate saturation of the water. Scientists predict that the ability of deep-water corals to build calcium carbonate skeletons will be impaired as the seawater becomes more acidic.



This sonar chart of a section of the seabed shows the effects of trawling by fishermen on coral reefs.

We are beginning to realise that cold-water coral reefs are very sensitive ecosystems. As scientists are discovering deep sea reefs and finding out about the ecology of the wonderful organisms that live amongst them they realise that these ecosystems need to be protected. The great news is that some marine protected areas for cold-water coral reefs have recently been established in the UK and Norway. Further recommendations for protection, conservation and sustainable management can only be achieved by a new generation of scientists willing to find out what is living in the dark, unexplored regions of our planet. These scientists will also need to make sure that the public and politicians know what natural treasures are down there.

Tina Kerby is carrying out MSc research into the satellite tracking of deep-sea fishing vessels with Jason Hall-Spencer, a Royal Society Research Fellow at the University of Plymouth.

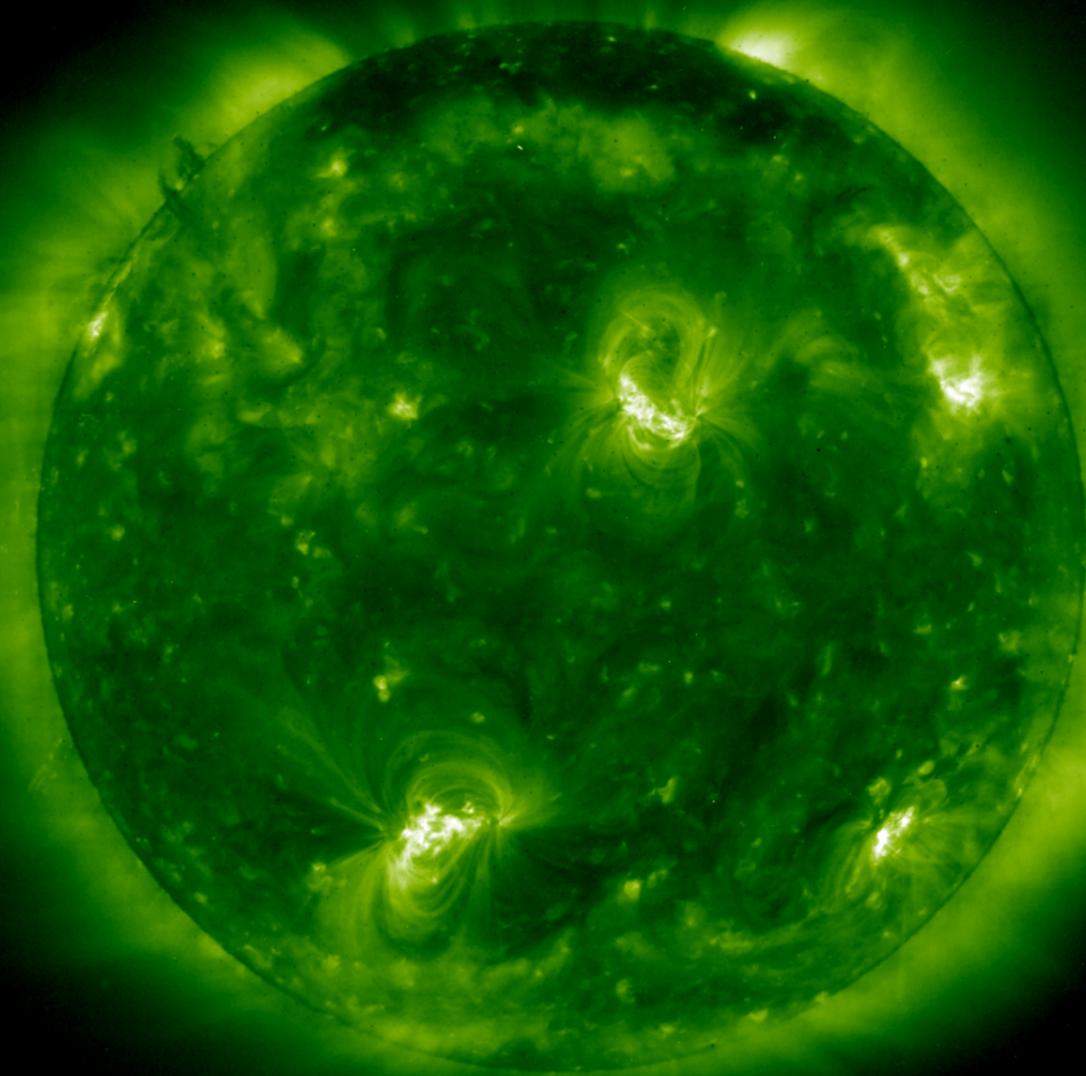
Look here!

Check out www.deepseaconservation.org for more about Britain's deep sea environments and how scientists are trying to protect them.



Year of the Sun

Lucie Green



The Sun's corona, seen by the SOHO satellite. This photo was taken using ultraviolet light, so the green colour is artificial.

Space science and technology are an integral part of our lives today. Astronauts have established a permanent presence in orbit, and we communicate and navigate effortlessly via the use of satellites. However, 50 years ago it was a different story.

In 1957 scientists knew very little about the solar system and the planet they lived on. The Sun, the eight planets, comets and asteroids were known to exist, but they were thought of as isolated and unconnected bodies. To further their understanding of the Earth and its place in the solar system, over 60 000 scientists came together to combine their efforts and finances. 1957 was named as International Geophysical Year. Scientists wanted to answer big questions and this required lots of people, money and importantly instruments in space. Contributing to this effort, the first satellites were launched in 1957.



In 2007 we are celebrating 50 years of space science with a new initiative that once again draws together scientists from around the world. This time it is the Sun, rather than the Earth, which is taking centre stage. The plans are more ambitious as scientists are working together to understand fundamental processes which take place throughout the entire solar system.

On February 19th 2007 International Heliophysical Year (IHY) was launched to provide a focus for this research. The name doesn't exactly roll off the tongue, but the word *helio* derives from the ancient Greek name for the Sun *helios*. In simple terms, IHY is about the science of the solar system, and in particular the effects the Sun has on the planets.

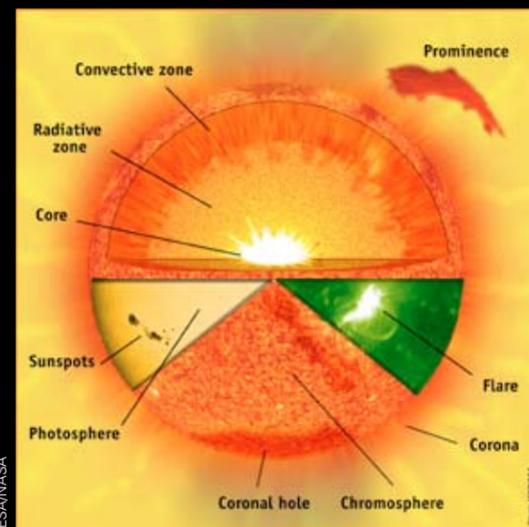
Box 1 International Heliophysical Year

International Heliophysical Year has been launched to celebrate 50 years of space science and to learn more about our Solar System. The scientific aims are:

- to understand how the planets are affected by the Sun
- to learn more about the fundamental physics of the Solar System
- to study how the heliosphere interacts with the region beyond called the interstellar medium

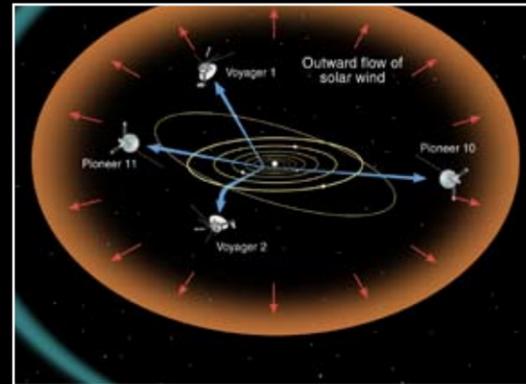
Our changing Sun

The Sun is a dynamic object. From the Earth we see the Sun's surface, called the photosphere. It is on the photosphere that we see changing black patches called sunspots. Placing our telescopes in space gives us a clear view of the higher layers of the Sun's atmosphere, first the chromosphere and then the corona.



The structure of the Sun

The Sun produces a gusty wind that streams out continuously into the solar system. This solar wind is made up largely of protons and electrons; at the point where it slows down and perhaps even turns back on itself, we have the edge of the solar system. In fact, the solar wind can be thought of as creating a bubble in space and this bubble is known as the heliosphere. The edge of the heliosphere is thought to be over 12 billion km from the Sun.



The heliosphere, showing the vast extent of the Sun's influence.

The Sun is also a magnetic object and its atmosphere is filled with giant magnetic structures which arch up from the photosphere. These magnetic fields are more concentrated in regions arching from sunspots. Just like compressing a spring or twisting a rubber band, these magnetic fields can get distorted and energy starts to build up. Under the right conditions this energy is released, producing a huge explosion that is called a solar flare. Solar flares manifest themselves in many ways and their symptoms last from minutes to hours. They heat up gases in the solar atmosphere to 100 million degrees and they produce radiation across the electromagnetic spectrum from radio waves to gamma rays. They also send a beam of particles (mainly electrons and protons) like a light-house beam out into the solar system.



This image, made by the Hinode solar observatory, shows the Sun's chromosphere with its magnetic field rising vertically from a sunspot.

Space hazard

The very energetic particles released by solar flares can pose a problem to astronauts; in particular, it is the protons from the solar flares which are the most dangerous. Humans on the Earth are protected by the atmosphere, but the higher up you go, the less protection you have. If you are an astronaut on the Moon or on your way to Mars you have no natural protection at all! Instead it must be built into spacesuits and the spacecraft. The high energy particles from solar flares can penetrate the human body and lead to radiation sickness and even cancer, in extreme cases. The situation is similar to receiving radiation from a nuclear bomb.

Solar flares also directly affect the ionosphere, the upper-most part of the Earth's atmosphere. The particles in the ionosphere are torn apart by the X-rays and ultra-violet radiation coming from the Sun. During a solar flare the amount of X-rays and UV emitted increases by many thousands and the day-side of the ionosphere becomes more heavily ionised. High frequency radio waves normally bounce off the ionosphere to provide communications over long distances, around the curvature of the Earth. During a solar flare the increased ionisation means that radio waves are absorbed by the ionosphere. This leads to a blackout in the high frequency radio range which can last from minutes to hours and so can seriously disrupt communications using this frequency range. Mariners and aviators who are travelling on the day side of the Earth may be affected; for example, flights that go over the poles rely on HF radio communications for a large part of the route. Blackouts can last for many hours. In 2001 (just after a solar maximum) 25 flights were diverted during a 23 day period as a result of solar flare alerts.

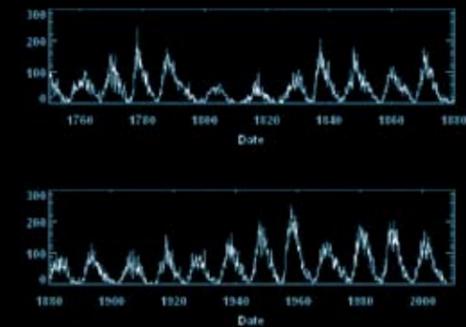
Solar activity, including solar flares and the number of sunspots, follows a cycle. Over 11 years the Sun goes from being very quiet with very few sunspots, to being very active, and back to quiet again. In 2007 we are currently at a minimum in solar activity but the Sun is still an interesting object to study even at this time.

In 1989, 6 million Canadians lost their power

Box 2 Did you know?

There are around 12 space missions studying the Sun and how the Sun affects the Earth during International Heliophysical Year. The charged particles of the solar wind form an electrical current connecting the Sun and the Earth. Between one and ten million amps flows in the circuit!

The Sun's activity follows a cycle which lasts roughly 11 years. This cycle was first realised through watching how the number of sunspots on the Sun varies with time.



The number of sunspots visible on the Sun's face clearly follows a cycle.

when a magnetic storm took place. In this case a coronal mass ejection (CME) was responsible, rather than a solar flare. CMEs are huge bubbles of solar magnetic field and hot gases which erupt into space at speeds of thousand of kilometres per second. The CME hit the Earth's magnetic field and interacted with it. Immense currents were generated around and through the Earth. These currents find the path of least resistance and in this case it was the power lines of the Hydro-Quebec power grid! The overload of current brought the system down.

The Sun from space

Scientists today view the Sun and the Earth as forming a connected and dynamic system, and the effects mentioned above are just two of many ways that we feel the influence of the Sun. During IHY around twelve space missions will be studying this connected system, with scientists in international teams analysing the data. Two of the most important solar missions being used during IHY are called STEREO and Hinode. STEREO is a NASA mission which UK scientists are contributing to. It is a unique mission that uses a pair of spacecraft, one behind the Earth in its orbit, and one ahead. Just as two eyes can give us a sense of depth and perspective, the two STEREO spacecraft will be able to build up 3-D images of the Sun's magnetic arches. The Hinode mission is a Japanese mission that UK scientists are contributing to. Hinode will also study the giant magnetic structures in the Sun's atmosphere and help us understand why solar flares happen.

Lucie Green has been observing the Sun since she was a student at Sussex University. Now she works at the Mullard Space Science Laboratory as well as giving talks about astronomy and space science on TV and radio, and in schools.

Look here!

For more information on IHY visit

www.sunearthplan.net

For more information on how the Sun affects the Earth visit: www.windows.ucar.edu and click on 'space weather'.

There were nine planets in the solar system until last year (2006), when Pluto was reclassified by International Astronomical Union – now it is classed as a dwarf planet.

The element helium (symbol He) gets its name from *Helios*, the Sun. The gas was discovered when the elements in the Sun were first identified by analysing the spectrum of sunlight.

Energy-efficient lighting – is it all good?

Traditional light bulbs are filament lamps. The UK Government has announced that sales of filament lamps will be phased out over the next few years. That means that we will all become much more familiar with their replacements, compact fluorescent lamps (CFLs). But not everyone agrees that this is a good idea.



How they work

In the filament lamp (on the left), a current flows through a tungsten filament. Electrons collide with tungsten atoms, giving them energy so that the metal gets hot and glows. In the fluorescent lamp (on the right), a current flows through low-pressure mercury vapour in a glass tube. Electrons collide with mercury atoms, giving them energy which they give out as ultraviolet radiation. This is absorbed by phosphor powder on the surface of the glass and re-emitted as visible light.

Issue 1: Energy consumption

Lamps are for producing light, but they are not very good at it. Less than 10% of the energy supplied to them is transformed to light. The rest ends up as heat.

60 W filament lamp: 2.3% efficient

11 W fluorescent lamp: 7.5% efficient

So a CFL takes about one-quarter of the electricity to produce the same amount of light as a filament lamp. Much less energy is wasted as heat.

The problem is this: The waste heat from lighting helps to warm our houses. If there is less of it, we will have to turn up our heating systems. So, where is the gain?

Light-emitting diodes (LEDs) are more efficient than CFLs, but more expensive – see Catalyst Vol 13 issue 3 in our online archive (www.sep.org.uk/catalyst).

Issue 2: The mercury hazard

CFLs contain mercury, a poisonous substance. If a CFL is broken, mercury vapour enters the air. Isn't this a hazard? And what about CFLs at the end of their lives – won't they pollute our rubbish dumps? This ignores another source of mercury – coal. Much of our electricity comes from burning coal, which contains mercury as an impurity. As coal burns, mercury is released into the atmosphere. We need some numbers to make a fair comparison. Mercury released by a filament lamp in its lifetime: 10.0 mg

Mercury released by a CFL in its lifetime: 2.4 mg

Mercury contained in CFL: 4.0 mg

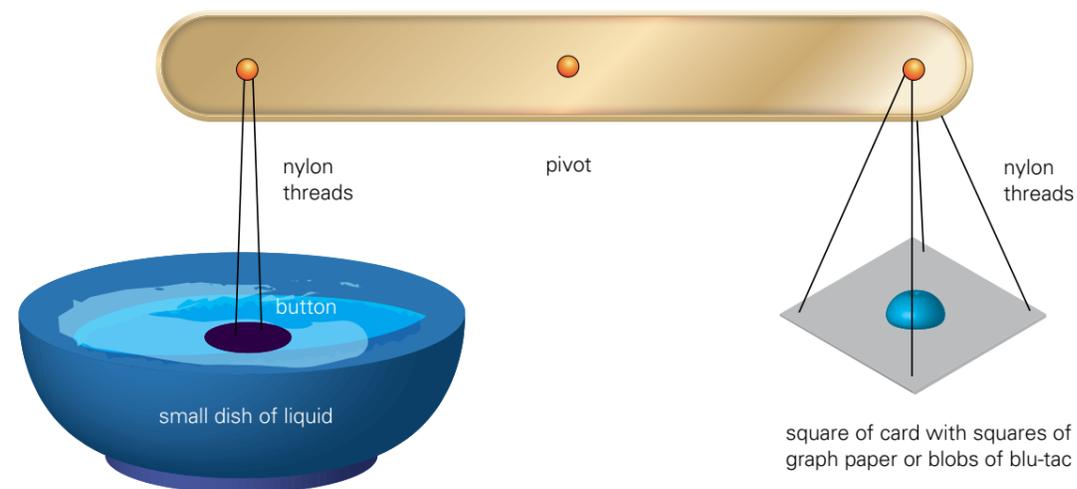
(These are typical figures.)

In fact, CFLs can be recycled and the mercury recovered – you already pay 15 p as the cost of recycling in the initial price of a CFL.

Estimate the concentration of mercury in the air if a CFL breaks in a room of volume 20 m³. Compare this with the safe level, about 0.05 mg/m³ over 8 hours.

Last year, IKEA recycled 80 tonnes of CFLs via its stores worldwide.

Measuring surface tension



In the mid-1800s a lady called Agnes Pockels was washing up when she noticed that there were currents in the water when salts were added. She devised a method for measuring the surface tension in her kitchen which is the precursor to the Langmuir Trough used today (see page xx).

You can make a simple version of this called a 'Button Balance' and use it to measure the surface tensions of different liquids.

You will need

- button (fairly plain and flat)
- lolly stick
- nylon thread or fishing line (this does not soak up water like other threads)
- 3 pins
- needle
- plasticine or blu-tac
- small dish for the liquid
- small square of card
- squares of graph paper (optional)
- water and washing up liquid

What you do

Push the pins through the lolly stick so that they stick out on either side. You will need one near each end and one in the middle. The exact locations of the pins is not critical. It is helpful to have a cloth of some sort to help you push the pins through.

Thread the needle with nylon thread. Pass the thread through the button leaving a long loop. Remove the needle and tie a knot in the thread. Re-thread the needle and use the thread to pass

through the card near each corner to make a small tray. Tie off the thread leaving a long loop. (See diagram.)

Loop the thread of the button round one of the end pins on the lolly stick and the thread of the card tray round the other end. Use the middle pin as a pivot. You can hold this pivot in your hand or balance it on something like two baked bean cans. Stick plasticine as required to the lolly stick to balance the two ends.

Fill the small dish with water. Balance the button on it. Add either squares of graph paper or small pieces of blu-tac to the tray to balance the button. Record how much is required.

Add a drop of washing up liquid to the water and observe the change in surface tension. You will need to add more blu-tac or graph paper squares to balance it. Record the amount required this time.

You can use the button balance to measure the difference in surface tension between different liquids and solutions.

If you want a little more accuracy in your results, weigh a few pieces of graph paper on an accurate balance. Calculate how much each square that you are using weighs.

Look here!

For more information about Agnes Pockels and what she achieved working from home see <http://tinyurl.com/35pfex>
For more experiments on surface tension which you can try at home see <http://tinyurl.com/2qkk3n>

Answer to Box 2
Area of single alveolus is 0.126 mm²
Total area closest to a squash court

JAGO

the Submersible

JAGO is a manned submersible used primarily in marine science research. It can carry a crew of two, pilot and observer, to a maximum depth of 400 m.

JAGO facts

Length: 3.2 m

Width: 2.0 m

Height: 2.5 m

Weight: 3033 kg

Displacement: 3200 litres

Cruising speed: 1 knot

Energy supply: batteries – 24 V, 540 Ah

Propulsion:

4 reversible thrusters (horizontal)

2 side-thrusters (360° rotatable)



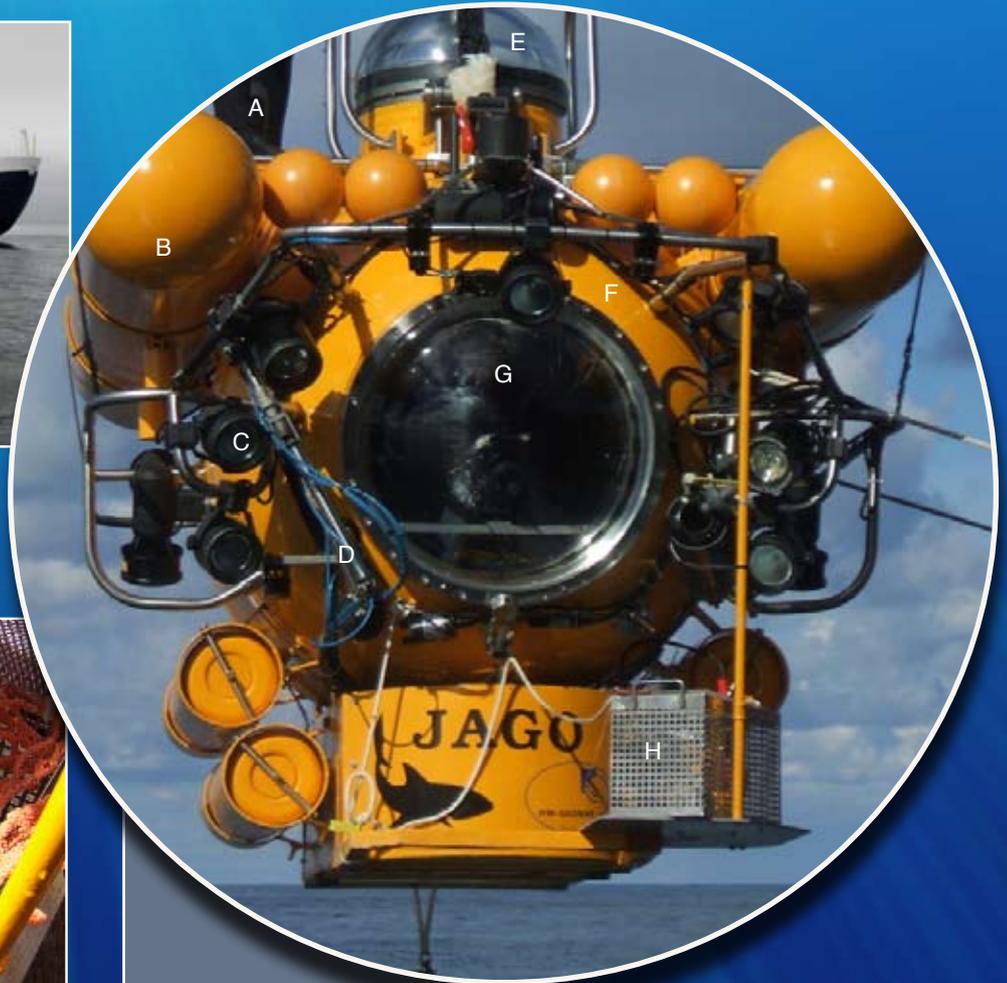
JAGO communicates with its 'mother-ship' by underwater telephone and VHF radio.



A basket of freshly-collected samples

Scientists using JAGO

marine biologists
microbiologists
geologists
palaeontologists
sedimentologists
biogeochemists
oceanographers
(not to mention film crews and photographers)



- A Jason Hall-Spencer's legs
- B Compressed air supply
- C Underwater lighting
- D Hydraulic manipulator with exchangeable claws
- E Entry hatch
- F Cylindrical pressure hull (15 mm thick)
- G Observation port (acrylic, 80 mm thick)
- H Sample collection basket

That name:

JAGO is called after the big-eye houndshark, *Iago omanensis*, which in turn is named after Iago in Shakespeare's *Othello*. JAGO celebrated its 1000th dive in June 2007.

JAGO finds its way around using an underwater tracking system, magnetic compass, GPS satellite navigation, vertical and horizontal sonar, and depth gauges.