Spring 2006 Issue 1

SCIENCE in SCHOOL

In this Issue:

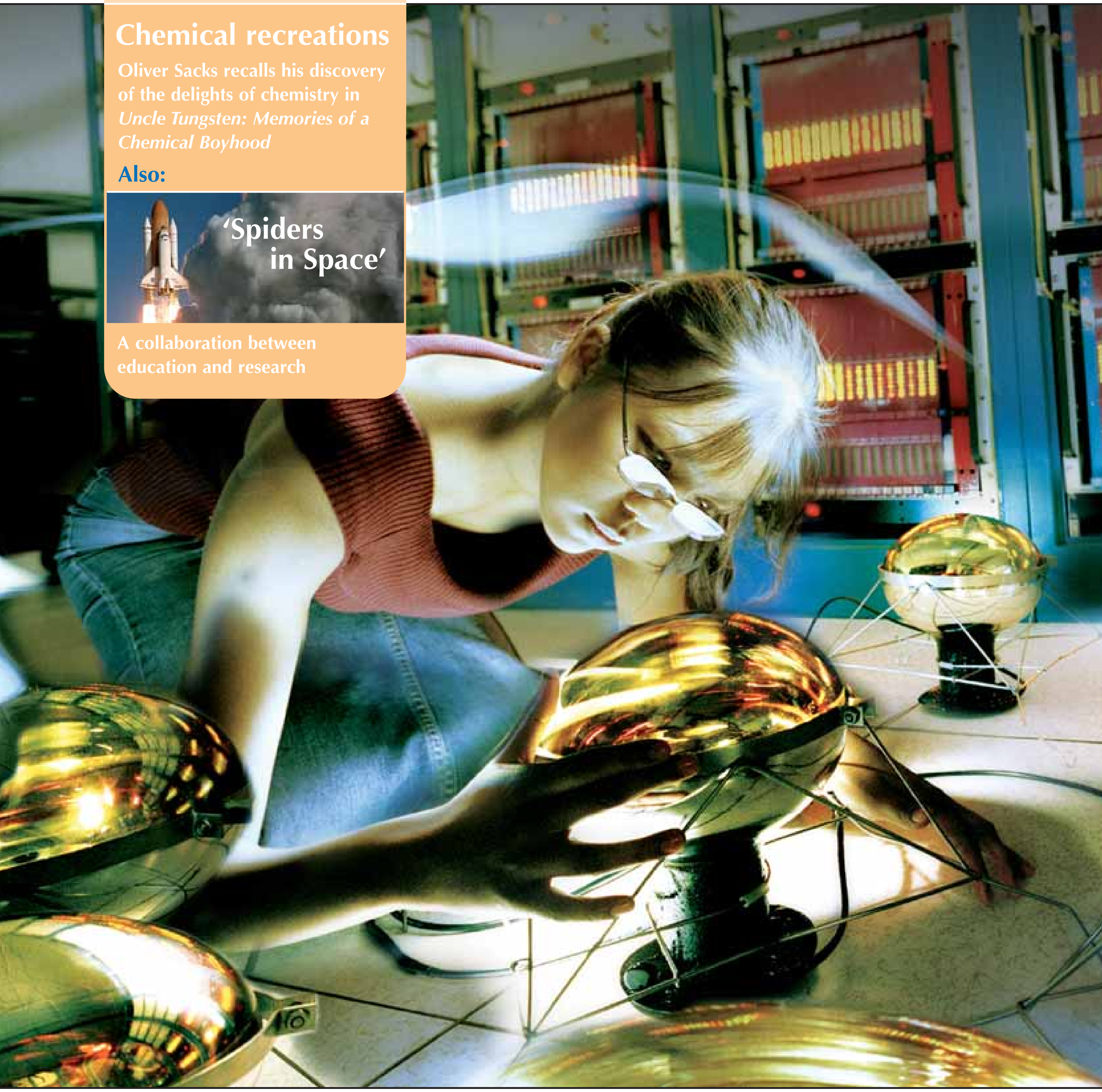
Chemical recreations

Oliver Sacks recalls his discovery of the delights of chemistry in *Uncle Tungsten: Memories of a Chemical Boyhood*

Also:

'Spiders in Space'

A collaboration between education and research



Highlighting the best in science teaching and research

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Cover Image
Jasmine Ma, a summer student working on the MiniBooNE experiment, inspects one of the phototubes that detect light from neutrino interactions (Credit: Fermi National Accelerator Laboratory)

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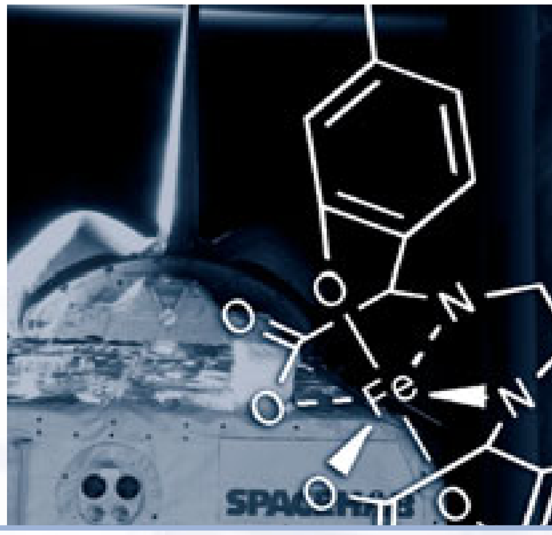


Welcome to the first issue of *Science in School*, a journal to promote inspiring science teaching in Europe. We hope you will be fascinated, informed and indeed inspired by the articles we have chosen.

In creating this journal, we are well aware of some apparent contradictions. Science is international, whereas science teaching is organised nationally or regionally. Most of today's science is highly technical and detailed, yet teachers need to excite beginners. Science is moving very quickly, but it can take many years for new discoveries to work their way into the curriculum. Finally, more and more, the principal language of science is English, whereas the language of the classroom is usually the local language.

But whenever we put teachers from different subjects and countries in the same room, these contradictions fade away in the face of bigger, universal issues. Science is becoming increasingly international and interdisciplinary. Education systems may be national, but children across the world are curious about the same types of things. The most exciting development of the day may happen anywhere in the world or even in space: it may be a discovery on Mars or in the depths of the ocean, a medical breakthrough or a natural disaster. On such days it would be a shame not to put the textbooks aside, and to capitalise on the greatest natural resource in both science and school: curiosity.

For these reasons, *Science in School* addresses science teaching not only across Europe, but also across disciplines: highlighting the best in teaching and cutting-edge research, drawing on the overlap between subjects and the potential for interdisciplinary work. Furthermore, the discussion forum on our website will enable our readers to pose questions, offer solutions and discuss current topics – communicating directly across national and subject boundaries.

We could never have reached this stage without the support and hard work of the scientists, education experts and many teachers who were so enthusiastic about our proposed journal. The European research organisations that constitute EIROforum developed and realised the idea, which the European Union has generously agreed to support for the first four years within the framework of a

larger science education project called NUCLEUS.

Of course, the support of the many teachers, scientists, journalists and others who sent us their articles was also crucial. A teacher may be keen to share a brilliant idea for teaching a new scientific topic or for presenting a worn-out theme in a new and engaging way. Or a scientist may be willing and able to explain a groundbreaking discovery. It is this communication – both among European teachers and between teachers, scientists and everyone else involved in European science teaching – that is key to *Science in School*.

Finally, we have some pleas for help. To achieve its purpose, *Science in School* needs to be read – by teachers, in museums, in ministries and by all those involved in European science teaching. If you can help us tell people about the journal – whether by email, via your website, by distributing flyers or even by sending out printed copies of the journal – please email us.

While we will make every effort to publish online in as many languages as possible, we need help! If you translate or adapt the articles, for example by creating versions of teaching materials that fit your curriculum, please send us your work so that we can make it available online to other teachers.

Very importantly, you can help by telling us what you think of our first issue. What do you like about it? What would you change? Which articles did you find particularly useful? Please give us your feedback via our online questionnaire: www.surveymonkey.com/s.asp?u=416071774513

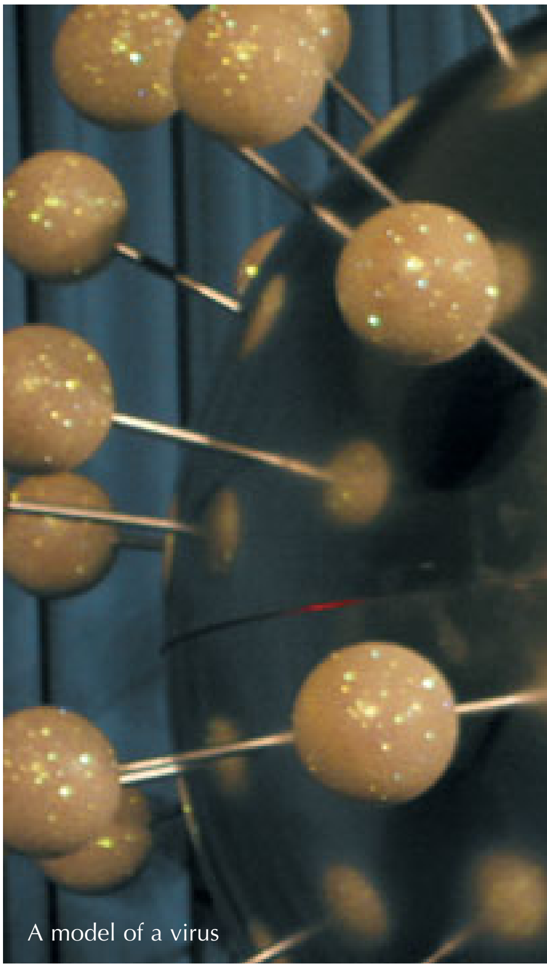
And lastly – please keep sending us your articles!

Eleanor Hayes
Editor, *Science in School*

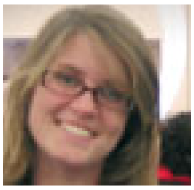
editor@scienceinschool.org

Science teachers take centre stage

Would you know how to turn a bucket into a seismograph, how to make a scale model of a DNA double helix from cans and bottles, or how to simulate a human eye with the help of a shampoo bottle? **Barbara Warmbein** from the European Space Agency in Noordwijk, the Netherlands, finds out.

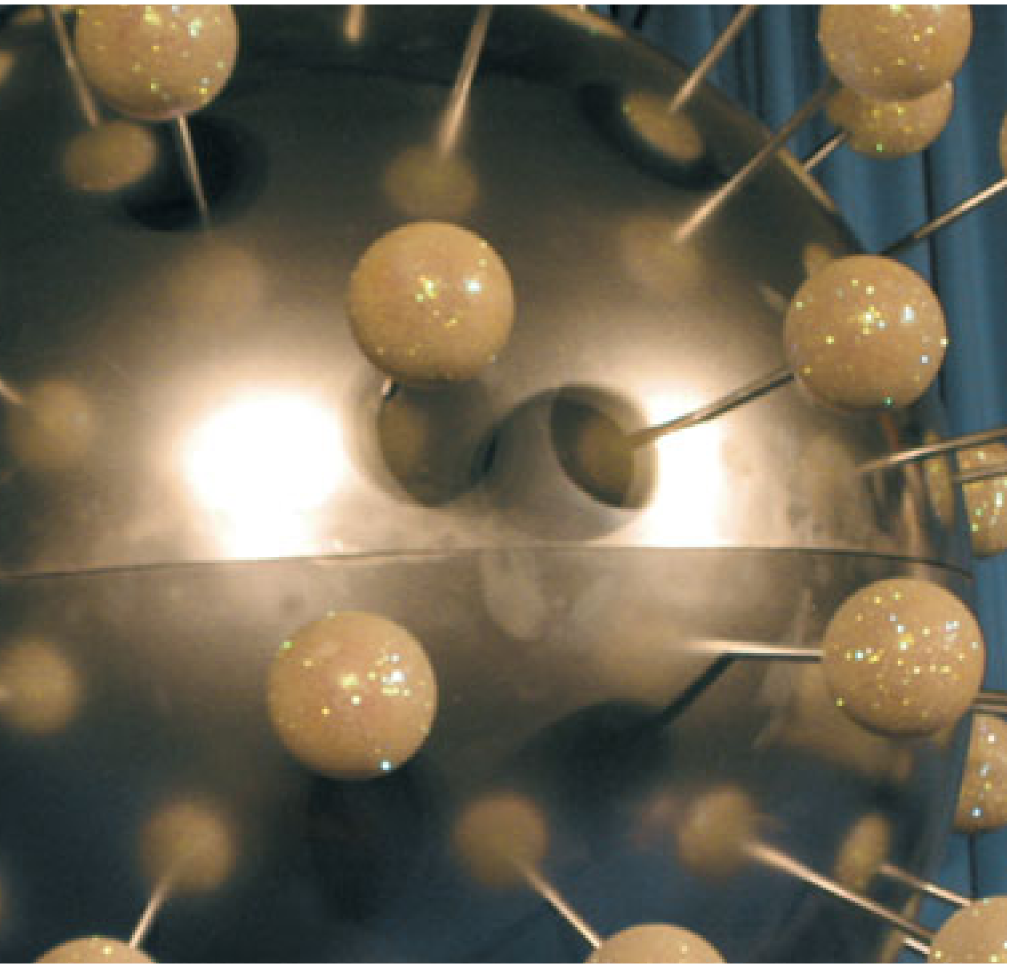

A model of a virus

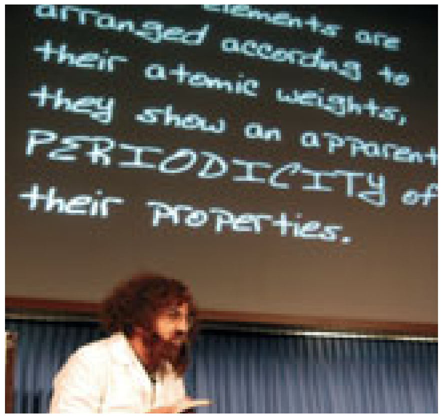
More than 500 science teachers from 29 European countries left with hundreds of new ideas for their classroom after a week of experiments, shows and workshops at Science on Stage at CERN, the European Organization for Nuclear Research, in Geneva, Switzerland. They are probably trying them out in the classroom right now.


Author, Barbara Warmbein

Science on Stage is the follow-up project to Physics on Stage, a science teaching festival organised by the seven research organisations of the EIROforum and supported by the European Commission. Whereas the first three events concentrated on making physics teaching more attractive, the festival now includes biology, chemistry and mathematics. Its formula hasn't changed, however. The heart and soul of the five-day festival is the science teaching fair, a big marketplace where every country has a booth and teachers can spend all day showing their experiments and projects and being inspired by their colleagues. They also meet in workshops to discuss trends in science teaching, to learn more about current research topics or to exchange ideas for school projects, and every day there are performances and presentations that approach science from a theatrical, artistic point of view.

"This is wonderful," says Melanie Sondershaus, a teacher from Germany who came to Geneva to present her interdisciplinary project on Einstein. "Five days are not enough to see





Above: German presentation: SOS the giants are coming!

Below: The Italian performance 'Elements: a magic chemical show'

everything!" A Romanian colleague agrees: "It's a great opportunity to meet other teachers and be inspired." Science on Stage had themed days ranging from Space and Astronomy Day, Einstein Day and Life Sciences Day, to Sustainability Day and Technology and Science Day. Many countries organised their booths accordingly, and at the end of each day science journalist Myc Riggulsford featured the most inspiring projects on a demonstration stage to wrap up the day's theme in an hour-long show.

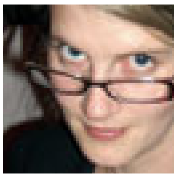
An international jury selected the most inspiring projects for the European Science Teaching Awards. Seven teachers received prizes donated by one of the seven EIROforum organisations, consisting of site visits, equipment or book tokens. Additionally, there were four cash prizes – money that will go into developing the project further and making it more widely known. See 'Space balloons, mousetraps and earthquakes: it's Science on Stage!' on page 8 for details of the award-wining projects.

The next Science on Stage international festival will take place in Grenoble, France, from 2-6 April 2007: www.scienceonstage.net

Albert Einstein in microgravity

Space balloons, mousetraps and earthquakes: it's Science on Stage!

Science on Stage and the European Science Teaching Awards 2005: choosing the best of the best, special mentions and how the jury voted. **Myc Riggulsford**, UK science broadcaster and journalist, and **Barbara Warmbein**, from the European Space Agency in Noordwijk, the Netherlands, describe how the difficult decisions were made.



Author, Barbara Warmbein

Author, Myc Riggulsford

Mad, scruffy, elegant, shock-haired and awesome, Europe's best science teachers were at CERN in Geneva, Switzerland, in November 2005 to celebrate the best of the best in physics, chemistry, biology, mathematics and general science teaching.

Well, 'scruffy' is a bit unfair, as the Swedish delegation turned out in full evening dress despite the freezing marquee and snow outside, to sing songs and make ice-cream in the Nobel Prize Junior project, demonstrating their dynamic approach to making science fun. And fun it was. Not to mention the excitement of €17000 in prizes in the final celebration of Science on Stage. So just how does a jury decide which top-class projects are worthy of even further praise and prizes, when each one has somehow inspired schoolchildren to find science exciting?

The jury was drawn from a wide range of backgrounds: Eleanor Hayes, editor of *Science in School*; Henri Boffin from the European Southern Observatory; Chris Warrick of the European Fusion Development Agreement; and Fernand Wagner, president of the European Association for Astronomy Education and a practising physics teacher.

And us: Barbara Warmbein, editor at the European Space Agency, and Myc Riggulsford, a science broadcaster and journalist who presented the Science on Stage festival highlight sessions, a brand new idea for this year's festival which singled out some of the best projects and put them on stage.

The jury looked for teaching excellence, inspiration and motivation of young people. The European Science Teaching Awards are backed by the European Commission and the EIROforum, a collaboration of international science facilities, with prizes

A Hungarian student demonstrates a model of the nervous system

to help make outstanding methods and models available to other European colleagues. Science on Stage was run in 29 countries, involved thousands of science teachers from around Europe, and finished with over 500 of the national winners representing their countries at the world's largest atom-smashing facility: CERN in Switzerland.

But with every single project in the science fair so excellent and inspiring, it made the judges' jobs tremendously difficult. We decided that we would look for extra special criteria – such as a project which inspired girls to take an interest in the traditionally male 'hard' sciences. Such as the Danish project in which recycled copper wire was stripped and turned into silver-plated jewellery, making Nanna Kristensen's idea so simple yet brilliant.

We wanted projects which crossed curriculum boundaries, which could be repeated elsewhere by other teachers, and which could be used in any type of school. And we wanted new ways of thinking and reaching out about science.

For too long, too many physics teachers have had mental walls around their laboratories, so it was a delight to find UK school librarian Mandy Curtis and her display of cross-curricular activities to celebrate Einstein Year, underlining the lesson that many more non-science students can be reached with the right approach outside the lab. In a similar spirit, Italian science teacher Gianluca Farusi used an exquisite Piero della Francesca painting to demonstrate the chemistry of pigment extraction and the physics of forensic painting analyses, see 'Teaching science and humanities: an interdisciplinary approach', p 30.

We also realised that some schools have access to more money and resources than others, and so we looked particularly at projects from the former Eastern bloc, those which made the best use of scarce materials, and those which cheaply demonstrated important scientific principles or had special relevance through explaining a difficult concept in a simple way. We found stands full of miniature volcanoes, impact craters, magnets, circuit boards, candles and electrostatic wigs. And teachers who presented the experiments with so much enthusiasm that you just had to stay and watch.

In the category 'cheap but successful', Tobias Kirschbaum's models from Germany were outstanding. He had set his students to work out how an ancient Chinese seismograph worked, so they designed a model which drops a marble from a dragon's mouth, showing the direction from which an earthquake came. They then used bicycle spokes and elastic to demonstrate wave propagation. See

The mousetrap:
it just runs and runs

'Tracing earthquakes: seismology in the classroom', p 41.

In an extraordinary combination of recycling, art and biology, Greece's Evanthia Papanikolau made a wonderful DNA helix from plastic drinks bottles, strung together by their lids, which was not only in proportion to the size of the biological components, but allowed cell division and DNA replication to be demonstrated by simply unscrewing the bottles and matching each half with new ones.

We could not decide on our best definition for innovation – were we looking for new ways of teaching old science, old ways of teaching new science, or a radical approach to the latest developments? In the end, we tried to look for all these things. From Portugal, we found Maria Matos and Maria Carvalho, who used reference fungus and lichen collections not only to identify the different species they found on field trips, but also as a cheap and simple way of measuring air and water pollution, showing that old taxonomic skills have new relevance today.

There was no prize category for team effort, a country, stand or group of exhibits, or perhaps the Swedish group would have won an award for their daily themed exhibits – arriving one day in full evening dress, another in space gear. We were looking for individual experiments, a special teacher to single out.

Some experiments came as an exciting themed package, such as the bombs, rockets and other action models of Eilish McLoughlin and colleagues from Ireland. Similarly, we were impressed by Wim Peeters from Belgium, whose box of experiments, called 'Physics is Cool', could be used in any school, narrowly beating other similar projects such as Giorgio Häusermann's Swiss version called 'Einstein's Box'.

In amongst the physicists, we also found biologists with new ways of explaining the functions of the human body, sometimes using several science disciplines. We liked the working model of a heart made by Dimitris

Why not join us at Science on Stage 2 in 2007?

Zamagias from Greece, but in the end we awarded the prize to Hungary's Agota Lang for her nerve model, 'Garfield the Lazy Cat', and to Jerzy Jarosz and Aneta Szczygielska, at the Polish stand, for their outstanding full-size body showing the workings of the cardiovascular system.

Our greatest assets as judges were the science teachers themselves, as sometimes we simply followed the crowds to see what fascinated them, and which experiments they liked best. And if we had a prize for sheer vivacity, enthusiasm and downright danger, then surely it would have gone to the whole Spanish delegation, whose constant energy – on stage and off – kept everyone enthralled. And nearly lost Myc his eyebrows.

Unfortunately, we could not award prizes to everyone, so we had to leave out Michael Sach from Germany, with his students' mousetrap-powered racing cars, Cypriot software designer Alberto Florentin's computer-based teaching tool, and the simple Romanian model eyeball made from a shampoo bottle. And if we had given a prize for the most effective but least high-tech project, it surely would have gone to Hungary for the simple trick of a sheet of paper and a piece of wood to demonstrate air pressure and resistance.

Finally, the experiment which most summed up the spirit of Science on Stage, and which we rewarded with the top prize of €4000, was Catherine Garcia-Maisonnier's weather balloon, with its gondolas designed, built and equipped by her French schoolchildren. They patiently worked out what they wanted to measure and how they wanted to measure it, throwing out the impractical and the too heavy, to achieve an outstanding experiment which worked on many different levels, and reached a truly impressive height!

Well done everyone – without you, science and Europe would be a greyer place. We rely on you, the science teachers, to inspire the youngsters of today to become the scientists of the future, and you exceeded all our expectations. It was a pleasure working with you and seeing how much fun science has become – we just wish you had been around when we were at school.

Now the only thing left to do is to tell the world. You can double the value of Science on Stage by forgetting your modesty and telling newspapers, radio and television about your success. Does your cousin work for the local paper? Is your neighbour a journalist? Go out and tell people, and inspire your colleagues and schoolkids, so that the cliché of boring science lessons becomes just as antiquated as the cliché of mad scientists that you all proved wrong during Science on Stage.

Science on Stage is not about prizes and winning – it's about exchange and inspiration. But the European Science Teaching Awards are part of the fun; they are something to show at home, a recognition of your effort. If you didn't receive a prize this year, try again at Science on Stage 2, which will take place in Grenoble, France, from 2-6 April 2007. Get involved in your national event now – all details are on www.scienceonstage.net

Upcoming events

3-4 April 2006
Manchester Conference Centre, UK
Science for All: is Public Engagement Engaging the Public?
Delegates are invited from all sectors, disciplines and communities to join the Engaging Science Conference, organised by the Wellcome Trust. Those interested in public engagement practice, the arts, science, communications, social inclusion, education, public debate or policy will have the opportunity to meet and consider how we can reach out to all sectors of society.
More information: www.wellcome.ac.uk/node6235.html
Contact: conferences@wellcome.ac.uk

3-4 April 2006
EMBL Grenoble, France
ELLS LearningLAB: Explorer les molecules: de la structure a la fonction
The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools. Teachers are invited to join this workshop on the structure and function of biological molecules (in French).
More information: www.embl.de/ELLS
Contact: ells@embl.de

26 April 2006
Università degli Studi di Milano, Milan, Italy
GMO as Natural Evolution of Agricultural Productivity
CusMiBio, the Centro Università di Milano Scuola per la diffusione delle bioscienze, invite high-school teachers and students to join a discussion on agricultural productivity and modern technologies for generating genetically modified organisms. The discussion will take place at 3pm in room 403, Università degli Studi di Milano, via Celoria 26, 20133 Milan. Invited speaker: Prof. Maurizio Cocucci, University of Milan.
More information: www.cusmibio.unimi.it
Contact: anna.cartisano@istruzione.it or cinisa@tiscali.it

11-13 May 2006
EMBL Heidelberg, Germany
From School to University: EMBO's 5th international workshop on secondary school biology education
This workshop focuses on the critical transition from secondary school to university. It will include scientific talks and an exhibition of education resources, as well as hands-on practical experiments organised by the European Learning Laboratory for the Life Sciences. Based on the presentations and discussions, a report will be produced for circulation to policy-makers throughout Europe. Practising biology teachers, academic scientists, policy-makers, ministry representatives and those involved in designing curricula, creating initiatives for modernising teaching and developing resources for the classroom are welcome.
More information: www.embo.org/scisoc/education.html
Contact: scisoc@embo.org

17 May 2006
Communication Centre of the German Cancer Research Centre, Heidelberg, Germany
2nd Symposium for Pupils of the Initiative Youth and Science
The Initiative Youth and Science cooperates with industry, research institutions, universities and schools to establish a network of out-of-school activities for young, talented pupils. This symposium offers school students the chance to present activities in the life sciences and technology, to get in touch with scientists and to learn about nanotechnology in a series of presentations.
More information: www.exploheidelberg.de/aktion/lernlabor/Schuelerforum2.htm
Contact: wendt@explo-heidelberg.de

19 May 2006
Oberhausen, Germany
'Innovative Technologies Move Europe' closing presentation
In September 2005, Lenord and Bauer and Science on Stage Deutschland e.V.

started the European project 'Innovative Technologies Move Europe'. Teachers and pupils from Germany, the Netherlands, Belgium and the Czech Republic work in teams to create innovative projects. The final projects will be presented in English at the closing session in Oberhausen, Germany. No registration is necessary.
More information: www.science-on-stage.de/254.0.html
Contact:info@science-on-stage.de

12-14 June 2006
EMBL Heidelberg, Germany
ELLS LearningLAB
The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools. Teachers are invited to join this workshop. (Theme to be arranged; the working language will be English.)
More information: www.embl.de/ELLS
Contact: ells@embl.de

3-8 July 2006
Santa Cruz de La Palma, Spain
10th EAAE Summer School
The European Association for Astronomy Education is the first all-European network for teachers interested in astronomy. The EAAE organises a summer school each year to offer teachers access to specific research, new educational materials and methods, and the chance to exchange experiences.

This summer school is open to all teachers who work in primary and secondary schools in European countries, and will be held close to Santa Cruz de la Palma on the Canary Islands, Spain. The preliminary theme of this summer school is 'Astronomy in Canary Islands: practical activities for schools'. During the week, around a hundred European teachers will attend general lectures, working groups, workshops and observational sessions.
More information: www.eaae-astro.org
Contact: ros@mat.upc.es

10-12 July 2006
Hellenic Pasteur Institute, Athens, Greece
ELLS LearningLAB
The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools.

The course will cover the following hot topics: sequencing of the human genome and applications in biomedicine; stem-cell technology and applications; new and re-emerging pathogens (resistance to antibiotics and antiviral drugs; a need for new antimicrobial drugs). Teachers are invited to join this Greek-language workshop.
More information: www.embl.de/ELLS
Contact: ells@embl.de

15-19 July 2006
Forum am Deutschen Museum and the Deutsches Museum, Munich, Germany
Euroscience Open Forum (ESOF) 2006
ESOF brings together all groups involved in scientific endeavour, including researchers, policy-makers, representatives of industrial research and development, science journalists and the general public. It fosters debate about science and society, presents science and the humanities at the cutting edge and stimulates scientific awareness. The programme will include hands-on experiments.

This year, ESOF and the German national science week (Wissenschafts-sommer) will be happening at the same time in Munich – a perfect excuse to visit the Bavarian capital.
More information: www.esof2006.org
Contact: siemin.beyersdorf@w-i-d.de

15-21 July 2006
Munich, Germany
German national science week (Wissenschaftssommer)
For this week, almost everything in Munich will revolve around science. Laboratories and institutes will be open to the public during the Lange Nacht der Wissenschaften (The Long Night of Sciences), exhibitions will display intersections between science and art, while current issues and research discoveries will be discussed in symposia, talk-shows and cultural events.

This year, the Wissenschaftssommer and ESOF 06 will happen at the same time in Munich – a perfect excuse to visit the Bavarian capital.
More information: www.wissenschaft-im-dialog.de
Contact: info@w-i-d.de

4-9 September 2006
Braga, Portugal
Socrates/Comenius Contact Seminar 'Building Bridges: Towards an Improved Science Education'
The 3rd International Conference and Symposium on Hands-on Science offers those involved in science education an opportunity to exchange experience on syllabus and policy matters, social factors and the learning of science, and other issues related to science education, concentrating on the increased use of hands-on experiments in the classroom.

The contact seminar, 'Building Bridges: Towards an Improved Science Education', will promote the discussion and preparation of

new Comenius 1 and Comenius 2 school projects.
More information: www.hsci.info/hsci2006
Contact: sasa.divjak@fri.uni-lj.si

22-24 September 2006
Wolfsburg, Germany
'Teaching Science in Europe' conference
At the conclusion of the biennial European exchange process for developing teaching concepts and materials in science education, the publication 'Teaching Science in Europe' will be presented.
More information: www.science-on-stage.de/312.0.html
Contact and registration: info@science-on-stage.de

27-29 September 2006
EMBL Heidelberg, Germany
ELLS LearningLAB
The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools. Teachers are invited to join this workshop (theme to be arranged; the working language will be English).
More information: www.embl.de/ELLS
Contact: ells@embl.de

3-4 November 2006
EMBL Heidelberg, Germany
7th EMBL/EMBO Joint Conference 2006: Genes, Brain/Mind and Behaviour
This conference will consider the current – and future – uses of new neurological knowledge and technologies. What are the consequences when biochemical solutions to behavioural problems such as depression, addiction, or eating disorders take precedence over attempts to repair the social environment or defective interpersonal relations? How do we avert the risk of psychopharmacology being abused for neurochemical enhancement?

Although new knowledge coming out of the neurosciences has an enormous potential benefit, treating or manipulating the mind also has important social, legal and bioethical implications. These are some of the main issues that will form the basis of this conference.
More information: www.embl.de/aboutus/sciencesociety/conferences/2006/scope06.html
Contact: halldor.stefansson@embl.de or andrew.moore@embo.org

Throughout 2006
Europe-wide
Marine photography competition
By sharing the enthusiasm of scientific discovery and the beauty of the sea, Marine Genomics Europe wishes to raise awareness among European citizens of the value of science and the need to protect our marine heritage. In a photography competition, underwater images will be publicly exhibited during 2006 in a travelling exhibition at aquaria, museums and schools. Schools, science museums and others are invited to host the exhibition.
More information: www.marine-genomics-europe.org
Contact: barbier@sb-roscoff.fr

Date by arrangement
Schullabor Novartis, Basel, Switzerland
Workshop 'Gentechnik Erleben' (Experience Genetic Engineering)
These workshops focus on practical laboratory work, but background information is given for all experiments. Students isolate plasmid DNA from bacterial cultures and digest it with restriction enzymes. The resulting DNA fragments are separated and visualised by gel electrophoresis. Students should already have the necessary theoretical background and be over 17 years of age. The workshops are free, are run in German or English (on request) and have a maximum of 20 participants.
More information: www.schullabor.ch
Contact: gesche.standke@novartis.com

If you are organising events that would be of interest to European science teachers and would like to see them mentioned in *Science in School*, please email details, including date, location, title, abstract, website and contact email address to editor@scienceinschool.org.

The feature article by Oliver Sacks could not be reproduced for copyright reasons. To read this article, please visit the *Science in School* website: www.scienceinschool.org.

Defying the laws of physics?

Scientists working at the Institut Laue-Langevin (ILL) and the University Joseph Fourier in Grenoble, France, have discovered a crystal that appears to defy the laws of gravity. **Giovanna Cicognani** from ILL reports.

Equipment required: one inelastic neutron scattering instrument

One of our first encounters with physics is the mysterious transformation of water: from its solid state in the freezer to a liquid at room temperature and finally to a gas on the stove. Later we learn that although different substances have wildly different freezing and boiling points, just about everything can be transformed into these states – and the key is temperature. But what about something that melts when cooled and solidifies when heated?

Marie Plazanet, an instrument scientist at the ILL, and her colleagues have identified an aqueous solution that forms a milky-white solid when heated to about 60°C and that turns back into a homogenous, transparent liquid when cooled. The solution is a mixture of water, a sugar called alpha-cyclodextrine, and methylpyridine, a component of plastic.

To get a feeling for just how strange this is, says Giovanna Cicognani, Scientific Coordinator at the ILL, you could imagine a glass of Coca-Cola® with ice in it. "Everybody knows what would happen with time – the ice would melt and the Coca-

BACKGROUND

The recipe

To create the mysterious mixture discovered by the Grenoble scientists, mix 200 mg of alpha-cyclodextrine ($H_{60}C_{36}O_{30}$) with 1 ml of 4-methylpyridine (H_7C_6N) and a very small amount of water. The mixture should be liquid at room temperature. When heated, it should become solid.

Neither the mixture nor its constituents are dangerous, but 4-methylpyridine is very smelly.

BACKGROUND

Hydrogen bonds

Water is a member of a group of substances called the Group VI hydrides. Many of these are vile-smelling gases: hydrogen sulphide, hydrogen selenide and hydrogen telluride - each more repellent than the next. Is that true of all of the Group VI hydrides? Well, not quite. Hydrogen oxide is an exception in several ways: for one thing, it is odourless; for another, it is a liquid. Of course, it too can be dangerous: prolonged contact with the solid form can cause tissue damage, and in gaseous form, it can cause severe burns. Nonetheless, hydrogen oxide – water – is also essential to life on earth.

So what makes water so different from the other Group VI hydrides? Principally, hydrogen bonds.

A hydrogen bond is an attractive force which exists between polar molecules of opposite charge. As the name implies, one part of the bond involves hydrogen atoms. Water molecules, for example, are polar molecules which have a partial negative charge (the oxygen atom) and a partial positive charge (the hydrogen atoms). When water molecules are close together, their positive and negative charges attract each other.

The hydrogen bonds that form between water molecules account for some of the essential – and unique – properties of water. It is the attraction due to hydrogen bonds that keeps water liquid over a wider range of temperatures. This is because the energy required to break multiple hydrogen bonds causes water to have a high heat of vaporisation; that is, a large amount of energy is needed to convert liquid water, in which the molecules are attracted through their hydrogen bonds, to water vapour, in which they are not.

Cola would cool down a bit. In this case, though, when you heat the glass to 60°C, the whole thing would solidify."

The scientists investigated the substance using neutrons generated by a nuclear reactor operated for research purposes at the ILL. A chain reaction in the reactor produces neutrons, which are collected in a controlled, tightly focused beam that is aimed at crystals or other materials. The neutrons in the beam collide with neutrons in the sample, creating a diffraction pattern that can then be reinterpreted into a high-resolution picture. This yields an atom-by-atom map of the sample.

"We used neutrons to probe the inner properties of our solution, showing that, in the solid phase, a rigid and ordered structure is formed, even though another part of the mixture remains liquid," explains Ralph Schweins, an ILL scientist and a member of the experimental team.

The Grenoble scientists believe that this change of state can be explained by the formation and breakage of hydrogen bonds. Above 60°C, hydrogen bonds form between either the cyclodextrine and the methylpyridine, or the cyclodextrine and the water molecules, maintaining the stability of the solid. At lower temperatures, these hydrogen bonds break and new hydrogen bonds form between the cyclodextrine molecules, which result in the solid becoming a liquid again. Modelling of the molecular movements in the solution has confirmed these findings.

So the substance doesn't really defy the laws of physics after all. But it does give some interesting insights into hydrogen bonds, which play a vital role in our lives – not just when it's cold outside and we're hoping for snow!

Resources

The findings are reported in more detail in: Plazanet M et al. (2004) Freezing on heating of liquid solutions. *Journal of Chemical Physics* **121***:* 5031-5034, doi: 10.1063/1.1794652

With its international funding and expertise, the Institut Laue-Langevin (ILL) offers scientists and industry the world's leading facility in neutron science and technology. From its Grenoble site in south-eastern France, the institute operates the most intense neutron source on earth. For information about ILL, its research and events, visit: www.ill.fr

Information on the Université Jacques Fourier in Grenoble can be found at: www.ujf-grenoble.fr

The Institut Laue-Langevin

CLASSROOM ACTIVITY

Discussion:

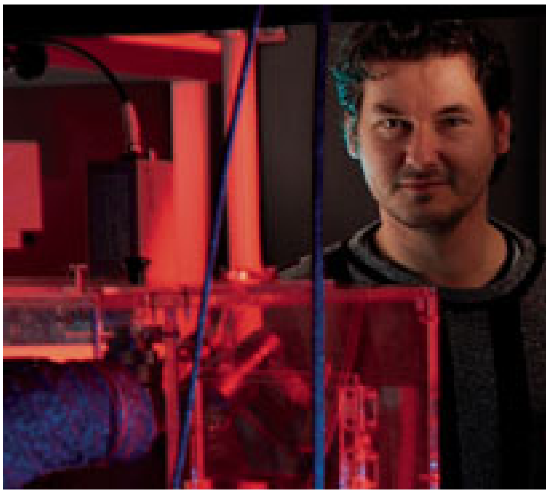
1. Can you think of a practical application for the newly studied mixture?
2. Can you think of any other mixtures that might behave in the same way?
3. Explain hydrogen bonding in your own words.
4. Why is hydrogen bonding so strong in water but not in other Group VI hydrides?
5. Do you know any other examples of hydrogen bonding?
6. Are you aware of any uses of state change?
7. How much do you know about neutron analysis? How much can you find out on the worldwide web?

REVIEW

The laws of physics are seemingly defied. In a humorous style, we learn that the gaseous state does not necessarily follow the liquid state as temperature increases. Instead, some substances melt when cooled. This article gives a nice example of investigating an old topic (hydrogen bonds) in the light of recent discoveries.

Monika Musilek-Hofer, Austria

A bright future for light microscopy



Want to catch an enzyme in the act? Or watch an embryonic brain hard-wire itself? **Russ Hodge** from the European Molecular Biology Laboratory in Heidelberg, Germany, explains how recent development in microscopy show cells and organism at work.

Between the 1830s and 1870s, a series of improvements in light microscopes led to a new era in biology. Earlier microscopes suffered from poor resolution and image distortion because they relied on a single lens. The addition of a second lens solved part of this problem, and in 1830, English opticist Joseph Jackson Lister discovered that setting the two lenses a specific distance apart eliminates a type of distortion called spherical aberration. The result was a huge jump in resolution that permitted German physiologist Theodor Schwann and Matthias Jacob Schleiden, a German botanist, to prove that animal tissues were composed of cells.

In the molecular age, the focus of most biologists has moved to proteins and other molecules that are too small to observe individually with the light microscope. Under the electron microscope, very large molecules or complexes can sometimes be seen as fuzzy shapes, but the most important details are still lacking, and it is impossible to use this method on living cells or tissues.

In the mid-1990s, scientists discovered that a molecule from jellyfish called green fluorescent protein, which makes the animal fluoresce, could be attached to specific proteins in other organisms. This process of tagging created new, glowing molecules that could be tracked under the light microscope as they moved through living cells and tissues. It gave researchers a fairly simple way to obtain information about when and where specific proteins are produced in the body, where they end up in cells, and what they might be doing there.

Now biologists and physicists have developed methods to obtain even more information from fluorescent proteins. And another invention is permitting researchers to watch biological processes as they happen, in three dimensions. Scientists at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, are using these techniques to take a new look at some of the most fascinating questions in biology.

FLIM, FRAP and FRET

Philippe Bastiaens' microscope looks like a cross between a kitchen counter and a laser light show. The instrument is mounted on a metal table large enough to seat ten people. When the young Dutch scientist flips a switch, a needle-thin ray of blue light zips between mirrors and lenses in a zigzag pattern.

The job of the laser is to illuminate a sample that contains fluorescent proteins. It excites the atoms of the tagged molecule, which then releases energy and makes the molecule visible. This happens only once before

Philippe Bastiaens, Eric Karsenti and Philipp Niethammer with a laser microscope used in FRET studies

the molecule's fluorescence is spent. If a large number of identical, tagged molecules are excited, they emit a unique pattern of energy. Philippe's instruments allow him to measure this energy with extreme precision, which can yield important information about a protein's activity.

"For example, the pattern of emission changes when the protein binds to another molecule," Philippe says. "So we can detect the rates at which proteins bind and release each other. These are often reactions that happen so fast you can't detect them any other way." The technique is called FLIM, for fluorescence lifetime imaging microscopy.

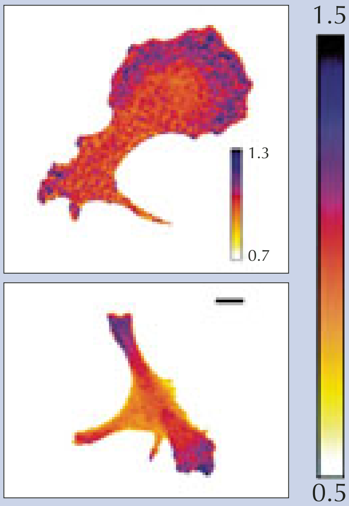
"There are other differences that can be detected as well," Philippe says. "Suppose that the protein you have tagged interacts with another molecule and causes a chemical change in it. When this happens, you find yet another fluorescence pattern. You can make profiles for all these different things and tell which one is happening. It puts us in the position of being able not only to watch close encounters between molecules but also to observe what they are doing to each other. Previously, if you wanted to say that one molecule is activating another, you had to rely on much less direct evidence."

If you illuminate a region of a sample for too long (for example, a section of the cell nucleus, or another cellular compartment), all of the fluorescent energy is used up, and the region becomes bleached. Philippe and his colleagues have used this bleaching technique to watch how molecules move through the cell. For example, receptor proteins on the outer membrane help cells receive signals from their neighbours and the environment. Scientists believed that these molecules are brought inside the cell for recycling, but it has been difficult to prove. They could see receptor proteins in the cell interior, but it was hard to tell whether these molecules were travelling towards the membrane or had been brought back in. Philippe and his colleagues focused the laser to bleach a tiny region inside the cell where receptor proteins are known to collect. Then they blocked the production of new proteins, to stop the flow of outward-moving molecules. When the bleached area once again filled with fluorescent proteins, the scientists knew that they were being brought in from the membrane. This method is called FRAP, for fluorescence recovery after photobleaching.

Over the past decade, scientists have added red, yellow and new shades of green to the palette of fluorescent protein tags. One of the most important new techniques in microscopy involves watching the behaviour of two molecules with tags of different colours. Philippe compares FRET (fluorescence resonance energy transfer) to the behaviour of a bucket of sand.

"If two molecules approach each other so closely that they are physically interacting with each other, you detect changes in the fluorescence that they emit," he says. "Suppose that you punch a hole in your bucket; the sand runs out at a certain rate. If you punch a second hole, the rate at which the bucket empties is different. That's a bit like what happens in FRET. The second fluorescent molecule absorbs some of the energy emitted by the first. By detecting the difference in the emission of fluorescence, you observe something that scientists have been trying to see for a long time – direct interactions between the proteins."

Philippe's lab has used FRET to solve some crucial questions. How many receptor proteins are needed to receive a signal, and what happens when they do? One study showed that for a particular receptor, only a tiny number of molecules needed to be activated to set off a rapid chain reaction of chemical signalling within the cell. (Only a small point on the cell surface flashed the fluorescent signature that marked the activation of a receptor.) And the group's most recent work shows how concentra-



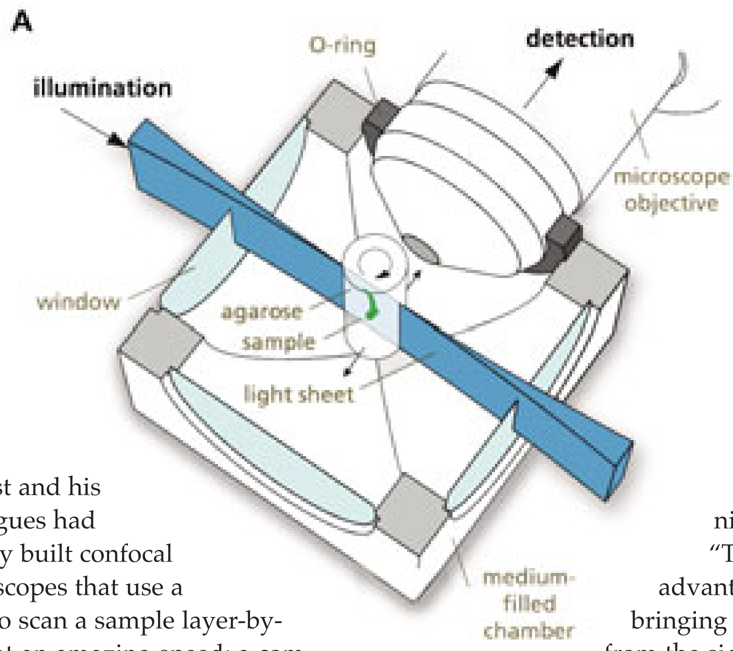
Most of what happens in cells is the result of interactions between molecules. The cell at the top is at rest; the cell at the bottom is crawling along a surface. Using FRET, scientists can reveal where particular proteins are binding to each other, explaining changes in the cell's structure and behaviour. Blue shows areas where many stathmin proteins are binding to molecules called tubulin. This is happening at a much lower rate in the red areas

tions of proteins within particular regions of the cell help create structures called spindles that are necessary for cell division. "Scientists have believed that different chemical sub-environments in the cell play a role in structuring it," Philippe says. "But it's been hard to prove. That's one of the things that FRET is helping us do, by painting a picture of the concentrations of different molecules as they interact with each other."

SPIM

Ernst Stelzer's microscopy group at EMBL has invented or helped improve many types of microscopes. Their latest instrument, called the selective plane illumination microscope (SPIM), allows scientists to peer directly into the bodies of living organisms as they develop.

The internal workings of SPIM

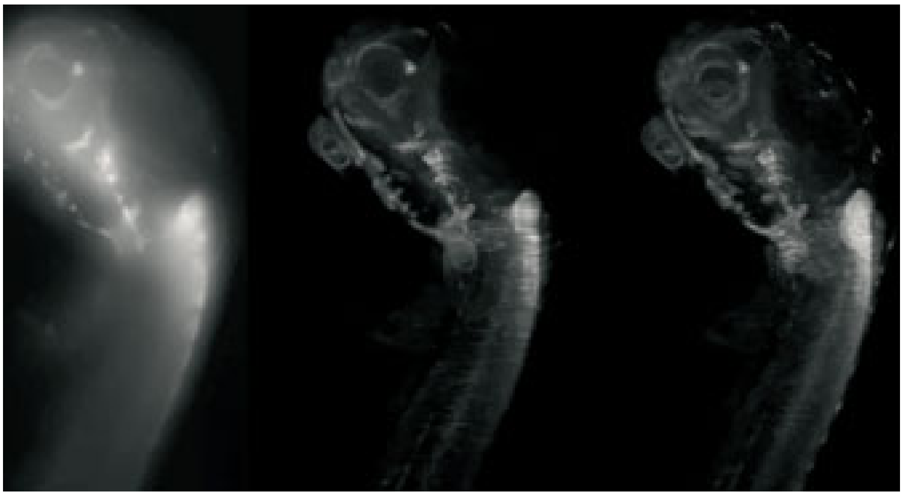


Ernst and his colleagues had already built confocal microscopes that use a laser to scan a sample layer-by-layer at an amazing speed; a computer then assembles the image slices into a three-dimensional stack. "That doesn't go far enough," he says, "because it's still fairly restricted to looking at tissues on flat surfaces – not the real context of cells and organisms." So he began looking for a way to scan whole organisms in their three-dimensional environments.

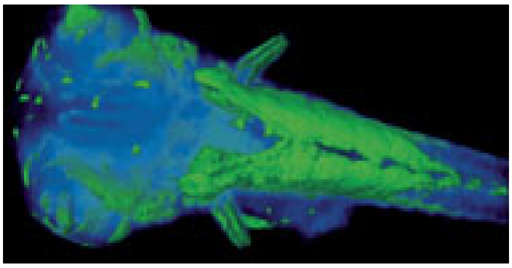
The first innovation was to put the sample – such as an embryonic fish – into a liquid tube, so that it could be seen from all sides. But this didn't solve a crucial problem of resolution. Most light microscopes illuminate a sample along the optical axis – shining a light from the position of the detector (an eye, or the camera) and looking at a reflection, or shining a light through the sample in the direction of the detector. SPIM, on the other hand, passes a very thin sheet of light through the specimen from the side. Only the objects in that slice – such as fluorescent proteins – are illuminated. The tube is quickly rotated so that images can be captured from different angles. As with the confocal microscope, a computer assembles the slices into three-dimensional images – this time a smoothly running film. "The advantage of bringing in light from the side has a lot to do with how microscopes achieve resolution," says Ernst. "If you shine light at an object and view it along the same direction, there are situations where there is just no simple way to judge what is in front and what is behind, or exactly how far away it is. You can obtain good resolution along the two-dimensional surface facing you, and you can study different layers of a sample by moving the focal plane up and down, but a simple fact is that you are still illuminating objects above and below the focal plane, which distorts the two-dimensional image. They are inevitably fuzzy – extended in the third dimension."

Images from SPIM are so sharp that it is possible to observe extremely subtle patterns within tissues. For example, developmental biologists hope to capture momentary bursts of genetic activity that have an important role in creating structures in the body, but which happen so fast that they are rarely observed.

The most immediate application is the chance to watch the development and physiology of inner organs.



An image taken with a standard confocal microscope. Compare with the image of the same type of specimen taken with SPIM (picture below)



A high-resolution colour reconstruction of proteins in the fish

Jochen Wittbrodt's lab, for example, is studying the development of a small fish called medaka. One project is to look at the heart, and with SPIM, an unprecedented view of its development in space and time can be captured. The scientists can visualise an organism's first heartbeats – by peering straight through the body into muscle tissues. "They are also getting an entirely new perspective on things that have been studied for a long time, such as the way the retina rounds up to form the eye cup. By watching how this works in both healthy fish and those with mutations, they have discovered that the textbook version – obtained from static pictures – has to be changed.

Another project with clear medical applications helped attract the interest of Zeiss, one of the world's major manufacturers of microscopes, with plans to further develop and market the instrument. "Fish have an amazing ability to regenerate damaged nerve pathways, and we can watch in real time as their axons re-establish contact," says Jochen. "Thus the new microscope has become a screening tool to help us find the genes that affect this process. One day that information may help us reawaken this regenerative capacity in our own tissues."

REVIEW

There have been significant advances in microscopy in the last decade or so. This interesting and informative article describes new microscopy techniques – fluorescence resonance energy transfer (FRET), fluorescence recovery after photobleaching (FRAP), and fluorescence lifetime imaging microscopy (FLIM) – and their fascinating applications. Green fluorescent protein, a molecule that fluoresces, is used to tag proteins so that molecular behaviour, for example receptor protein interaction and spindle structure and synthesis in cell division, can be visualised. Further development of the confocal microscope has resulted in the selective plane illumination microscope (SPIM), which can scan whole, untreated tissue using a laser to take image slices which are reassembled by a computer programme to form a three-dimensional image. This has been used to track the development of the eye cup, resulting in new information that overturns the current model.

Advanced-level biology students and their teachers usually consider the application of light and electron microscopy, discussing their limitations. This article will inform them of the fascinating developments that take these techniques further and help scientists discover mechanisms in the hidden world of molecular interaction. The article is well written, and is enhanced with illustrations that bring it to life for both teachers and students.

Shelley Goodman, UK

Shipwreck: science to the rescue!

The *Mary Rose* is one of several famous and historical ships salvaged from the sea in recent decades. Thanks to the anaerobic conditions on the seabed, the remains of the *Mary Rose* are well preserved. **Montserrat Capellas** and **Dominique Cornuéjols** from the European Synchrotron Radiation Facility, in Grenoble, France, explain how scientists are working to preserve the ship from decay in the air.

The *Mary Rose*

The *Mary Rose*, the flagship of the English Tudor king, Henry VIII, is the only 16th-century warship on display anywhere in the world. Built in Portsmouth and launched in 1511, she was the pride of the Tudor navy for 34 years until a battle with the French in 1545. The exact cause of the loss of the *Mary Rose* is unclear, although handling error appears to be most likely. Whatever the reason, as the ship leaned and the water entered the gun ports, her fate – and that of hundreds of men on board – was sealed. For over 400 years, she was buried in clay on the seabed at a depth of 14 metres off the south coast of England, until marine archaeologists salvaged her in 1982. The ship offers a rare insight into life at sea in Tudor times, but she needs to be carefully conserved.

Photo courtesy of the Mary Rose Trust

About one-third of the hull of the *Mary Rose* remains after being buried in clay on the seabed for 437 years

The danger of sulphur and iron compounds

Sulphur compounds that have accumulated in the wooden structure of the ship pose the main threat to the salvaged *Mary Rose*. In seawater, bacteria feeding on organic matter, e.g. carbohydrates, $(CH_2O)_n$, reduce sulphate ions, SO_4^{2-}, to hydrogen sulphide, H_2S.

$$(CH_2O)_n + {}^{n}/_{2}SO_4^{2-} \rightarrow {}^{n}/_{2}H_2S(aq) + nHCO_3^-$$

Dissolved hydrogen sulphide, $H_2S(aq)$, then penetrates the wood, where it is transformed into solid reduced sulphur compounds, such as thiols, R-SH (R denotes an organic part), in the lignin of the wood and to iron(II) sulphides when iron ions are available. Over the centuries, the reduced sulphur has accumulated; chemical analyses showed that the hull timbers of the *Mary Rose* now contain about 1% (in total, 2 tonnes) of the element sulphur (S).

Once the ship is removed from the water, the sulphur compounds in the wood slowly oxidise, forming sulphuric acid, H_2SO_4. The acid, if left untreated, could eventually degrade the cellulose fibres of the wood and thus decrease the stability of the hull timbers.

In the presence of iron ions, the threat of acid becomes particularly acute, because iron ions catalyse the oxidation processes and amplify the production of sulphuric acid. The wooden structure of the *Mary Rose*, like that of many other wrecked ships, contains iron from corroded iron bolts, nails and other objects on the ship. On the seabed, dissolved iron(II) ions have combined with the hydrogen sulphide to form iron sulphides, for example pyrite, FeS_2, which is unstable when the moist wood is exposed to oxygen:

$FeS_2(s) + {}^7/_2O_2 + (n+1)H_2O$ Æ $FeSO_4{\cdot}n(H_2O)(s) + H_2SO_4(aq)$

The hydrated iron(II) sulphates melanterite, $FeSO_4{\cdot}7(H_2O)(s)$, and rozenite, $FeSO_4{\cdot}4(H_2O)(s)$, are commonly found as precipitates on sulphur-infested marine-archaeological wood.

X-rays to the rescue

X-rays are known for their medical use in imaging and radiotherapy, but can also help take care of vulnerable shipwrecks. X-rays can non-destructively analyse the elements in an object and their chemical state. To obtain such information for sulphur, the technique of choice is X-ray absorption spectroscopy. X-rays of a given energy are sent to the sample being studied, causing electrons in the inner shells of the sulphur atoms to be excited to higher energy or ejected as photoelectrons. Then either the kinetic energy of these photoelectrons is measured (in a technique known as photoelectron spectroscopy), or the X-rays emitted by the sample when the excited atoms return to their normal state (X-ray fluorescence) are analysed to measure the X-ray absorption. In these ways, the binding energy of the excited electron can be obtained, which is characteristic of the type of sulphur compound. For the *Mary Rose*, it was essential to find the quantities and locations of the sulphur and iron

Photo courtesy of the Mary Rose Trust

The hull of the *Mary Rose* has been sprayed with a solution of polyethylene glycol for the past 10 years to replace the water and prevent cracking when drying the timbers

CLASSROOM ACTIVITY

Comprehension questions:

1. The hull timbers of both the *Vasa* and the *Mary Rose* have been found to contain about 2 tonnes of sulphur, as the element S. If 1000 kg sulphur in the wood were in the form of the pyrite, FeS_2, how much sulphuric acid ($H_2SO_4(aq)$) would be produced when all the pyrite is fully oxidised? Two pathways are common: to hydrated iron(II) sulphate:

   $FeS_2(s) + {}^7/_2O_2 + (n+1)H_2O \rightarrow FeSO_4{\cdot}n(H_2O)(s) + H_2SO_4(aq)$

   or to goethite, alpha-FeOOH (as in rust):

   $FeS_2(s) + {}^{15}/_4\ O_2 + {}^5/_2H_2O$ _ $FeOOH(s) + 2H_2SO_4(aq)$

2. Sodium hydrogen carbonate (sodium bicarbonate, $NaHCO_3$) has been added to the re-circulated sprayed conservation solution of the *Mary Rose* to keep its pH about 7. How much sodium hydrogen carbonate would be needed to neutralise the acid formed in Question 1 (from oxidised pyrite containing 1000 kg sulphur)?

3. Crystalline pyrite has a volume of 40 Å^3 per FeS_2 unit and expands dramatically when oxidised. For example, the volume per formula unit of the crystalline hydrated iron(II) sulphate melanterite, $FeSO_4{\cdot}7(H_2O)(s)$, is 243.5 Å^3 and of rozenite, $FeSO_4{\cdot}4(H_2O)(s)$, 162.7 Å^3. Also natrojarosite, $NaFe_3(SO_4)_2(OH)_6$, with a volume of 266.0 Å^3 per formula unit, is commonly found on the *Vasa's* wood.

   Estimate how many times the volume will increase when a pyrite crystal oxidises and a) $FeSO_4{\cdot}7(H_2O)(s)$, b) $FeSO_4{\cdot}4(H_2O)(s)$ or c) $NaFe_3(SO_4)_2(OH)_6$ salts crystallise as products. What effects could these processes have if they took place inside the wood structure?

4. In a chemistry textbook, look up a schematic molecular orbital energy level diagram for the oxygen molecule O_2 in its ground state. Explain how uptake of energy from light can produce singlet oxygen, ${}^1O_2$, with all electrons paired.

Answers are provided on page 88.

BACKGROUND

Synchrotron X-rays

In a synchrotron, electrons are accelerated until they reach a very high energy (six billion electron-volts at the European Synchrotron Radiation Facility (ESRF), in France). These high-energy electrons are then injected into a storage ring where they circulate in a vacuum at close to the speed of light. The synchrotron X-ray beams, emitted when the electrons change direction in strong magnetic fields, are directed towards the experimental stations that surround the storage ring.

The X-ray beams produced by the ESRF are a thousand billion times brighter than the beam produced by a hospital X-ray machine. As a result, these thin and very intense beams of synchrotron light can be used to resolve the structure of matter at a level of detail impossible to reach with standard X-rays. Synchrotron light sources can therefore be thought of as super-microscopes, and are used in numerous fields of research, including materials science, archaeology, biology and physics.

There are currently about 70 synchrotrons in the world. Various techniques, ranging from X-ray diffraction and small-angle scattering to photoelectron spectroscopy and X-ray absorption on a microscopic level, are available to an ever-growing number of scientists. These techniques are used to study matter in its different forms – as a crystal or a polymer, as biological or environmental samples, or as solid, liquid or gas.

The ESRF synchrotron

Synchrotron X-rays are useful for analysing wrecked historical ships, where they are used to determine the quantities, location and chemical state of sulphur and iron compounds in microscopic detail. In this way, researchers can monitor the deterioration of the marine-archaeological wood and improve the methods of conservation.

For this purpose, Magnus Sandström and his team at the University of Stockholm, Sweden, have been travelling periodically to the Stanford Synchrotron Radiation Laboratory in California, USA, since 2001. They started by investigating why acid was forming in the timbers of the *Vasa*, a 17^{th}-century Swedish warship, and have now extended their research to other historical shipwrecks, such as the *Mary Rose*. Last year, they gathered at the ESRF to carry out experiments to complement those performed at Stanford.

compounds in the wood. Very intense X-rays, known as synchrotron light (see box), were needed to investigate the chemical composition of the *Mary Rose* in microscopic detail, and to deduce the best strategy to prevent her from further degradation.

Improving conservation

For long-term preservation of the *Mary Rose*, it seems necessary to remove the strongly acid-forming iron sulphides from the wood. During the current conservation spray treatment, which began ten years ago, the acid is washed away as it forms (see photo). To more rapidly exhaust the acid-forming iron sulphides during spraying, mild oxidation by singlet oxygen ($^1O_2$, short-lived energy-rich oxygen formed by using ultraviolet radiation to excite a valence electron in an ordinary O_2 molecule) could be tested. To increase the rate of the reactions, the temperature of the spray solution could be moderately increased, but the possible formation of *Legionella* bacteria then becomes a health hazard.

Recent investigations, including X-ray microscopic analyses at the European Synchrotron Radiation Facility, allowed researchers to suggest further steps. One method that is being tested removes iron by means of a complex-forming compound, or chelate, known as EDMA (ethylenediiminobis (2-hydroxy-4-methyl-phenyl) acetic acid). EDMA forms very strong bonds with iron(III) and dissolves the iron compounds. Even rust, FeOOH(s), forms water-soluble complexes in alkaline solution with EDMA and can be washed out of the wood. In the absence of iron, the remaining sulphur oxidises slowly and can be controlled with a stable climate and antioxidants.

Above all, it is important to monitor the effectiveness of the treatment, and X-ray analysis is an efficient way to evaluate the iron extraction procedure and the removal of specific sulphur compounds.

Resources

The *Mary Rose* can be visited in the *Mary Rose* Museum in Portsmouth, UK. Information about the ship, activity

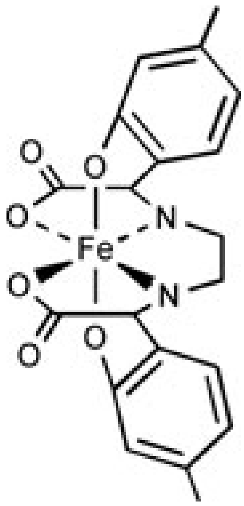
BACKGROUND

Extracting the iron compounds from shipwrecks

Scientists investigating the Swedish warship *Vasa*, which sank on its maiden voyage on 10 August 1628, hit on the idea of dissolving the iron compounds present in the wood and removing them as water-soluble complexes. A chelate called EDMA is being tested. The sodium salt of the soluble iron complex, [Fe(III)-EDMA]-, is used in large quantities as an iron micronutrient in citrus agriculture, for plants that cannot extract iron from alkaline soil in which the iron is insoluble. The compound is used to fertilise orange groves in Spain and to grow lemons and grapes in Italy and France.

When a piece of black oak from the *Vasa* is submerged in alkaline sodium-EDMA solution, the iron compounds in the wood dissolve in the blood-red complex [Fe^{III}-EDMA]-.

Photo courtesy of Stefan Evensen, The Vasa Museum, Stockholm, Sweden. ©Stefan Evensen



The [Fe^{III}-EDMA]- complex with the iron(III) ion, Fe^{3+}, centrally positioned and surrounded by the polydentate EDMA ligand. Six ligating atoms, two nitrogen and four oxygen, surround the small Fe^{3+} ion in a well-fitting octahedral cage. The electron-donating phenol rings enhance the bond strength, but also provide the blood-red colour to the complex. (Carbon atoms are indicated by the corners in the drawing; hydrogen atoms are not shown.)

sheets, and details of visits are available on the website: www.maryrose.org

The *Vasa* is displayed in the *Vasa* Museum in Stockholm, Sweden. Details of the history of the *Vasa*, continuing research into its preservation, and how to visit are available on the website: www.vasamuseet.se

Details of the work of Professor Sandström and his group to preserve the *Vasa* and the *Mary Rose* are available here: www.fos.su.se/~magnuss/

The European Synchrotron Radiation Facility (www.esrf.fr) is an international facility which operates, maintains and develops the most powerful synchrotron light source in Europe with 18 participating countries. More than 5000 researchers come to the European Synchrotron Radiation Facility every year to use the light source and its associated instruments.

REVIEW

This article would be of great interest to teachers of the physical sciences and also to colleagues who teach history. It would be useful for teachers who wish to put more applications of chemistry and physics into their teaching and to promote more positive uses of the physical sciences in unusual situations. It would also serve as stimulus material for older students who could use the very helpful web links for further research into other scientific or historical aspects of this article.

I enjoyed the article. It stimulated me sufficiently to follow up some of the information given.

Tim Harrison, UK

Teaching science and humanities: an interdisciplinary approach

There is an increasing demand for an interdisciplinary approach to teaching, but providing inspiring and achievable lessons is no easy task. Chemistry teacher **Gianluca Farusi** explains how he used two Italian Renaissance paintings to delve into the chemistry of pigment extraction and the physics of forensics.

An interdisciplinary approach

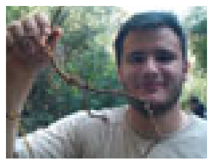
Students are often unaware of the links between the sciences and humanities, as a result of the differences – and, sometimes, opposition – in the way the subjects are taught. In an interdisciplinary approach, a painting provides a very useful starting point. We considered Piero della Francesca's *Pala di San Bernardino* from different points of view.

Approaching the painting from the perspective of the humanities, we asked students to consider its abundant symbolism. For instance, the infant Jesus wears a necklace of coral beads with a small coral branch lying on His chest. Is it a chance choice? Certainly not! The red of the coral represents the blood of Christ (placed on the chest, where Jesus was speared on the Cross), and is symbolic of the Passion and the Resurrection. The ancient Greeks, in fact, connected coral with a heroic feat of Perseus: when he cut off Medusa's head, the gushing blood changed into coral upon contact with the sea, and for this reason, coral is a symbol of rebirth. Students could also discuss the symbolism of the shell, the ostrich egg or other features of the painting.

In terms of mathematics, perspective and the golden ratio are undoubtedly the most important topics to address, but students could also set themselves a geometric goal: to calculate the volume and the area of the vault, for example.

Students addressed the earth sciences by identifying the stone illustrated on the walls, by comparing it to samples of marble, jasper, porphyry and other materials on display in their local museum. Other possibilities in the earth and natural sciences would be to investigate the gems worn by some characters, or to identify the clams and coral and to study their natural environment and life cycle. The most appropriate discussions would depend on the type of museum available.

The chemist's imagination is bound to be captured by colours, and so we decided to prepare one of the pigments that was used by the painter. What kind of pigments did he use? When a painter or a painting is as famous as Piero della Francesca and his works, you can find a lot of information on the worldwide web. Further assistance was available from the Monuments and Fine Arts Office for Pisa, Lucca and Massa Carrara. We looked through entries and reports, and discovered that the linen cloth on the nine wooden boards which support the painting was dyed with alizarin lake. Alizarin is obtained from the roots of madder, *Rubia tinctorum*, a common European plant. And so we departed for the woods and hills, looking for madder roots…

Gianluca Farusi and his students in search of madder roots

The Brera Altarpiece, 1472-74 (tempera on panel) by Piero della Francesca (c.1419/21-92).

Image courtesy of the Pinacoteca di Brera, Milan, Italy / Alinari / The Bridgeman Art Library

From madder to alizarin

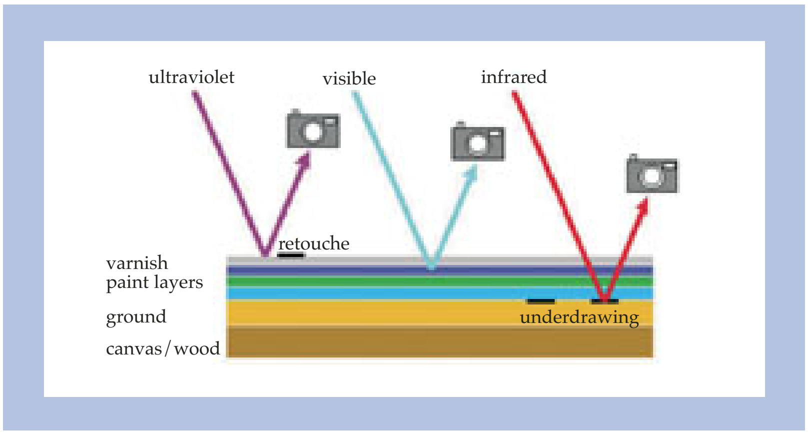
Alizarin is one of two main dyes, the other being purpurin, that come from the roots of the madder plant. It was used to dye cloth in Asia in ancient times and in Egyptian textiles as early as 1600 BC. Its first known use on paper is much later, in 972 AD, when it was used as ink on the marriage certificate of the Byzantine Empress Theophano. It has been used in painting since the 16th century. Madder, common across Europe, is a crawling plant up to 1.5 metres long. The flower is white-yellow and the fruit is a pink-red berry. The stem bears clusters of five or six leaves, the lower sides of which are sticky and rough. The roots are reddish.

Alizarin exists mainly in the fleshy roots in the form of its glycoside, ruberythric acid. Pieces of rinsed roots are treated with a hydrochloric acid solution to hydrolyse the ruberythric acid and remove flavonoids, which would otherwise dull the pigment. The roots are then dried and treated with a solution of alum to extract the alizarin, which forms a red complex.

To obtain the pigment, a soda solution is added to precipitate aluminium hydroxide, which adsorbs alizarin. The pigment, once strained, rinsed and dried, can be used for tempera and oil painting.

The madder plant

The team



Using multispectral imaging to visualise different layers in the painting


Visualising a restoration

BACKGROUND

Alizarin extraction

- The alizarin content of the roots depends on the season and on the kind of soil, although the average content is about 1.9% w/w.
- Soak x g of dried madder root in 0.27 M hydrochloric acid solution (HCl) for 48 h at room temperature. Remove the roots and dry them.
- Add 1.9x cm^3 of alum solution ($KAl(SO_4)_2.12H_2O$) at a concentration of 0.021 mol/l.
  $Al^{3+}{}_{(aq)} + 2C_{14}O_4H_{8(aq)} \rightarrow Al(C_{14}O_4H_8)_2{}^{3+}{}_{(aq)}$
- Boil the mixture for 3 h, keeping the volume constant by adding small quantities of water.
- Allow the mixture to cool and separate the roots from each other.
- Dropwise, add 0.63x cm^3 of soda ($Na_2CO_{3(aq)}$) at a concentration of 0.094 mol/dm^{-3} to the solution.
  $2Al(C_{14}O_4H_8)_2{}^{3+}{}_{(aq)} + 3Na_2CO_{3(aq)} + 3H_2O_{(l)} \rightarrow 2Al(OH)_{3(s)} + 4C_{14}O_4H_{8(s)} + 3CO_{2(g)} + 6Na^+{}_{(aq)}$
- Once the pigment has precipitated, collect it using a Buchner funnel, and rinse and dry it.

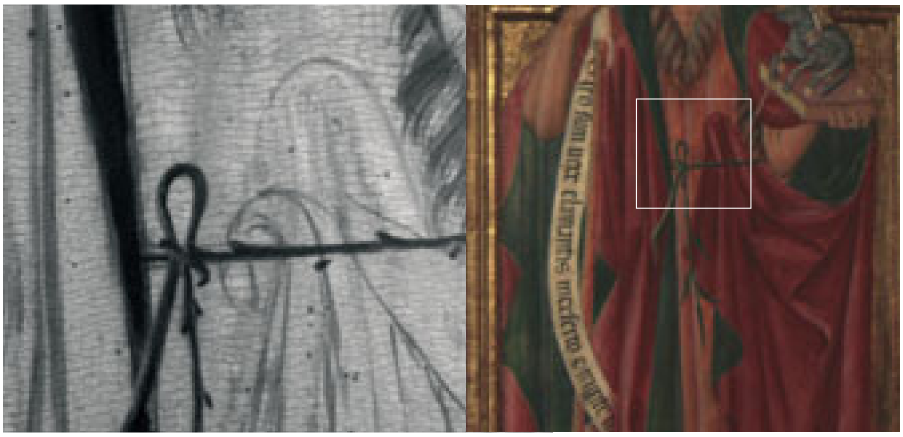
The search for hidden images in the paintings of Pietro da Talada

From the physicist's perspective, a painting is an excellent opportunity to investigate the interaction between matter and electromagnetic waves. The multispectral imaging technique fitted the bill, but where could I find the necessary equipment? And how to do the study? A multispectral imaging investigation of a painting as famous as one of Piero della Francesca's would be too much to hope for!

I contacted the Pisan branch of the National Research Council and Vincenzo Palleschi, head of the Applied Laser Spectroscopy Laboratory, was enthusiastic. A fellow teacher of mine, Lucilla Simonini, a literature teacher, suggested we study Pietro da Talada's works. This minor 15th-century painter can be tentatively identified with the Maestro di Borsigliana and was an exponent of the International Gothic style. Most of his paintings are kept in churches in Garfagnana, northern Tuscany, but two are in Lucca at the Villa Guinigi Museum and at the Lucca Savings Bank Foundation. I contacted Mrs Filieri, head of the Monuments and Fine Arts Office, who allowed us to take photos of both paintings.

Multispectral imaging requires a digital camera interfaced with a monochromator and linked to a computer. The system records light intensity as a function of both wavelength and location. Images can be captured and analysed in broad spectral bands within the ultraviolet-visible and near-infrared regions, and processed and analysed with specially developed software.

If an image is captured in the red, green and blue bands, the superimposition of these three images results in an image of three times better quality than that of a normally exposed film. The image resolution depends on the pixel density on the sensor and on the pixel colour depth (pixel bits linked to each colour tone). With a



Visualising traces of an earlier painting

14-bit colour depth, we had 16384 tones for each primary colour and $(16384)^3$ – almost 4400 billion – colours.

If a painting is illuminated by white light, blue-ultraviolet images include information mainly on surface features, whereas images captured at longer wavelengths carry information on deeper layers of the painting. Therefore, by taking images using different wavelengths, we hoped to discover pentimentos: hidden traces of earlier painting.

The chemical composition of a painting begins to change the moment the painter finishes working on it, because substances undergo oxidative and degradative processes, so pigment colours may change or fade with time. Further changes in composition may be due to restorations. When a mercury lamp filtered to transmit 365 nanometres is used as the excitation light source, part of the ultraviolet radiation is absorbed and given off with a lower energy in the visible region of the spectrum: as fluorescence. With this apparatus, we were able to look for restorations made with pigments that differed from those originally used by Pietro da Talada.

I have seldom seen my students working with such enthusiasm as when, burning with curiosity, they searched for pentimentos. One fine day, the much-anticipated discovery was made! While analysing the painting kept at the Lucca Savings Bank Foundation, we found a pentimento: Pietro da Talada appeared to have changed his mind about the position of a fold of cloth (see above). We were in seventh heaven!

The same day, using fluorescence, we discovered a restoration, highlighted by different shades of pink (see above).

It was a very snowy and cold day, but when I realized that my students were fully aware of how much beauty there is in science, and how much science in beauty, it warmed my heart.

Gianluca Farusi teaches chemistry at the technical school (istituto tecnico industriale) Galileo Galilei in Carrara, Italy. He is also teaches stoichiometry at the University of Pisa, Italy.

REVIEW

This article is an interesting indication of the links between the humanities and the sciences, showing different ways of approaching the topics of electromagnetic waves and dyes.

The protocol for extracting dye is straightforward enough to be carried out in schools and also provides a link to history and botany – as well as an excuse to take a chemistry class outside to search for plants.

The physics-based section describes an interesting way to introduce the idea of the electromagnetic spectrum but is probably more difficult to reproduce in most secondary schools, as it requires specialist equipment. It does, however, provide an interesting link to forensic science and how art forgeries can be identified.

The main difficulty with reproducing the science in this article in many schools would be in obtaining access to the specialist lighting and spectral analysis equipment as well as appropriate works of art. The article can, however, be used as a source of information or as a topic of discussion.

Mark Robertson, UK

Discovering DNA

Dean Madden from the National Centre for Biotechnology Education at the University of Reading, UK, describes how DNA was discovered – and how it can be simply extracted in the classroom.

Johann Friedrich Miescher

In 1868, Johann Friedrich Miescher travelled from his native Switzerland to Tübingen in Germany. The 24-year-old had come to study in the laboratory of Ernst Felix Hoppe-Seyler, a pioneering biochemist who coined the modern name for the red pigment in blood: haemoglobin. After several months of toil in a laboratory in the cellar of Tübingen Castle, Miescher managed to isolate a previously unknown acidic substance from white blood cells (leucocytes) which had been washed from pus-laden bandages from a nearby hospital. Miescher called his discovery 'nuclein' because it was found in the nuclei of the cells. This substance was impure, however, and Hoppe-Seyler insisted on repeating the work himself before he would allow an account to be published in his newly formed biochemistry journal.

Upon returning to his home in Basel in 1870, Miescher refined the method and was able to extract nuclear material from the sperm of the salmon for which, in those days, the Rhine was famed. Like those in leucocytes, the nuclei in sperm cells are relatively large. From these, Miescher extracted pure nuclein for the first time. In 1889 a pupil of his, Richard Altmann, gave us the modern term for nuclein: nucleic acid. Thus, in 2003, we celebrated the golden jubilee of the double helix and not '50 years of DNA'.

To a science teacher, an account of Miescher's methods makes fascinating reading, not least because of the crude techniques available and the striking resemblance they bear to many of today's classroom protocols. Compared with Miescher, however, today's teachers have an easy time. With no refrigeration, Miescher had to start work at 5 a.m. to ensure that the reagents were cold enough to precipitate DNA, and he had to prepare his own protease enzymes from the stomachs of freshly slaughtered pigs (Judson, 1996).

Classroom protocols

The isolation of DNA from everyday materials has become a popular and widespread activity in school laboratories over the past 20 years. Although similar practical protocols had been described previously (e.g. Sands, 1970), these were not widely adopted owing to their complexity and the hazardous nature of several of the required reagents (Falconer & Hayes, 1986). Simpler methods of isolating DNA first appeared in American textbooks in the mid-1980s (e.g. Helms et al., 1986) and subsequently made their way into specialist school biotechnology projects (e.g. Rasmussen & Matheson, 1990). By the early 1990s, these methods had crossed the Atlantic, featuring in German and English publications (Bayrhuber et al., 1990; NCBE, 1991). With the arrival of simple and inexpensive methods, what was an undergraduate or post-16 practical exercise moved down the age range and even into the primary classroom (Assinder, 1998).

DNA from onions

The most commonly used (if not, for obvious reasons, the most popular) method of extracting DNA requires little more than onions, household detergent and salty water. This method became widespread in the UK due to the practical workshops and publications of the National Centre for Biotechnology Education (NCBE, 1991; 1993). More sophisticated methods of extracting DNA from cress and dried peas were developed by Science and Plants for Schools and the Australian CSIRO education centre 'The Green Machine'

The laboratory in Tübingen where Miescher isolated nuclein.

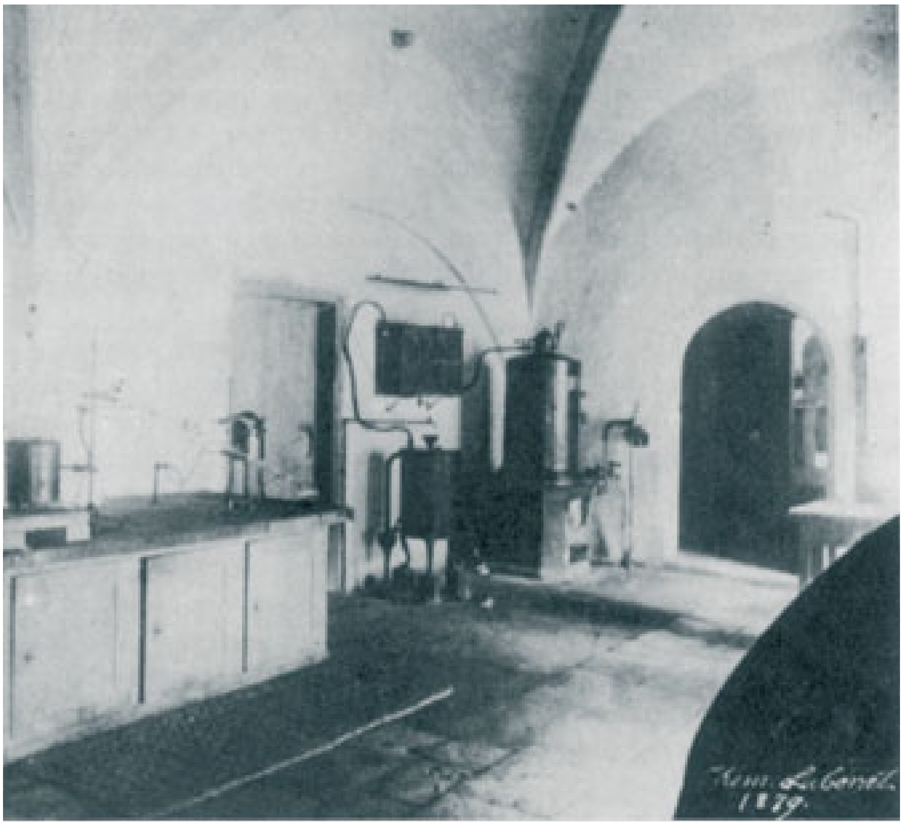


Photo courtesy of the University of Tübingen Library, Tübingen, Germany

(NCBE, 2001), but their inclusion of DNA gel electrophoresis restricted these protocols to use by older students.

In the search for sweeter-smelling alternatives to onions, several have suggested applying the 'onion method' to a variety of fruits, including kiwi fruit, bananas and strawberries. Although these fruits seem to yield copious amounts of DNA, the 'DNA' produced is in fact little more than pectin. This can be demonstrated simply by adding pectinase to the preparation (it's also quite easy to precipitate pectin in alcohol, an old jam-maker's trick).

DNA from peas

The protocol described here uses frozen peas. This has several advantages over the traditional onion method. Firstly, no blender is needed to break up the plant tissue. Provided the peas have thawed, they can be squashed with the back of a spoon or a glass rod. Secondly, supplies of peas can be stored easily in the freezer and taken out in suitable amounts when required. And last, but not least, the peas don't smell! Isolating the DNA (and RNA) takes about 35 minutes, including an incubation period of 15 minutes.

Advance preparation

The ethanol must be ice cold. Place it in a plastic bottle in a freezer at least 24 hours before you attempt this activity. Please read the safety note, below.

Materials and equipment needed by each person or group

- Peas, about 50 g (frozen ones are suitable, but thaw them first)
- Household liquid detergent, 10 ml (use a watery type, not the thicker, concentrated variety)
- Table salt, 3 g
- Distilled water, 90 ml
- Very cold ethanol, about 10 ml, straight from the freezer (industrial denatured alcohol (IDA) is suitable, but please see the safety note)
- Novozymes Neutrase (a protease), 2-3 drops (optional)
- Ice, in a jug with cold water
- Coffee filter paper (do not use laboratory filter paper, as liquid takes too long to pass through it)
- 1 ml plastic syringe (without a needle)
- Large plastic funnel
- Two 250 ml beakers
- Boiling tube or plastic graduated tube
- Glass rod with a flattened end or a spoon for stirring the mixture
- Water bath, maintained at 60°C

Procedure

1. Dissolve the salt in 90 ml of distilled water. Add the liquid detergent and mix gently.
2. Mash the peas using a glass rod or a spoon. Add the pea pulp to a beaker with the salty liquid detergent solution.
3. Stand the beaker in a water bath at 60°C for *exactly* 15 min. This treatment causes the pea cell membranes to break down. The detergent forms complexes surrounding the membrane phospholipids and proteins, causing them to precipitate. In

addition, the sodium ions from the salt shield the negatively charged phosphate groups of the DNA molecules, causing them to coalesce. At 60°C, DNase enzymes, which would otherwise start to cut the DNA into fragments, are partially denatured.

4. Cool the mixture by placing the beaker in an ice-water bath for 5 min, stirring frequently.
   This slows the breakdown of the DNA that would occur if a high temperature were maintained.
5. Filter the mixture into a second beaker. Ensure that any foam on top of the liquid does not contaminate the filtrate.
   The filtrate contains the soluble proteins and DNA.
6. Optional: add 2-3 drops of protease to about 10 ml of the pea extract in a boiling tube and mix well.
   The protease will degrade some of the proteins in the preparation.
7. Very carefully pour ice-cold ethanol or IDA down the side of the boiling tube, to form a layer on top of the pea extract.
8. Leave the tube, undisturbed, for a few minutes.
   Nucleic acids (DNA and RNA) are insoluble in cold ethanol and will precipitate into the upper (ethanol) layer.

Further investigations

A hook for recovering the DNA can be made by briefly heating the tip of a Pasteur pipette in a Bunsen burner flame, then bending the tip round before allowing the glass to cool. To electrophorese the DNA extract, simply dissolve some of it in about 0.5 ml of bromophenol blue loading dye, then load about 20 μl into a well in a 1% agarose gel. Staining with 0.04% (w/v) Azure A solution after electrophoresis will reveal the nucleic acids. RNA shows up a lighter pink colour (Madden, 2000).

Variations of this extraction procedure can be used for other food items, such as fish sperm (milt or soft roe) or fish eggs (Strömberg, 2001). Several publications refer to the use of calf thymus tissue, but its use in schools is no longer recommended (see safety note, below).

Safety

Ethanol in freezers

Most freezers are not spark-proof. Consequently, you must ensure that ethanol is placed in the freezer in a sealed, vapour-tight container. An alternative to using a freezer is to stand the sealed bottle of ethanol in ice for several hours before use. For more information about safety in schools when working with DNA, teachers in the UK should consult *Topics in Safety* (Delpech & Madden, 2001).

Use of animal tissue

Since the discovery of bovine spongiform encephalopathy and variant Creuzfeldt-Jakob disease in the UK, UK school safety authorities advise that calf thymus should no longer be used in schools, as there is a risk (albeit small) of accidental exposure to the infectious agent while the extract is being prepared.

Suppliers

Most of the items required for this procedure can be obtained from a supermarket.

Novozymes Neutrase can be bought in small volumes from the UK's National Centre for Biotechnology Education (www.ncbe.reading.ac.uk).

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Acknowledgement

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Scientists at play: teaching science process skills

Sometimes in the wealth of detail of modern science, we lose sight of the unifying factor: the scientific method. **Alfredo Tifi, Natale Natale** and **Antonietta Lombardi** explain how they encourage the skills of enquiry, hypothesis and testing.

Process skills are fundamental to science, allowing everyone to conduct investigations and reach conclusions. We are convinced that there is a serious educational gap in this area, both in bringing these skills into the classroom and in training teachers to do this. It is obviously a multifaceted problem, which involves school administration and teacher education, as well as the development by students of the necessary social skills to collaborate effectively, share, debate, defend and extend ideas in groups. To facilitate the introduction of science-enquiry principles in school, we developed a set of lab activities for use in primary and secondary schools.

Most school science practical lessons are based on content: doing experiments to determine the variables that affect bean growth, for example. Even when those practical sessions are well managed, the contents often overwhelm the process of investigation, preventing students from extrapolating what they are doing to more general principles of scientific method. To develop a scientific way of thinking, students need "multiple opportunities to work with these skills in different content areas and contexts"[w1]. Thus our approach has been to create content-free laboratory games where the focus is on the process rather than on particular scientific content. Process skills tend to last longer than learned content, and we believe these thinking patterns can be readily transferred to new situations. We think that method-based, hands-on investigative activities should be a significant component of science teaching, at the same level as hands-on content-based activities, rather than both being superficially covered even in the more fortunate schools.

From content-based activities to black boxes

In the past, our group has researched content-based hands-on activities in subjects ranging from the properties of matter to materials, interactions and systems and energy. We were inspired by the Science Curriculum Improvement Innovation Study program, from which we had drawn content such as variables and models and theories, without being completely aware that these were mainly process areas. During our research on modelling activities we discovered that:

1. Students in the grades 3-5 (age 8-12) found highly demanding activities based on investigation and modelling challenging and amusing.
2. Younger students used a lot of imagination to make sound hypotheses about relevant problems.

We concluded that enquiry can be the most appealing part of science for students of every age, and that children's imaginations permit them to carry out abstract processes.

So, over the past two years we concentrated on developing activities in which students probe black-box systems or phenomena. Their task is to find patterns, develop explanations and build models that reproduce the behaviour of these black-box systems. Working out a model implies activating most science process skills: observing, inferring, predicting, controlling variables, hypothesising, planning experiments and carrying them out.

The black boxes need to be tailored to the age and level of the classes. Some examples are given below.

Grades 1-2 (age 6-8)

Children shake a sealed can. They weigh it, listen to the sounds, and try to guess what materials or objects are contained inside. There is a software counterpart of this game for older students in which a hidden object must be identified through simulated tests: squeezing, dilution, flame-testing, weighing, X-ray analysis, two-dimensional sonar imaging and magnetism[w2].

Children in grade 2 (age 7-8) and above can also use the operating machines described below.

Grade 3 (age 8-9)

In the ‘circuit game’, students use a self-made lamp probe and contact points to reveal a hidden network of connections made from aluminium strips. When students remove the cover and see the real circuit, they are usually disappointed because it differs from their prediction.

Grade 4 (age 10-11)

The ‘dice-in-a-box’ game has a dice with coloured faces in a box with a translucent window, so that only one face of the dice is visible at any time. Students must toss the dice in the box, guess how many of the faces have which colour, and draw an unfolded, two-dimensional model of the dice. This demonstrates to the children that scientists need to design models when they are unable to directly examine real objects. As an example, we tell students that the earth’s core is just a model that was drawn from studies of how seismic waves are reflected at a certain depth, from which the existence of a discontinuity was deduced.


A triangular array of bottle tops


Students acting as attribute transformer machines

Grades 5-8 (age 11-14)

In pattern experiments, students have to find regular patterns among coupled variables. For example, in a triangular array, they try to determine the relationship between the side number and total number of bottle tops.

Using a plastic Slinky®, the students try to determine the relationship between the rhythm of oscillations and the number of coils free to oscillate. In another experiment, they deduce from the elongation of a spring how many coins are weighing it down. Using a guitar string, they try to determine the relationship between tension and pitch.

In other experiments, the students make predictions graphically or using empirical mathematical relations, without mechanistic explanations based on physical laws.

Work in progress

Thanks to in-service teacher trainers and other volunteer tutors, we are testing a range of tools with students. We are keen to gain support from an educational research institution, to be able to plan and implement systematic teacher training. By reassessing teacher training, awareness could be raised of science-process principles, in line with European projects to introduce enquiry-based methodology into science education[w3, w4].

Operating machines

These games involve ‘transformer machines’ that are fed input and emit processed elements of the same type. The elements can be attribute blocks or integer numbers.

Attribute block machines: ideal for grades 2-3

This activity uses coloured attribute blocks – a typical Italian set has 48 pieces (four shapes, three colours, two dimensions and two thicknesses). The ‘attribute transformer machine’ changes one or two attributes at a time according to a rule. For example, the transformer rule might be ‘ALL red OR thick blocks become yellow AND big’. Other blocks remain unchanged as they pass through the machine. The class conducts experiments to guess the mechanism. This involves a series of trials, an analysis of outcomes, the development of hypotheses, and tests to confirm or discredit these hypotheses, to create more or less stable models.

When we begin this game, we let a student play the role of a ‘virtual transformer machine’, holding the rule in his or her head. The student might think up the mechanism, or it might be chosen from a set of mechanism cards prepared beforehand. The other children play the roles of investigators, with the goal of predicting the outcome of the transformation. The student who is running the mechanism puts the input block into a box and extracts the output block.

Students could then progress to the software version, MOBL (the Italian acronym for attribute blocks operating machine[w5]). This can also be projected onto a screen while the class tackle the problem as if they were a team of scientists. If there are enough computers, they could also work in groups of three to four.

Numeric operating machines

These machines have integers as inputs and outputs. Transformations involve the four elementary operations, odd-even comparison, < = >, modulo, and combinations of these operations for higher levels.

To introduce the number-operating machines, the students can simulate the machine, as above.

We have developed three software machines[w6], MO11, MO12 and MO21, the names of which indicate the number of inputs and outputs. MO21 is the most intriguing because of the opportunity it offers to control two experimental variables (Table 3). Currently, we are developing operating machines that can be used online. Teachers or children can select the appropriate level of complexity of the transforming mechanism, from grade 2 (age 7-8) up to high school.

These machines permit the students to save the hidden randomly generated mechanism and to reload it later, allowing more difficult investigations to be shared with or delegated to other 'scientist teams'. With this option, we aim to encourage persistence and to foster cooperative strategies, both of which are fundamental to scientific work. The following tables show examples of trials and experimental outcomes.

As the students use the operating machines, they discover that the models must be changed as new evidence is acquired. There are different models possible to explain Table 1, for example:

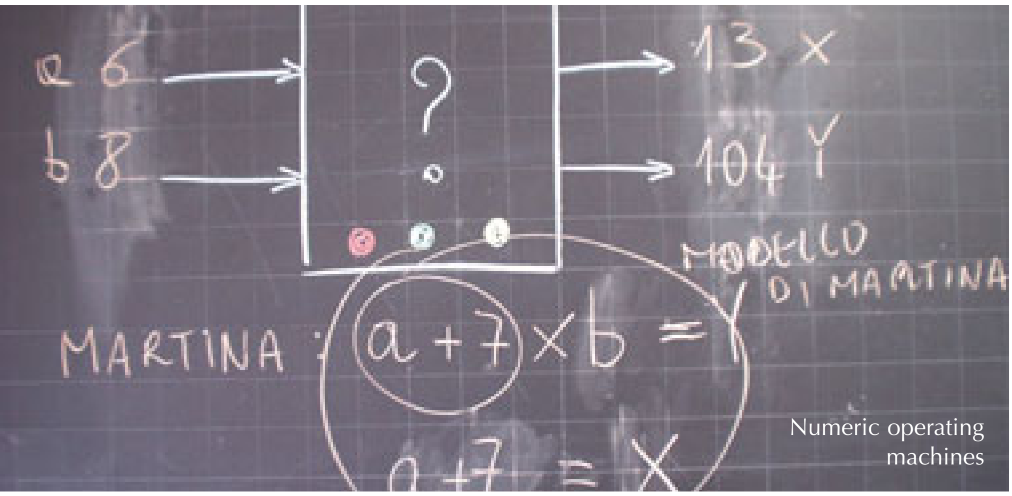
a) Output = input + (input – 2)
b) Output = (2 x input) – 2

Children of different ages envisage these models very differently – primary school children will not think of them in terms of algebra, of course. For very young children, mechanism a) is beyond their comprehension for numbers below two, because they are unable to calculate (1 – 2) or (0 – 2).

As teachers lead these activities, they should concentrate on highlighting the underlying principles: students need to become aware of the skills and principles they are using, and to talk about them using general terms such as variables, outcomes, predictions, evidence, experiments, tests, hypotheses, confirmation and models. We consider that this vocabulary makes up 50% of process skills and meta-cognition; the other 50% lies in applying these skills in authentic problem-solving activities.

Some basic principles of the science process skills that emerge are:

1. Both input and output data in experiments must be recorded.
2. The first approach to exploring a phenomenon involves 'open field' experiments.
3. Experiments should be conducted according to a systematic plan.
4. Data from the experiments should be presented according to specific ordering criteria; some presentations are better than others to help the enquirer recognise a pattern.
5. Effective models must account for all the experiments, rather than each piece of evidence from the experiment having a separate model.



Numeric operating machines

Contraptions

The principle behind contraptions is similar to that of operating machines, but these are physical black-box

Input	3	5	8	4	1
Output	4	8	14	6	0

Table 1: Experiment with an MO11 mechanism

Input	1	2	3	4	5
Output	0	2	4	6	8

Table 2: When principles 3 and 4 are applied to the data in Table 1, the pattern emerges more clearly

Input	2;1	2;2	2;3	3;2	1;2
Output	4	8	14	6	0

Table 3: An MO21 mechanism in which the effect of two variables is investigated

CLASSROOM ACTIVITY

Submit your own contraptions!

In the next issue of *Science in School*, Alfredo Tifi, Natale Natale and Antonietta Lombardi will describe some of the contraptions they have developed and provide detailed instructions for building them. In the meantime, why not send us your own ideas and designs for contraptions to develop process skills in students?

machines that have at least two external, movable parts that act as input and output. The parts may be coloured threads, rotating knobs or stems, penetrating bars or tilting levers. The two are coupled through an inner mechanism of gears, pulleys, belts and wheels.

Final comments

We would be delighted if this project contributes to and triggers similar ideas and a discussion on method-based science practical sessions. We are convinced that a crucial ingredient of doing science – the development of process skills – should be taught first in content-free investigations, where more attention can be paid to the spontaneous discovery, elicitation, generalisation and sharing of principles captured by authentic problem solving. From this starting point, students can move on to content-based enquiry. True experimental contexts bring in high levels of background noise, and put a heavy load on the memory; in this context, it is almost inevitable that process skills are neglected.

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w2 – Laboratorio. Download or execute from: www.scuolamediacaiatino.it/ didattica/lab/prova8.swf

w3 – Scienceduc: www.xplora.org/ww/en/pub/xplora/nucleus_home/scienceduc.htm

w4 – 'Pollen' Project: www.paueducation.com/news/docs/241/187-2-1.pdf

w5 – Download or execute MOBL software from: www.scienzainrete.it/MOBL/macch_operatrici_BL.htm

w6 – Download operating machines: www.scienzainrete.it/unita_didattiche/macch_operatrici.htm

Resources

Proceedings of European Summer School for Primary Science Trainers (held in Sicily from 9-14 July 2005) are available from: www.xplora.org/ww/en/pub/xplora/nucleus_home/scienceduc/workpackages.htm

Metzenberg S. Reading: The Most Important Science Process Skill: www.youth.net/ysc/educnews/readscie.htm

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REVIEW

This article deals with science process learning in school, and I recommend it for teachers in both primary and secondary schools. It emphasises the importance of teaching science-inquiry principles from grades 1-2 upwards.

Sølve Marie Tegner
Stenmark, Norway

Tracing earthquakes: seismology in the classroom

Chinese dragons that predict earthquakes? Waves of glowing jelly babies? Earthquake-proof spaghetti? Physics teachers **Tobias Kirschbaum** and **Ulrich Janzen** explain how they teach geophysics.

Ulrich Janzen (centre) and Tobias Kirschbaum (right) discuss Tracing Earthquakes at Science on Stage

Wave diffraction and energy transport are standard components of physics courses for 16- to 19-year-olds across Europe. Usually, students have to prove their knowledge in examinations which concentrate on the exploration of springs, Slinkies® or other classical mechanical devices.

Recent didactical research, however, stresses the importance of integrating scientific theories and models into contexts to which the students can relate. No one will have been left unaffected by the destruction caused by Hurricane Katrina in the USA or the recent earthquakes in Iran, for example.

Simplifying and explaining a concept to younger pupils is a powerful way for older students to make sure that they have thoroughly understood the topic. Developing effective demonstrations, as well as actually teaching younger pupils, fosters the multiple intelligences which proponent Howard Gardner describes as inherent to all groups of students.

The basics of seismology can be integrated into normal coursework. The experiments we describe, however, are also well suited for presenting natural sciences and their importance to a wider public – for example at school open days. And of course, the presentation skills developed by the students can be important later in life.

So much for our reasoning, as we planned a physics course with our older students. At this point, however, the creativity and enthusiasm of the students took over.

The students used web resources, newspaper reports and their textbook, but above all, they soon started to develop their own ideas of what is central and essential to seismology. They began to create model experiments, starting with coupled pendulums and culminating in an attempt to model a tsunami. Three topics proved particularly rewarding: an ancient Chinese seismograph, a simple wave machine and an investigation of earthquake-proof buildings.

Reconstructing an ancient Chinese seismograph

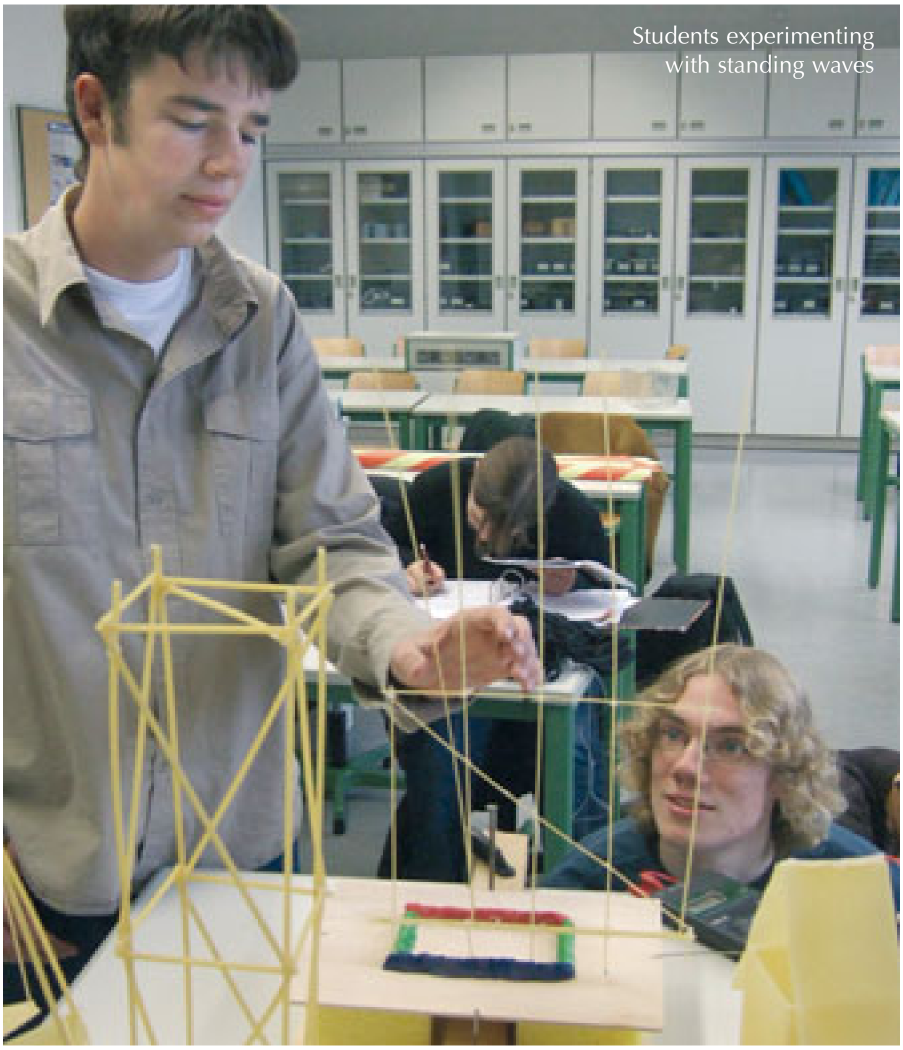
Reports exist of an ancient Chinese seismograph, built some thousand years ago and supposedly of incredible sensitivity. As descriptions survive only of the external appearance, nobody knows how the seismograph was constructed inside. Even though there are books which offer some

The ultimate in recycling: a Chinese seismograph reconstructed from a dustbin

ideas, nobody – to our knowledge – has ever managed to reconstruct a working model of the original seismograph.

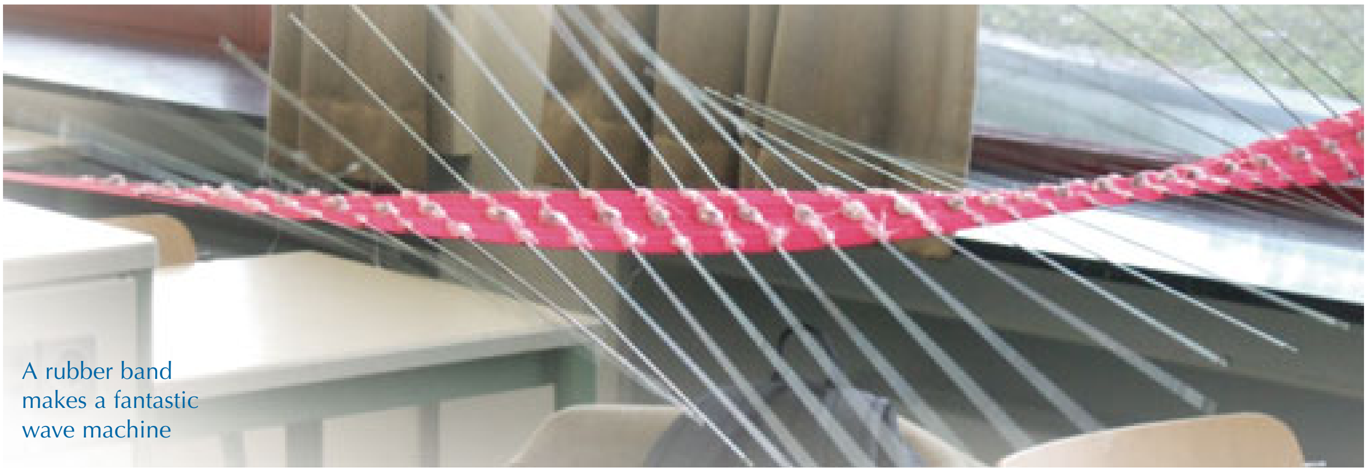
In the seismograph, eight dragons arranged around a bell-shaped metal form held little pearls in their mouths. When an earthquake occurred, the dragon pointing in the direction of the epicentre would drop its pearl into a bowl below. Earthquakes were reputedly registered from hundreds of kilometres away – solely on the evidence of the pearl lying in the bowl.

After studying images on the worldwide web and in old reports, the students quickly deduced that inertia could be used to open the dragons' mouths. The students' dragons were made of two little wooden blocks connected by tape and – not essential to the function – painted to resemble dragons. A spiked pendulum provided a central mass to trigger the dragons, marbles replaced pearls and an upside-down plastic dustbin served as an outer frame of the seismograph.



Students experimenting with standing waves

The main purpose of the model had been to offer a possible explanation of how the ancient Chinese seismograph worked, but the results exceeded all our expectations. Not only did even light blows to the side of the table on which the seismograph was placed cause the dragons to release their marbles, but the direction of the blow was reflected in which dragon dropped its marble. Improvements, such as using a larger mass, preventing lateral movement of the dragon heads, and constructing stiff connections between the pendulum and the dragon heads, should increase the accuracy even further.



A rubber band makes a fantastic wave machine

A simple wave machine

Most wave machines are made from wood and metal spikes, but they tend to be fragile or too small for classroom display. Instead, some of our students came up with the idea of using wide bands of rubber, used in the waistbands of skirts or trousers and cheaply available. Four old bicycle wheels were donated by a local bike shop and the spokes served perfectly as arms to indicate the wave movements. The spokes were pushed through the rubber band several times and fixed with hot glue. In total, the homemade wave machine was about four metres long.

When stretched across the length of the classroom, the rubber band can be used to demonstrate all important wave phenomena: travelling waves (both transverse and longitudinal), wave reflection and standing waves. For the final presentation on the school's open day, jelly babies were attached to the ends of the spokes. In black light, the waves glowed mysteriously – not necessary for physics, but definitely an impressive sight.

Investigating earthquake-proof buildings

When searching for information on earthquake-proof buildings, our students quickly came across the Salters Horners Advanced Physics (SHAP) project of the York University Education Group. To test different building constructions, the SHAP authors suggest an earthquake table built from wood, stiff foam and an oscillator. We also used another of the SHAP team's ideas, presented at Physics on Stage 3 in 2003: instead of constructing buildings from straws or metal kits, Liz Swinbank and her UK team tested buildings made from spaghetti. This was not only effective, but impressive to watch.

Our students were intrigued by this crazy but highly effective choice of material and started modelling different designs of earthquake-safe buildings which they learned about on the worldwide web. They also focused on ways to show the factors that influence the formation of standing waves inside the buildings. The earthquake table with its different models drew crowds at our school's open day.

Looking back

Though it took some time to develop and produce the demonstrations, the motivational potential of this approach cannot be exaggerated. The students spent hours after school improving their models and testing yet further variations. All members of the course were able to contribute to the success of the project, irrespective of their abilities. This alone made the effort worthwhile, as the experience of a successful project not only helped to strengthen the group, but also enhanced their motivation and interest in other aspects of physics. And of course, the students' understanding of waves and the underlying physics improved enormously.

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Resources

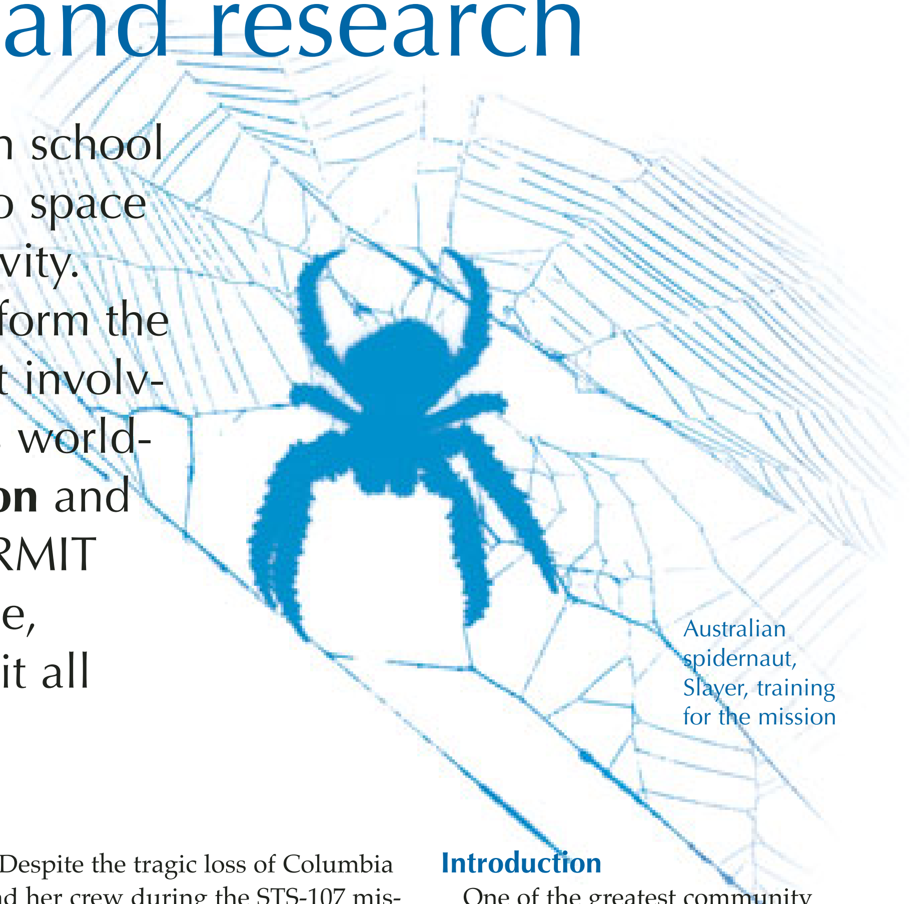
Physics on Stage was the forerunner of Science on Stage, an international teaching festival organised by the EIROforum. See 'Space balloons, mousetraps and earthquakes: it's Science on Stage!' on p 8 and 'Science teachers take centre stage' on p 6. For more details, see: www.scienceonstage.net

A useful web resource on wave propagation, *Seismic Waves*, can be downloaded free of charge from: www.geol.binghamton.edu/faculty/jones/

Tobias Kirschbaum teaches at the Städtisches Gymnasium Kamen and the Teacher Training Centre Arnsberg, Germany, while Ulrich Janzen teaches at the Franz-Stock-Gymnasium Arnsberg, Germany.

‘Spiders in Space’: a collaboration between education and research

An ambitious Australian school project sent spiders into space to experience microgravity. ‘Spiders in Space’ will form the basis of a future project involving many more schools worldwide. **Lachlan Thompson** and **Naomi Mathers**, from RMIT University in Melbourne, Australia, explain how it all started.



Australian spidernaut, Slayer, training for the mission

On 16 January 2003, eight Australian spiders embarked on a 16-day mission into space on board the space shuttle Columbia STS-107. The experiment was the culmination of a three-year collaborative programme between students from Glen Waverley Secondary College, RMIT University and the Royal Melbourne Zoo (Thompson et al., 2000), and put the students in direct contact with established space entities NASA, BioServe and SPACEHAB as well as with international researchers.

The students were involved in all aspects of the design of the experiment as well as in investigations into issues such flight clearance and mission simulation.

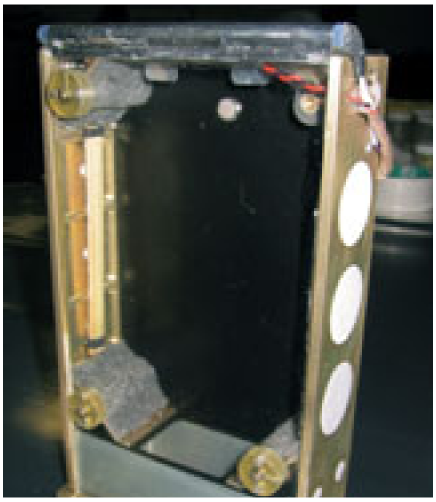
Despite the tragic loss of Columbia and her crew during the STS-107 mission, the project highlighted the educational benefits of school students being part of a real-life space science project.

Spider experiment (far right) just before closing for launch

Introduction

One of the greatest community benefits resulting from NASA’s space shuttle programme has been education. Examination of previous shuttle missions found there was often excess payload capacity that could be used for small educational experiments. A NASA initiative to make use of this capacity enabled a number of schools in the USA to play an active role in space research.

In the late 1990s, NASA contracted out its commercial space research to SPACEHAB, Inc. This provided an opportunity for SPACEHAB to offer commercial education experimental programmes and resulted in the Space Technology and Research Students (STARS) programme (www.spacehab.com/smi/stars.htm).



The habitat with infrared night lighting to facilitate photography of the spider making a web, a biological feeding system and the ability to carry extra spiders

The STARS experiments flown on STS-107 came from participating schools from the USA, Australia, Canada, Japan, China, and Israel (Goulart et al., 2005).

With the support of scientists and other professionals, each class was responsible for developing their own experiment and liaising with the launch-provider SPACEHAB, the public and other schools.

The research topic chosen for the Australian experiment was 'Spiders in Space: the effect of microgravity on spider behaviour and web composition'. Spiders had previously flown into space on Skylab 3 in 1973, but the two spiders died before the experiment was completed (Witt et al., 1977). Scientists at RMIT University chose this topic for its accessibility and appeal to students across a broad range of ages and capabilities.

The experiment aimed to add to the current body of knowledge on the biological effects of microgravity on living organisms, with particular focus on web-building and the microstructure of spider silk spun in microgravity. Gravity is believed to have a strong influence on behaviour, particularly on the way they move and build their webs. Gravity is also thought to influence the thickness of their silk and the 'north-south' asymmetry of their webs, and to help them to orient themselves, particularly when rebuilding webs that have been disturbed.

The class as a whole developed the mission-specific hypothesis that 'a spider will build a different web in microgravity than on earth'. This was to be investigated by observing differences in shape, pattern and silk thickness.

The class of 26 Year-9 students (14-15-years old) formed groups to examine the core areas of the project: animal husbandry, habitat development, mission protocols, 'spidernaut' training, instrumentation, media and communications.

From the development of the mission hypothesis, each research group set out to conduct a series of experiments to develop the mission specifications. This included selecting the species of spider, spider size and age, lighting, food and feeding mechanisms and habitat features to encourage web-building.

Team meeting to select the best spidernauts

The isolated nature of the experiment encouraged students to anticipate and plan for complications such as spider redundancy (how to carry one or more back-up spiders), failure of the feeding mechanism and whether mechanical or biological feeding techniques should be used.

Students were required to interact with SPACEHAB in the USA through the protocols of experiment approval, hardware definition, live materials list, experimental protocol, 'delta phase three' clearance (flight approval), and mission simulation.

'Spiders in Space' in the school curriculum

To facilitate the introduction of a major project into the classroom, a curriculum was developed that identified the key topics in the research project and the student tasks which met the educational, teaching and learning objectives for Year 9 sciences. Most of the normal science curriculum (Board of Studies, 1999) could be blended into the project. The project ran with the same students for three years, starting in 2000 and concluding in June 2003. When the students entered Years 10 and 11, the spider project was completed after hours in addition to their normal classwork.

RMIT University and the Zoo provided scientist mentors one day per week for the duration of the project. Team groups met for 30 minutes each week to review overall progress.

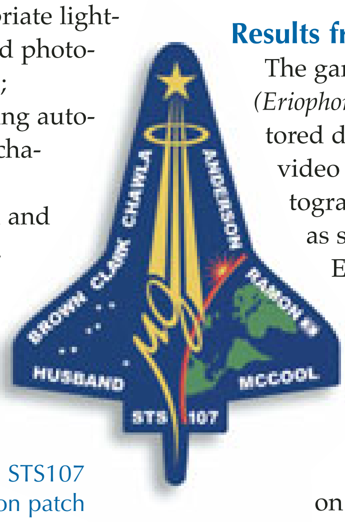
Students preparing the spider habitat at the Astrotech Facility in Titusville, FL, USA

The spider experiment allowed a wide range of spin-off pre-flight experiments and activities such as:

A student preparing the fly chamber

- breeding spiders;
- ‘training’ spiders for flight conditions;
- pre-flight environmental conditioning;
- developing and constructing spider habitat;
- developing appropriate lighting for viewing and photographing the webs;
- designing and testing automated feeding mechanisms;
- performing control and flight experiments.

To engage the broader school community, the class commissioned spider habitat boxes from the technology classes, and obtained video cameras and lighting from the electronics classes. A competition was run for Year-11 and -12 students to design the school mission patch.



STS107 mission patch

Results from STS-107 Columbia

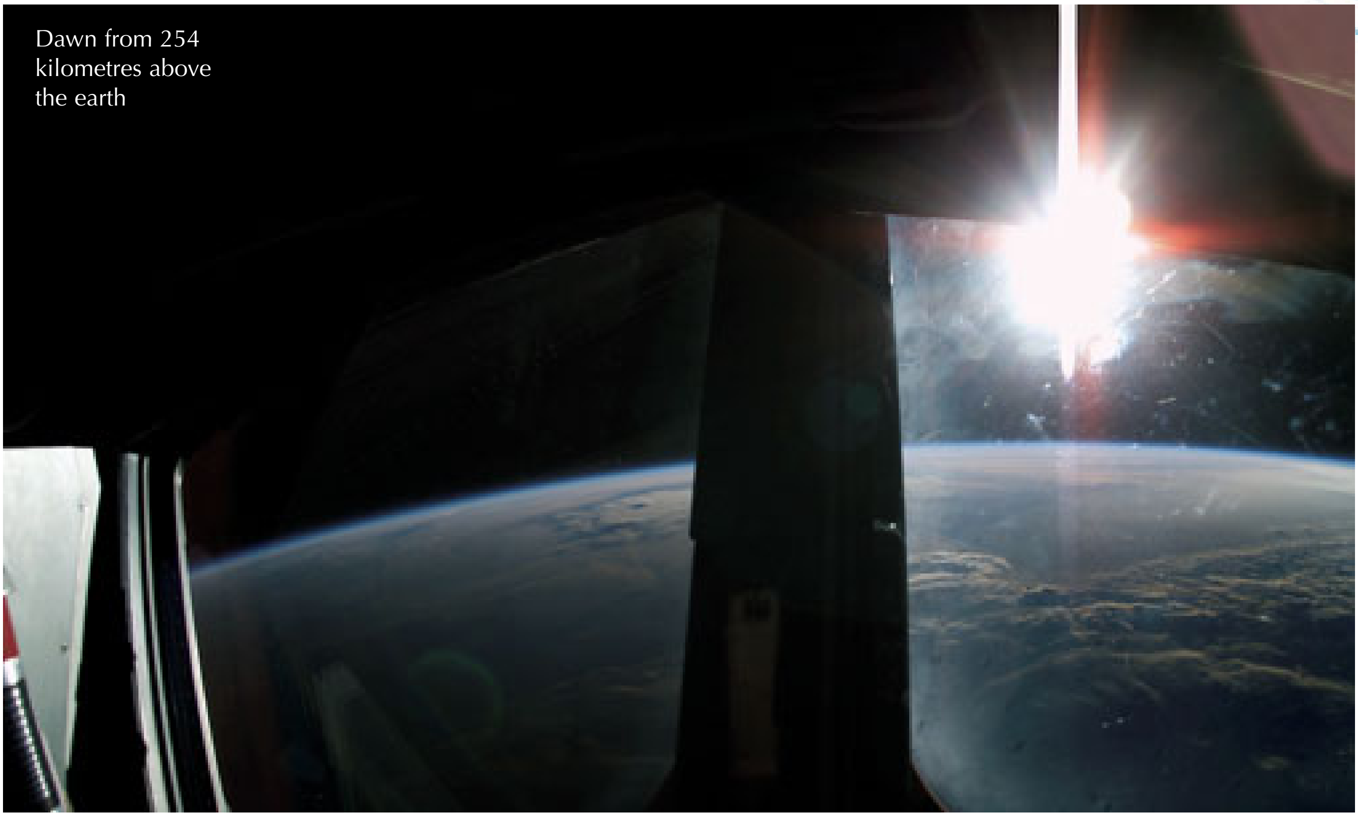
The garden orb-weaver spiders *(Eriophora transmarina)* were monitored day and night with still and video cameras. The night photography was the most useful, as spiders are nocturnal. Excellent images were taken of the spider during its web-making. This allowed the class to examine the spider’s web-making prowess.

While eight spiders flew on Columbia, a second spidernaut team was undergoing the control experiment in an identical locker box and habitat on earth. In both habitats, the spidernauts were provided with food by placing fruit-fly larvae in agar gel at the base of their habitat. The flies were recorded on video emerging from their pupae in both the Columbia and the ground control experiment. This biological feeding process was shown to be a viable mechanism to sustain the spiders.

Comparing the performance of the two lead spiders showed that Wako in microgravity was able to construct her web in just over half the time it took her land-based control, Cadbury. A video of Wako shows the spider manoeuvring more deftly on the web than the earth-bound Cadbury. Other observed differences in web shape supported observations made on Skylab 3 (Witt et al., 1977).

During the mission, experimental data were downloaded to mission control and made available to the research team. The Columbia crew worked particularly closely with the student experiments. Israel’s first astronaut, payload specialist Ilan Ramon, released the back-up spiders and took web samples. His observations, comments and insights, trans-

A beautiful sight as Columbia lifts off



Dawn from 254 kilometres above the earth

BACKGROUND

'Spiders in Space' will be followed by a much larger space experiment, 'Bees in Space'. Expressions of interest are being accepted from schools worldwide. To find out more about the project, contact Naomi Mathers at naomi.mathers@rmit.edu.au, or Lachlan Thompson at lachlan.thompson@rmit.edu.au.

In future issues of *Science in School*, you can read about:

- how the 'Spiders in Space' project was developed as an interdisciplinary project between a school, a university and a zoo;
- how to get involved in 'Bees in Space', the new worldwide project.

mitted during the mission, conveyed his pleasure in working on the experiment and led to a close bond between the 'Spiders in Space' team and the Columbia crew.

Further analysis was thwarted by the loss of Columbia, her crew and significant data, including the high-definition images of the spider-webs, the spiders and the web samples.

Research and teaching outcomes

The outcomes of the experiment have broad applications. Investigation and development of life-support systems for spiders and similar life-forms in space contribute to the knowledge necessary to support ecosystems in space.

Observing how the spiders learn to move without the aid of gravity and how they develop new techniques for web-building provides insights into techniques for building structures in microgravity. For example, the two-dimensional nature of the spider-web is comparable to the large planar structures used to support solar arrays.

In developing their hypothesis and designing the experiment, the students gained insights into the role of science in our community. They developed individual expertise and an understanding of the responsibility of scientists to disseminate their findings within the scientific and broader community.

The students were required to conduct independent research activities and apply problem-solving skills to real-life situations. Some of the concepts that they encountered during the course of the project include:

- the relationship between weight perception and the structure and microstructure of the web;
- the role of gravity in orientation and web-building;
- adaptation to and movement in conditions of microgravity ;
- the phenomenon of fluid shift and other aspects of health in space;

Photograph courtesy of NASA

Israel's first astronaut, payload specialist Ilan Ramon, prepares to take a web sample on day 8 of Columbia's mission

- spider biology and behaviour;
- experimental techniques and validation;
- the use of clinorotation to simulate weightlessness;
- running an experiment with contingency planning and minimal human intervention;
- building a mini-space ecosystem;
- the development of a biological feeder;
- life-support requirements in a space environment;
- shuttle missions: procedures, deadlines, simulations, live materials list, awareness of factors influencing shuttle launches;
- objective analysis of experimental results;
- transfer and sharing of findings with other researchers;
- working with professional scientists, astronauts and technicians to solve complex scientific problems;
- communicating the results of experiments to the professional scientific community.

Epilogue

The tragic loss of Columbia and her crew on 1 February 2003 stunned the world as debris was scattered across the southern USA. With the death of the Columbia crew, science became personal for the 'Spiders in Space' team. What should have been a joyous celebration of Columbia's successful return was characterised instead by shock, horror and grief. A harsh lesson that science challenges the frontiers of human achievement – driving individuals and teams – but that the pursuit of that achievement is not without risk.

"Our team has been driven by the loss of the crew of Columbia to complete and publish the experiment results as a tribute to the seven astronauts" – Greg Carstairs, student

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REVIEW

This interesting and informative article describes a three-year educational project between scientists and school pupils that was set up to investigate the influence of gravity on spider silk and web-making. Students worked and met with scientists, which enabled the students to understand and appreciate the wide range of skills that are involved in setting up a project, for example design technology, information technology and biological knowledge. Students were encouraged to develop experimental-design skills that included learning the importance of pilot experiments to test methodology and equipment. The use of live subjects and the loss of the Columbia mission showed the students how frustrating research can be.

The project provides examples of both how the school science curriculum can be extended and how novel projects can be incorporated successfully within a national curriculum. Students could be set the challenge of designing similar novel experiments via group work and/or classroom discussion or applying to participate in the 'Bees in Space' project. This would stimulate their imaginations, a prerequisite for carrying out novel research, and would show how scientists in different subject areas need to collaborate for a successful outcome.

The article may be linked to other topics in biology, for example, the different types of spider silk, the effect of drugs on spiders and web production, and problems associated with breeding programmes such as genetics or habitats. This would broaden the horizons of students and teachers and may encourage them to be more curious about the world.

Shelley Goodman, UK

Launching a dream: the first European student satellite in orbit

One hour and 34 minutes after the bright tail of the Kosmos 3M rocket disappeared from view, more than one hundred students are checking their watches nervously. **Barbara Warmbein,** from the European Space Agency in Noordwijk, the Netherlands, continues.

A day before the launch, the team watches the rocket being erected

BACKGROUND

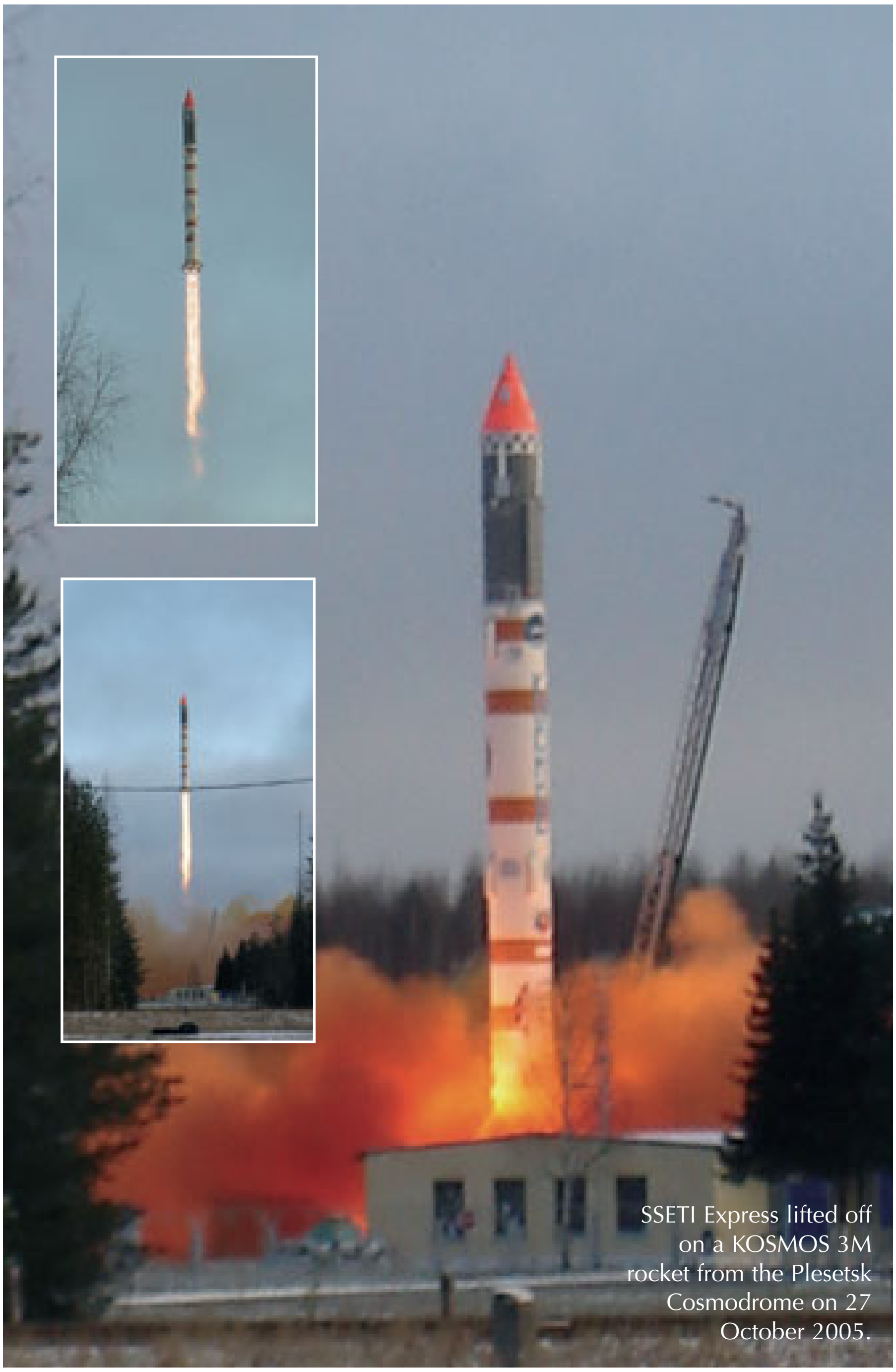
SSETI Express background

The SSETI Express mission started in December 2003, as a spin-off from the European Student Earth Orbiter (ESEO), because many of the students involved in the Student Space Exploration and Technology Initiative (SSETI) would graduate before their hardware would be anywhere near ready to fly. Its primary goal was to serve as a precursor mission to ESEO and to test some of the hardware already available for flight. The management and legal negotiations were performed by the Education Department of the European Space Agency (ESA).

The project boosted the motivation of all the students and experts involved – the new 'express' mission was a motivational aid, a technological test-bed, a logistical precursor, and, most importantly, a demonstration of capability to the SSETI and educational communities, the support network at ESA, and the space community in general. Its objectives were, apart from providing the all-important European networking and technology experience for the students, to deploy three miniature satellites, test student hardware, take pictures of the earth and involve the amateur radio community.

SSETI Express cost about €100 000. Although ESA paid for the central management, testing and transport, provided an expert technical review and facilitated the launch on the Russian launcher, the student teams found local funding for the satellite, its on-board experiments and most subsystems. The students had weekly meetings in a chatroom to discuss latest developments, configurations and problems, and only met in person during three workshops organised by ESA. All student teams had to have the approval of at least one professor at their university, but they did all the work themselves – quite a feat considering that parts for the satellite were built all over Europe and fitted perfectly when they were put together by the students at ESA's Space Research and Technology Centre in the Netherlands.

In the mission's ground-control centre in Aalborg, Denmark, students working as 'mission control' shift nervously in their chairs. The transformed university classroom is full of camera teams, cables have been secured to the floor with tape, and partitions display hastily pinned-up posters of the Student Space Exploration and Technology Initiative Express: SSETI Express. They don't need fancy rows of monitors, buttons and levers or large screens along the wall, just a few tables, computers and a team of extremely excited students. Then, with a crackle and a beep, the radio comes on – SSETI Express is alive! The first few chapters of the story – describing how hundreds of European students designed, built, tested and launched their own satellite to experience life as an engineer first-hand – read like a fairy-tale. Twenty-three universities from 14 different countries had teams working on SSETI Express – the 'fast track' satellite conceived by students who had had enough of theory and wanted to know what it was really like to launch a satellite. They teamed up with the Education Department of the European Space Agency (ESA), and within 18 months had achieved what normally takes three to four years and costs a lot more than the €100000 that went into SSETI Express. ESA provided the launch on the Russian rocket from the Plesetsk Cosmodrome, and when the satellite blasted off on a crisp October morning in 2005 and sent its first signal back from orbit at a height of 690 kilometres, all signs pointed to a happy ending.



SSETI Express lifted off on a KOSMOS 3M rocket from the Plesetsk Cosmodrome on 27 October 2005.

Photo courtesy of J. Page

But that was where the fairy-tale ended and real life began. After a successful first day, contact to SSETI Express was lost: it could not recharge its batteries because of a failure in the electrical power system. The students tried to recover it – there was still a slight but significant chance. "Of course we are disappointed. But in a way this meets our educational objective," says Neil Melville, Project Manager and System Engineer of SSETI Express. "We wanted to give students an idea of what it is like to launch a satellite, and troubleshooting is certainly an important part of it!"

Despite the disappointment of the power failure, Neil and the teams considered their mission a success. Two of the three miniature satellites on board SSETI Express were released, leading to some "stunningly perfect" results: the satellite passed over the observation point at exactly the planned orbit, and the timing of the first signal was exactly right. Ground control was able to talk to the satellite and it replied. Perhaps more importantly, the students learned useful and valuable lessons.

The majority of the students were studying for a degree in engineering.

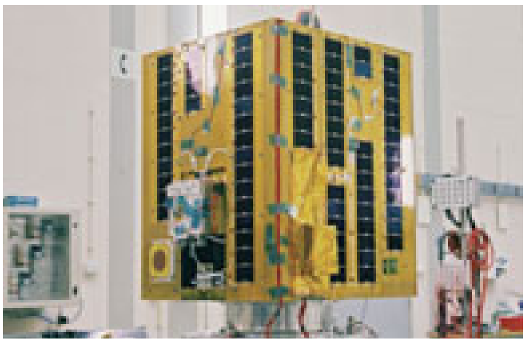
BACKGROUND

ESA and ESA education

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the people of Europe. By coordinating the financial and intellectual resources of its 17 member states, ESA can undertake programmes and activities far beyond the scope of any single European country. ESA's job is to establish and execute the European space plan. Its projects are designed to find out more about earth, its immediate space environment, the solar system and the universe, as well as to develop satellite-based technologies and promote European industries. ESA also works closely with space organisations outside Europe to share the benefits of space worldwide.

The ESA Education website[w1] is the focal point for information on space education programmes run by ESA's Education Department and its partners. It offers links to, and free downloads of, various educational or supporting documents. There are still many differences between the national curricula of ESA's member states, but several topics are taught at all levels of education in all countries. ESA's Education Department has developed or adapted tools and courses for the various curricula with the help and knowledge of ESA experts, using results from space missions. Most courses fit many disciplines, including physics, geography, biology, mathematics, languages, sports or history.

Space, space travel, exploration and astronomy have always been multidisciplinary – this is why space is such a popular topic. Most of the ESA education projects are multidisciplinary, such as ideas for projects or competitions, and give new opportunities to the teacher at primary level, or to teams of teachers at secondary level. ESA also provides teacher training (for example, for new teaching tools or websites), organises workshops (e.g. Teach Space) and co-organises large-scale international events (e.g. Science on Stage). The aim is to bring teachers from all across Europe together and let them exchange their ideas on the best ways of teaching – not only space!



The student-built satellite in the cleanroom

But because a project like SSETI Express also needs a legal background, there was also a team of law students – and if students of journalism hadn't set up a public relations team, you might never have heard of the project at all. Discipline was not an issue: "We were all doing it of our own free will, and of course we were all extremely enthusiastic about it, so it was very easy to control because we all wanted it to happen," explains Neil. Their next satellite, the European Student Earth Orbiter or ESEO, is scheduled for launch in 2008, and the more ambitious students want to go even further: they are looking at ways to build and launch a moon orbiter.

Web references

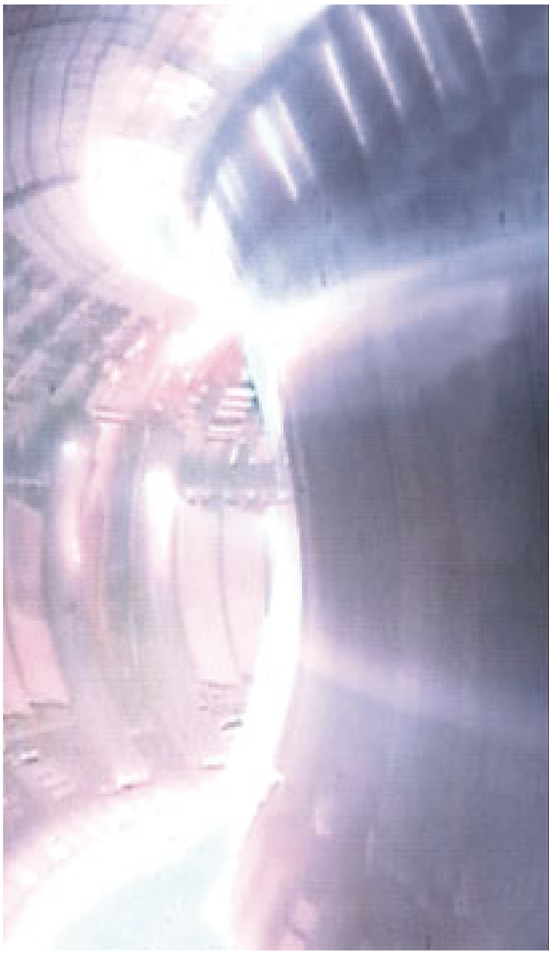
w1 – ESA Education website: www.esa.int/education

REVIEW

This article reports on a very exciting satellite project planned and performed by university students. It proves that students can be directly involved in aerospace technology, and will encourage both teachers and students of secondary schools to develop or join similar projects. The main problems are highlighted, to enable others to benefit from the experience gained.

Alesssandro Iscra, Italy

Interior of the JET vessel, with plasma inside (left)



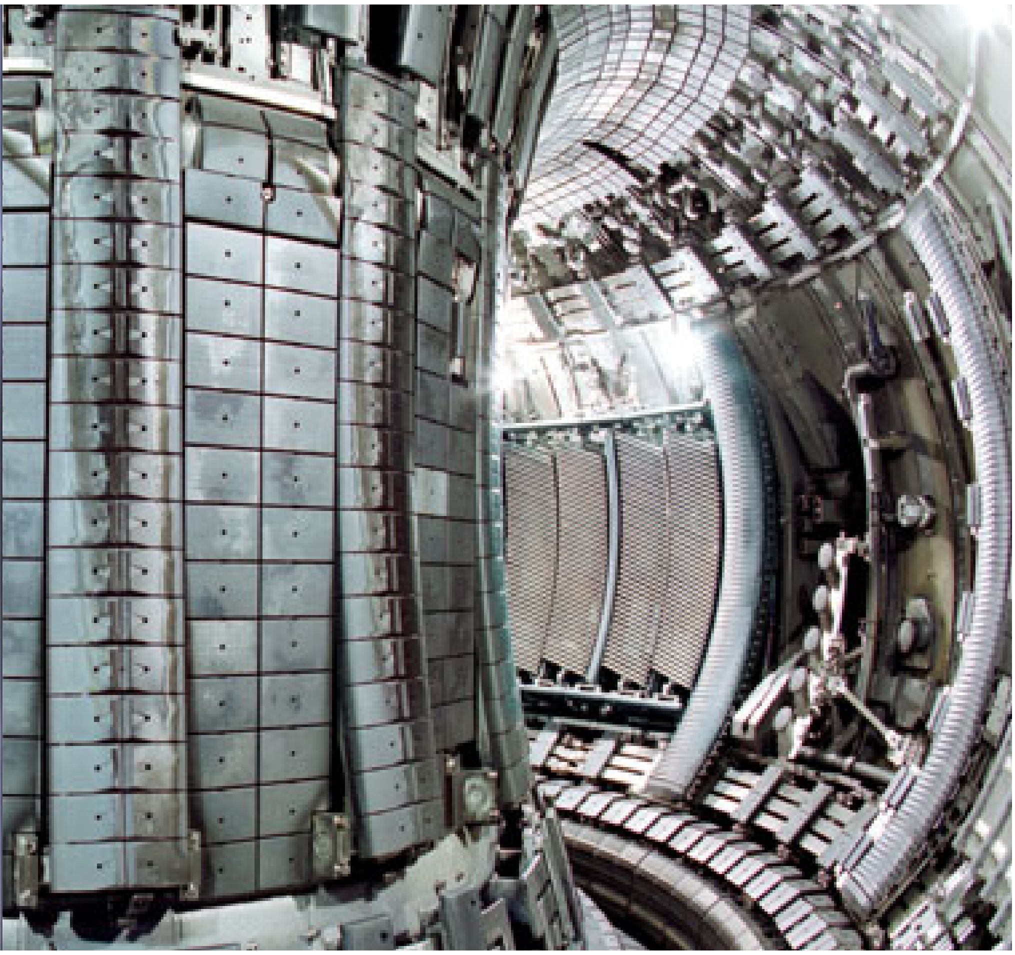
Fusion – ace in the energy pack?

The energy demands of our society continue to increase, while the stocks of fossil fuels – still our major energy source – are declining. **Chris Warrick** from the European Fusion Development Agreement explains why research into fusion offers the hope of a safe and environmentally responsible energy source.

Harnessing fusion – the power source of the sun – has long been a dream, as it could provide an almost limitless supply of energy in an environmentally responsible way. With the construction of a new reactor-scale fusion device, ITER, about to start in Cadarache in the south of France, that dream will come a large step closer to reality.

Why research a new form of energy production? Worldwide energy use is expected to double in the next 40 years, and lifting developing countries out of poverty will require an even larger increase. At present, 80% of the world's energy is generated by burning fossil fuels – driving global and climate change and generating pollution. Eventually, fossil fuels will be exhausted; the first sign will be a decrease in the rate at which oil can be produced, which could occur relatively soon. There is no magic wand that will solve the problem. Instead, a measured response to the problems we face would include a cocktail of approaches. Likely ingredients will be an increase in energy efficiency, a deployment of more renewable and nuclear fission energy sources, and intensified research into new technologies such as fusion.

The idea of extracting the net energy from controlled fusion reactions is nothing new. The difficulty has been recreating on earth the kind of reactions observed in the sun. Unlike fission (splitting apart) of heavy nuclei, fusion of light nuclei requires extreme conditions to be attained and sustained. The chosen reaction in experiments here on earth is the fusion of deuterium and tritium – two heavy forms of hydrogen – producing helium and a neutron, which carries the excess energy. This requires a high temperature (or energy) of the particles in a super-hot ionised gas called a plasma: around 150 million degrees Celsius. This must be combined with a sufficient density of particles and a



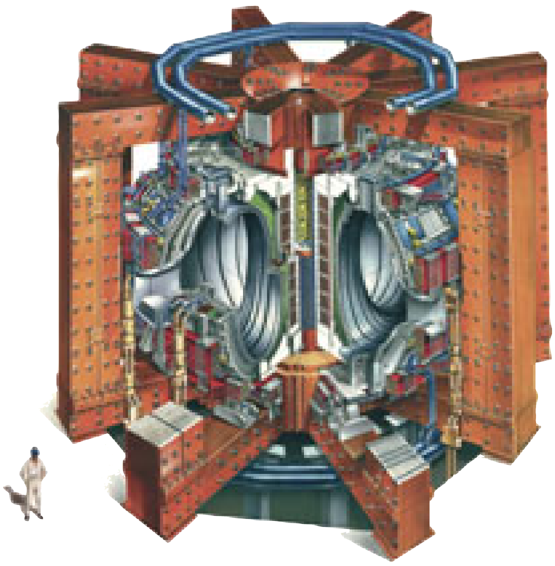
Fusion powers the sun

confinement method that enables the plasma energy to be held inside the plasma long enough for the fusion reaction to become established and for more power to be released than is needed to keep the fuel hot.

One important feature of fusion energy, and one which distinguishes it from fission, is that fusion is not a chain reaction. This makes it inherently safe: there is no possibility of a 'runaway' reaction. At any one moment, only a few grams of fuel are present in the plasma vessel, enough for a minute of burn time. To stop the reaction, it suffices to stop the supply of fuel, just like in a gas oven.

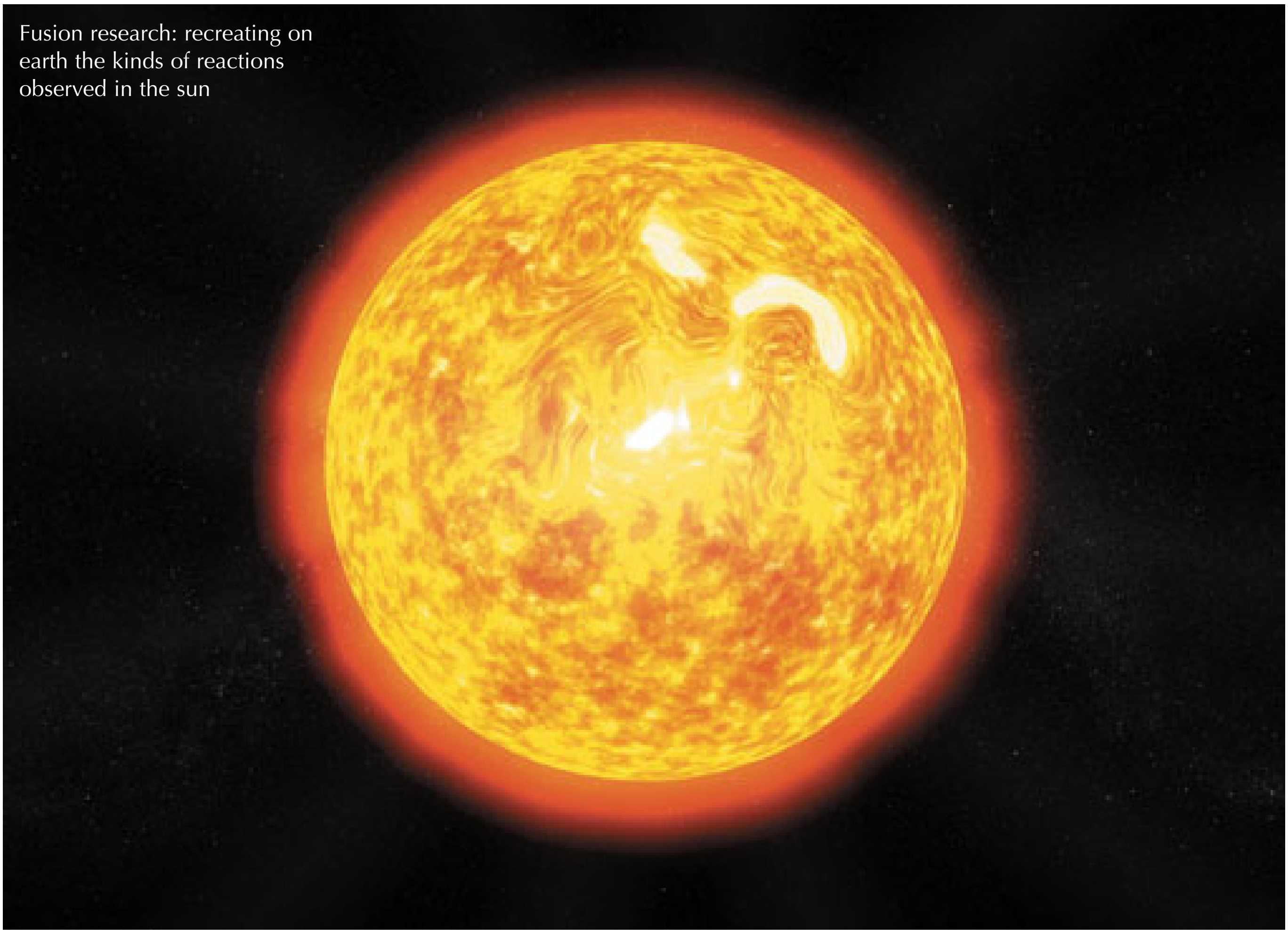
For the past three decades, the strongest line of research has concentrated on the so-called tokamak device. In a tokamak, a doughnut-shaped ring of plasma is confined in a vacuum vessel. To heat the plasma to 150 million degrees Celsius, an effective way of holding the plasma away from the vessel walls is needed. As the plasma comprises charged particles (ions and electrons), this is done with powerful magnetic fields generated by large magnetic field coils around the vessel. Heating the plasma to such extreme temperatures requires several complementary methods. One of these methods consists of passing a powerful electrical current through the plasma, while additional heating power is provided by externally injected microwaves and beams of neutral particles.

Significant progress has been made in tokamak experiments all around the world, with the European-funded Joint European Tokamak (JET) device at Culham Science Centre in the UK providing the focus of the European research effort. JET is at the pinnacle of European fusion research, and is supported by many smaller tokamaks at laboratories across the continent. The programme of work on JET is organised and co-ordinated by the

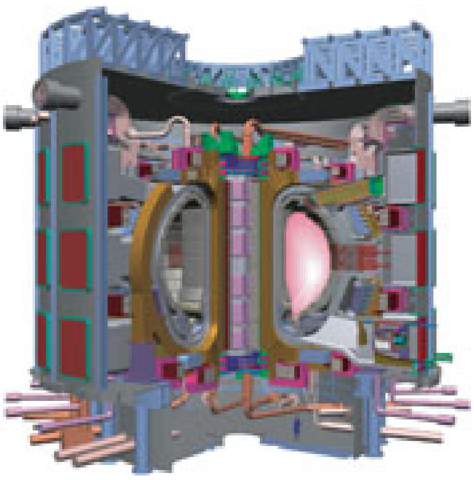


The JET tokamak

Fusion research: recreating on earth the kinds of reactions observed in the sun



European Fusion Development Agreement. As the largest operating tokamak in the world and the only one capable of operating with both fusion fuels (deuterium and tritium), JET has obtained the necessary conditions in the plasma for fusion to occur. More crucially, JET has provided valuable lessons in how to maintain plasma stability and confinement in the face of a host of plasma instabilities.



The ITER fusion device

The measured fusion output power in JET (approximately 16 megawatts) is close to, but still lower than, the power required to maintain the plasma at fusion temperatures (25 megawatts). Less power out than in – not promising for a power station! However, scaling studies using data from JET and smaller fusion experiments tell us that a larger machine will reverse this balance, producing a much larger fusion output power than the power needed to heat the plasma.

Although there is confidence that a fusion power station can be constructed in this way, further studies are required, especially into the technologies needed to ensure that a fusion power plant is safe, reliable and economically viable. The International Tokamak Experimental Reactor (ITER) will be such a device: a stepping-stone to a commercial fusion power station. It will be twice the size of JET, and should produce over 500 megawatts of fusion power in ten minutes – at least ten times the power needed to heat the plasma. As its name suggests, ITER is an international project with seven partner organisations: the EU, Japan, USA, South Korea, China, Russia and India. The design – using cutting-edge technologies such as superconducting magnetic field coils and advanced

BACKGROUND

EFDA education and outreach

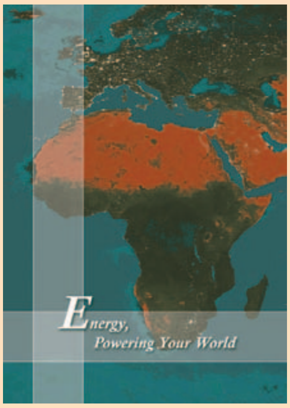
Many of the fusion research institutes in the European Fusion Development Agreement (EFDA) have their own outreach programmes, which often include lectures, and visits to schools and research facilities such as JET. Details of the individual research institutes are available on the EFDA website: www.efda.org.

Within the framework of the EIROforum (www.eirofo-rum.org), EFDA participates in *Science in School*, the Science on Stage festival (www.scienceonstage.net) and other outreach and education projects.

EFDA has produced a 60-page brochure for secondary schools, 'Energy, Powering Your World', giving a broad introduction to the world of energy. Topics include the ways we use energy in our daily lives, where it comes from, and how we will deal with our energy needs in the future. Suggestions for energy discussions in the classroom are available as a separate, accompanying document.

To receive a free printed copy of the brochure, available in English and Dutch, send an email to aline.duermaier@efda.org, including your name, postal address and the number of copies you would like (up to five). The brochure can also be downloaded in electronic form from www.efda.org/education/energy.html. Later this year, the brochure will be available in Spanish, French, German and Italian.

EFDA has a range of other educational materials available, such as a CD-ROM, 'Fusion, an energy option for the future', and a general poster on fusion, both of which can be requested via the EFDA website. The website also provides basic and more advanced information about fusion science.



EFDA brochure for secondary schools

instrumentation – is already finished and a decision was taken in June 2005 to build the device at Cadarache in the South of France. Preparations are now underway to start construction, ready for operations to commence in 2015.

One issue that inevitably arises with this technology is the use of radioactive tritium. In a future fusion power plant, tritium will be made inside the reactor itself in a closed cycle, so no transport of radioactive material outside the plant will be necessary during operation, and only a limited quantity will be present in the plant. The inside of the plasma vessel will become radioactive during the operation of the plant due to the neutrons produced in the fusion process. However, if the appropriate materials are used, these can either be disposed of as non-radioactive waste or recycled after a period of about 100 years, owing to their relatively short half-life. This compares favourably with the many thousands of years required before the components of a fission reactor become safe to handle. Part of the fusion research programme focuses on developing these 'low-activation' materials.

ITER is essential for testing and integrating the various technologies on the scale of a power station, and should confirm that it is possible to build a fusion power station. However, before a fusion power station can be built, years of testing of the materials under working conditions will be required before a licence is granted, to ensure that it is safe and reliable. This can only be done in a special device called the International Fusion Materials Irradiation Facility (IFMIF). ITER, which will cost some €5 billion, and IFMIF, which will cost slightly under €1 billion, are key to the development of fusion as a workable energy source. Although these costs may sound high, they are very small on the scale of the total world energy market, approximately €3 trillion per year.

So, the big question is 'when will fusion produce electricity for the world?' Building and operating ITER and IFMIF in parallel should allow the first prototype fusion power station to produce power in 30 years' time. Although this is not soon enough for an imminent move away from fossil fuel energy sources, it will enable fusion to provide a very valuable extra energy option for the latter half of the 21st century.

Running one of the world's largest telescopes

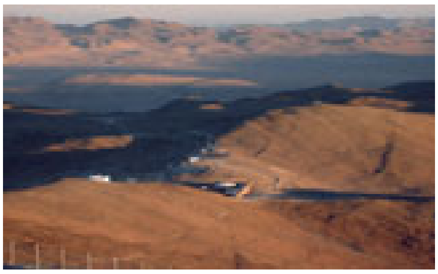
The Residencia

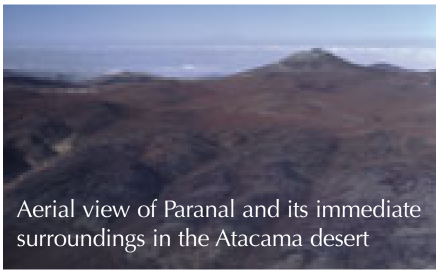
Ever wondered what – and who – lies behind the beautiful and fascinating astronomical photographs and observations made with modern telescopes? **Douglas Pierce-Price** from ESO, the European Organisation for Astronomical Research in the Southern Hemisphere, describes a day in the life of the Very Large Telescope.

In the past, the life of an astronomer may have been one of quiet nights spent peering through a telescope eyepiece. At the start of the 21st century, however, astronomy is an exciting, international endeavour. Modern astronomical research encompasses the greatest distances and masses, and the most extreme conditions, to be found in the universe.

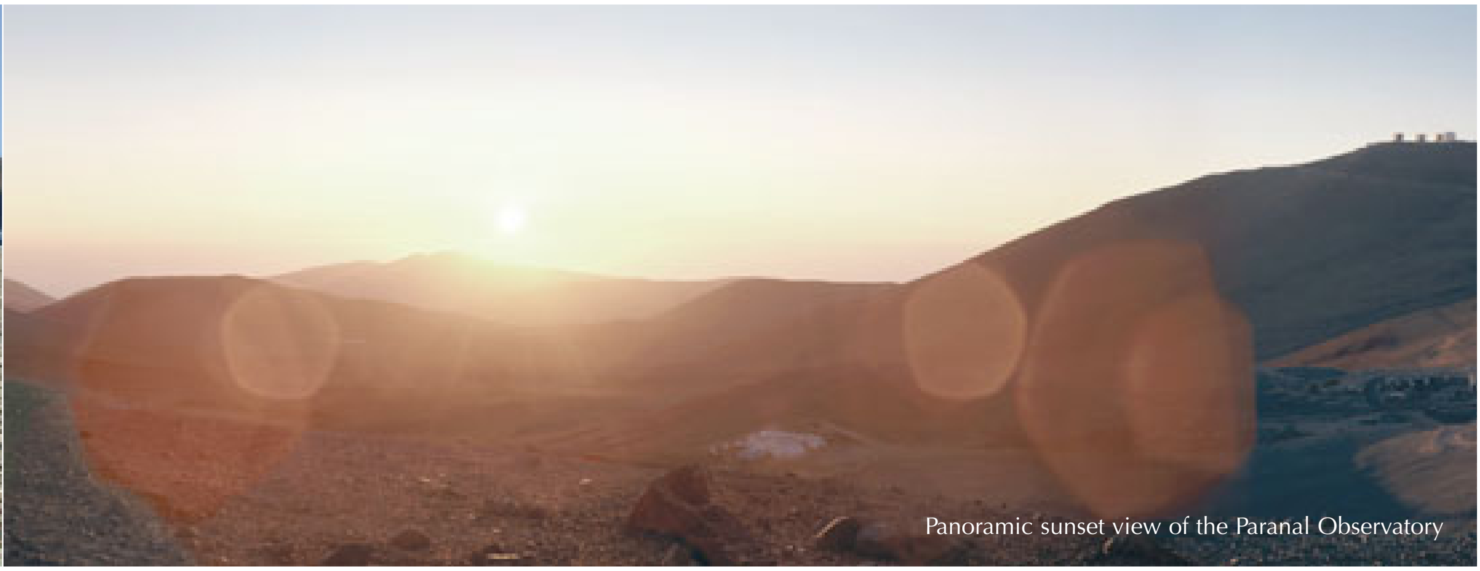
Not everyone who is involved with astronomy is necessarily an astronomer, however. Research-class telescopes are the state of the art. Their advanced detectors are cryogenically cooled to temperatures close to absolute zero, the telescope systems use the latest optical techniques, and the whole structure is a complex feat of engineering. Sophisticated computer systems are needed to handle the flow of data. To support this technology, a modern observatory also employs engineers, technicians, computer specialists, and a host of support staff.

Let's take a look at a day in the life of the Very Large Telescope (VLT), operated in Chile by ESO . You'll see how people with many different skills work together to keep the telescopes running throughout the year.





Aerial view of Paranal and its immediate surroundings in the Atacama desert



Panoramic sunset view of the Paranal Observatory

Observations with research-class telescopes are in such high demand that every night is precious, and every day is filled with activity.

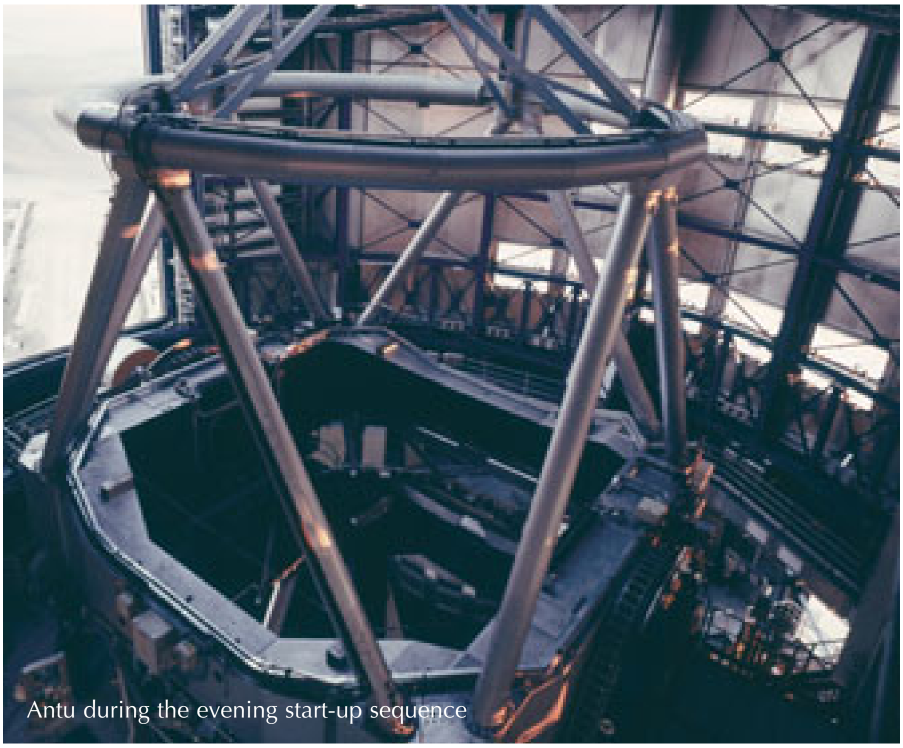
The VLT is situated on Cerro Paranal in Chile, a 2635-metre-high mountain in the Atacama Desert, thought to be the driest place on earth. There are parts of this region where no rain has ever been recorded. The high-altitude site and extreme dryness make excellent conditions for astronomical observations.

We begin our day at the VLT in the afternoon, before the sun begins to set. In the Paranal Residencia, the team who will operate the telescope tonight get ready for work. The Residencia is a futuristic building where the observatory staff live and work, built partly underground and with a 35-metre-wide glass dome in the roof. It is part of the VLT's 'base camp' facility, situated a short distance below the summit of Cerro Paranal.

The excellent astronomical conditions at Paranal come at a price. In this forbidding desert environment, virtually nothing can grow outside. The humidity can be as low as 10%, there are intense ultraviolet rays from the sun, and the high altitude can leave people short of breath. The nearest town is two hours away, so there is a small paramedic clinic at the

The swimming pool in the Residencia was introduced as a part of the humidification system


Kueyen tilted towards the horizontal position during a test exposure sequence


Antu during the evening start-up sequence

base camp. Living in this extremely isolated place feels like visiting another planet. Within the Residencia, a small garden and a swimming pool are designed to increase the humidity inside. The building provides visitors and staff with some relief from the harsh conditions outside: there are about 100 rooms for astronomers and other staff, as well as offices, a library, cinema, gymnasium, and a cafeteria. The building has four levels, although due to its subterranean construction, the entrance is at the top.

From the Residencia, the visiting astronomer and the night-time astronomer drive the four kilometres along a specially constructed, paved road to the telescope platform. Here, on the flat summit region of Cerro Paranal, are the telescopes of the world's most powerful optical and infrared observatory.

The astronomers prepare the computer systems for their night's observations, and then step out onto the platform to enjoy the Chilean sunset. A 'Star Trail', which also runs between the Residencia and the summit, is a popular recreational walking route for VLT staff and visitors.

Despite its name, the Very Large Telescope is really a collection of several telescopes. The four-unit telescopes of the VLT each have single mirrors 8.2 metres in diameter. They are joined by several smaller, movable auxiliary telescopes, two of which are currently operational, with a third being commissioned and a fourth to follow. The unit telescopes are named Antu (the Sun), Kueyen (the Moon), Melipal (the Southern Cross), and Yepun (Venus, the Evening Star), in the local indigenous Mapudungun language.

One of the most important measures of a telescope is its size – specifically, its diameter. This governs both the amount of light it can collect (to see fainter objects) and the angular resolution it can measure (to see more detail in objects). The individual unit telescopes, with their 8.2-metre mirrors, are already among the largest visible-light telescopes on the planet. Their size means they can detect objects billions of times fainter than those visible with the naked eye. With its adaptive optics systems, which remove much of the blurring effect of the earth's atmosphere, the VLT's vision is sharp enough to allow someone, theoretically, to read a newspaper headline at a distance of over 10 kilometres.

The light from the unit telescopes can also be combined with that from the auxiliary telescopes, using a technique called interferometry, to give the effect of a single telescope as large as the entire array of individual telescopes. This allows the combined system, known as the VLT interferometer, to behave like a telescope with a diameter of up to 200 metres. With this angular resolution, the VLT interferometer could theoretically see an astronaut on the surface of the moon.

Just before sunset, the astronomers are joined by the telescope and instrument operator (TIO). These highly skilled technicians handle the actual operation of the telescope and instruments. As part of their role is to look after the telescope and the observers,

Bright enough to be seen with the naked eye, the Orion nebula is a complex of gas and dust several tens of light-years wide

it is perhaps no coincidence that 'tio' is Spanish for 'uncle'.

The TIO and the ESO astronomers usually live in Santiago or Antofagasta, but come to Paranal for duty shifts. The journey takes about two hours by aeroplane followed by another two hours in a bus, over a partially unpaved road. ESO astronomers spend part of their time performing duties at the telescopes, and part pursuing their own astronomical research.

The Crab nebula is the remnant of a supernova explosion

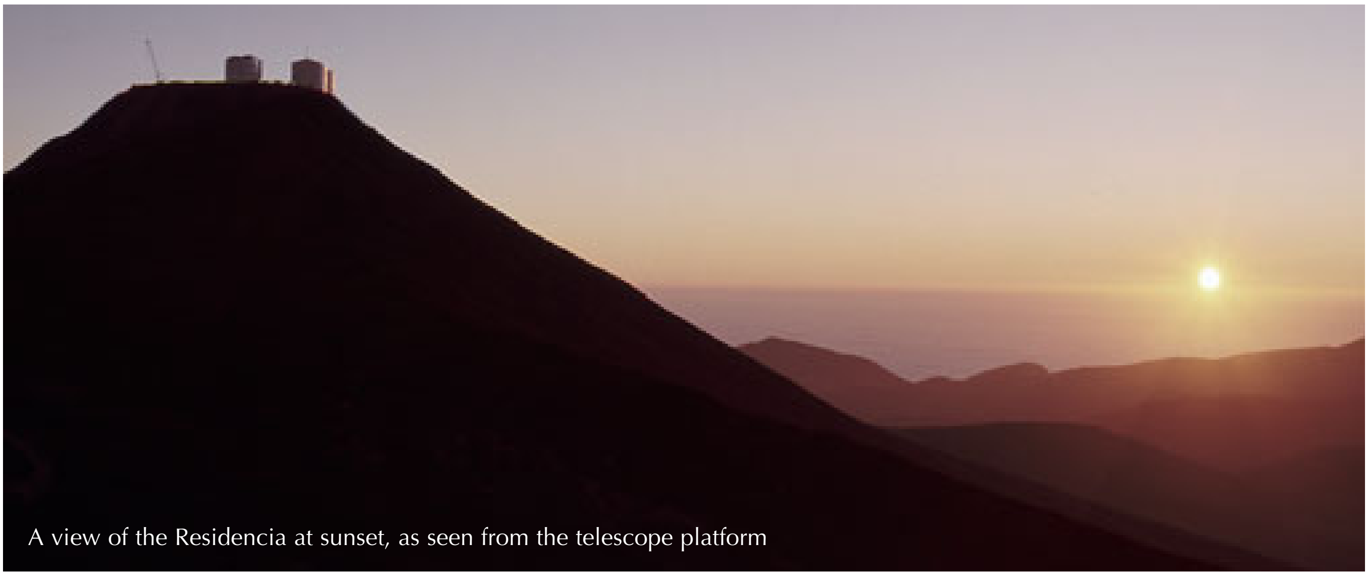
The visiting astronomer, on the other hand, could have come from anywhere in the world. Although most applications come from the ESO member nations, researchers from any institution worldwide can apply to use the telescopes. This is a competitive process, as the VLT is significantly oversubscribed – the amount of time requested is three or four times more than is actually available.

About half the observing time at the VLT is allocated to projects with visiting astronomers, and about half to 'service observing', where the TIO and ESO astronomer make observations on behalf of researchers who therefore do not need to leave their home institutions.

Now that the sun has set on Cerro Paranal, observations can begin. The giant building has already been opened, allowing the telescope to look out into the night sky. The visiting astronomer does not control the telescope directly, leaving that to the TIO. The visiting astronomer need only describe the observations he or she wants to make.

Although the excellent atmospheric conditions at Paranal are one of the reasons why the site was chosen, one cannot always rely on the weather. Sometimes it is not good enough for the planned observations, and the astronomer gets 'weathered out'. If this happens, then they may be able to switch to one of their backup projects or to one of the stock of 'service observing' projects.

Since 1998, when Antu, the first of the unit telescopes, saw its first light, the VLT has been at the forefront of astronomical research. It has been used to look at objects in our own solar system, and beautiful nebulae and supernova remnants in the Milky Way. Astronomers have watched stars orbit in the gravitational pull of the supermassive black hole at our galaxy's heart, and have found distant galaxies far beyond our own. VLT observations have shed new light on the mysterious cosmic explosions known as gamma-ray bursts, which are the most powerful blasts in the



universe. And astronomers using the VLT were the first to make an image of an 'exoplanet': a world outside our solar system.

Throughout the night, the team may make long observations of a few astronomical objects, or they may move from target to target, always trying to make the best possible use of the time and weather conditions. But all nights must come to an end, and as the sun rises over Cerro Paranal, the observations are completed. The TIO puts the giant telescope into standby position, closes the building, and the TIO and astronomers return to the Residencia to rest and sleep.

Kueyen by moonlight

The VLT stands empty on the mountain for a short time, until a different group of workers arrives. The day crew of engineers and technicians, joined by daytime duty astronomers, are responsible for telescope maintenance. The engineers typically live in Antofagasta, but may work shifts of one week at the VLT, and one week off. They could be working to fix problems that occurred during the night, or to upgrade the facilities. Some work is done at the VLT itself, but there are also laboratories and workshops in the base camp, near the Residencia.

When the sun starts to set, the day crew make radio contact with the TIO, who is driving back up to the summit. They prepare the telescope hardware, and open up the building again, ready for the arrival of the TIO and astronomers. Once the telescope is handed over, and perhaps after watching the sunset, the day crew drive back to the Residencia. As one day comes to an end, a new night of discovery begins.

REVIEW

This article describes how scientists and engineers work at a modern telescope and would serve to inform teachers about what astronomers actually do at these telescopes. The article is of special interest to physics teachers, although those teaching general scientific subjects may also be interested.

The diary style makes it very readable even for those who are not familiar with astronomy. Although this article does not contain any direct teaching materials, science teachers and their students may find it interesting to hear about scientists at work.

Although this article gives a rather idealistic picture of astronomers' lives at the Very Large Telescope (VLT), it also raises all sorts of questions and awakens interest in the subject.

Roeland van der Rijst, the Netherlands

Diabetes mellitus

The incidence of diabetes is on the rise, in both the developed and developing worlds. **Klaus Dugi**, Professor of Medicine at the University of Heidelberg, Germany, discusses the causes, symptoms and treatment of diabetes.

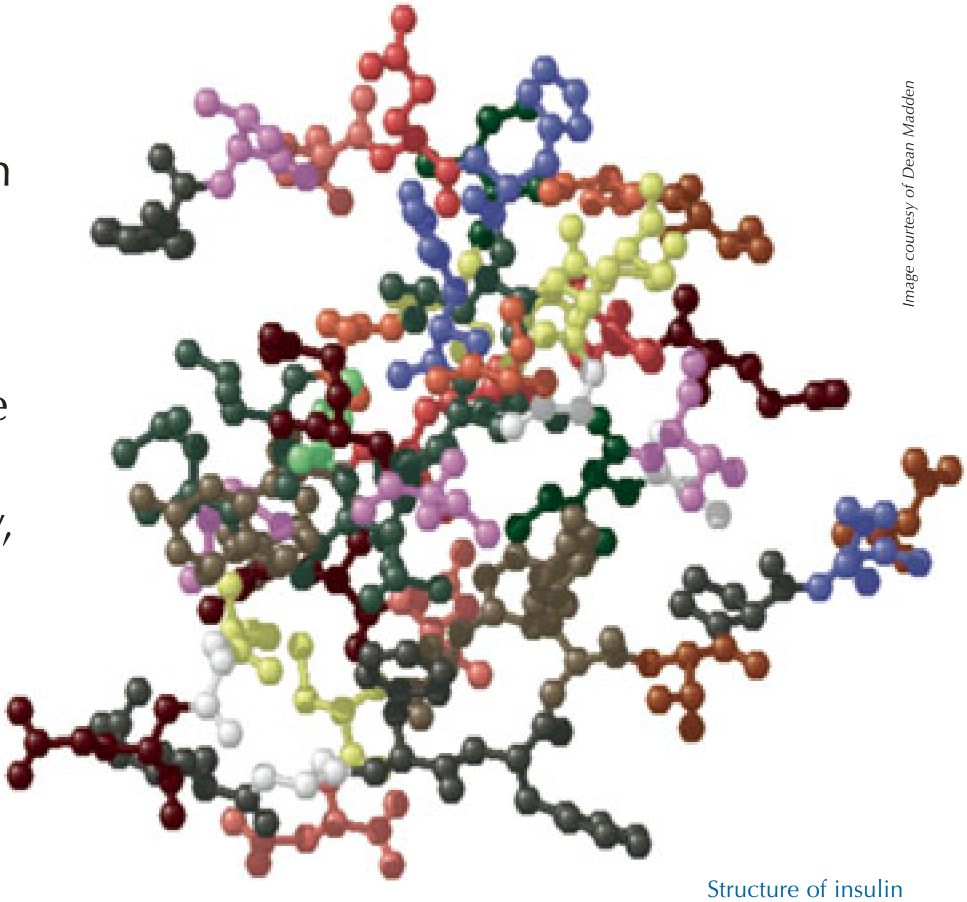


Image courtesy of Dean Madden

Structure of insulin

Translated from ancient Greek, diabetes mellitus means 'honey sweet flow' and stems from a time in which tasting a patient's urine was still part of the physician's diagnostic repertoire. By the sweet taste of the urine, diabetes mellitus could be distinguished from diabetes insipidus, another disease with increased urinary output.

The term diabetes mellitus covers several disease states with underlying causes that are characterised by an abnormal increase in blood sugar (glucose) levels.

Classification

In 1997, the World Health Organization and the American Diabetes Association agreed on a new classification for diabetes mellitus. The most frequent diabetes forms are Type 1 diabetes and Type 2 diabetes. Type 1 diabetes typically manifests during childhood or adolescence, but it has recently become apparent that adults can also develop this form, in some cases as late as in their forties or fifties. Type 2 diabetes is mainly a disease of the elderly, but as rates of obesity increase, more and more young adults, and even adolescents, are being diagnosed with this form of the disease. Other forms of diabetes include gestational diabetes (pregnancy diabetes), diabetes after operative resection of the pancreas, and rare forms of genetic diabetes.

Epidemiology

About 90% of patients with diabetes mellitus have Type 2 diabetes. An estimated 150 million people worldwide have Type 2 diabetes, and this number is expected to double within the next 20 years. Most of the increase will stem from developing and threshold countries such as India and China. In the USA, where the prevalence of diabetes is high, it is estimated that one in three people will develop Type 2 diabetes.

Pathophysiology

Normal situation

The body derives glucose from several sources. Firstly, it is taken up from food in the gut, either directly as glucose or after more complex carbohydrates have been digested into glucose and other simple sugars. Secondly, glucose is synthesised from other energy sources, mainly in the liver, in a process known as gluconeo-

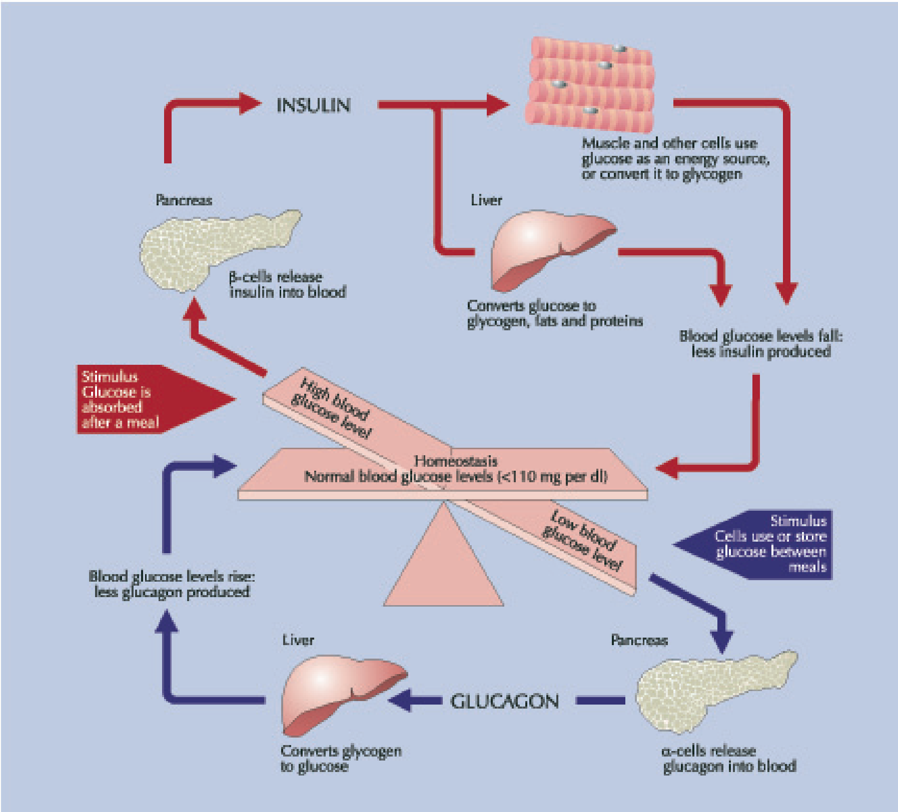


Image courtesy of Dean Madden

Glucose regulation

genesis. Thirdly, glucose is stored in the liver, muscles, and other tissues in the form of glycogen. On demand, glycogen is broken down into glucose and secreted into the bloodstream.

Glucose is transported via the blood, whence it is absorbed by tissues needing glucose. After a meal, about 80% of the uptake of blood sugar is by muscle cells. During fasting, however, over 50% of glucose uptake is by the brain. This imbalance is probably because the sole source of energy for the brain is glucose , and the body needs to safeguard the brain's glucose supply. If the blood sugar level falls too low (hypoglycaemia), the brain malfunctions, causing such symptoms as lack of concentration, dizziness and faintness, or, in severe cases, convulsions, coma and death.

The processes of glucose uptake and release are tightly regulated by hormones. The most important hormone is insulin, because it is the only hormone that can lower blood sugar levels. Insulin is synthesised and secreted only in the beta or islet cells of the pancreas. It lowers the blood glucose level by facilitating the uptake of glucose from blood by all cell types, reducing gluconeogenesis, and encouraging the storage of glucose in the form of glycogen.

Several other hormones, such as adrenaline, glucagon, thyroid hormone and growth hormone, are involved in increasing the blood sugar level.

Insulin resistance

The vast majority of patients with Type 2 diabetes or pre-diabetes are characterised by insulin resistance. Despite normal or even elevated blood levels of insulin, insulin has less effect than in normal individuals. Peripheral insulin resistance means that insulin is less effective at mediating the uptake of blood glucose by muscle cells. In the liver, insulin fails to suppress the production of new glucose and the breakdown of glycogen. Thus, insulin resistance tips the glucose homeostasis towards high blood sugar levels (hyperglycaemia).

Type 1 diabetes

Type 1 diabetes is an autoimmune disease. In genetically susceptible individuals, an inflammation of pancreatic beta cells is triggered, most likely by a viral infection. Because beta cells are the only ones able to produce and secrete insulin, complete insulin deficiency ensues. As a result, all Type 1 diabetic patients require insulin replacement therapy. The only exception is during the 'honeymoon period' that some patients experience shortly after diagnosis and initial treatment, owing to some residual insulin secretion early in the progress of the disease.

Type 2 diabetes

Type 2 diabetes is a prime example of a disease caused by a combination of genetic and environmental factors. The genetic influence is greater than for Type 1 diabetes: the identical twin

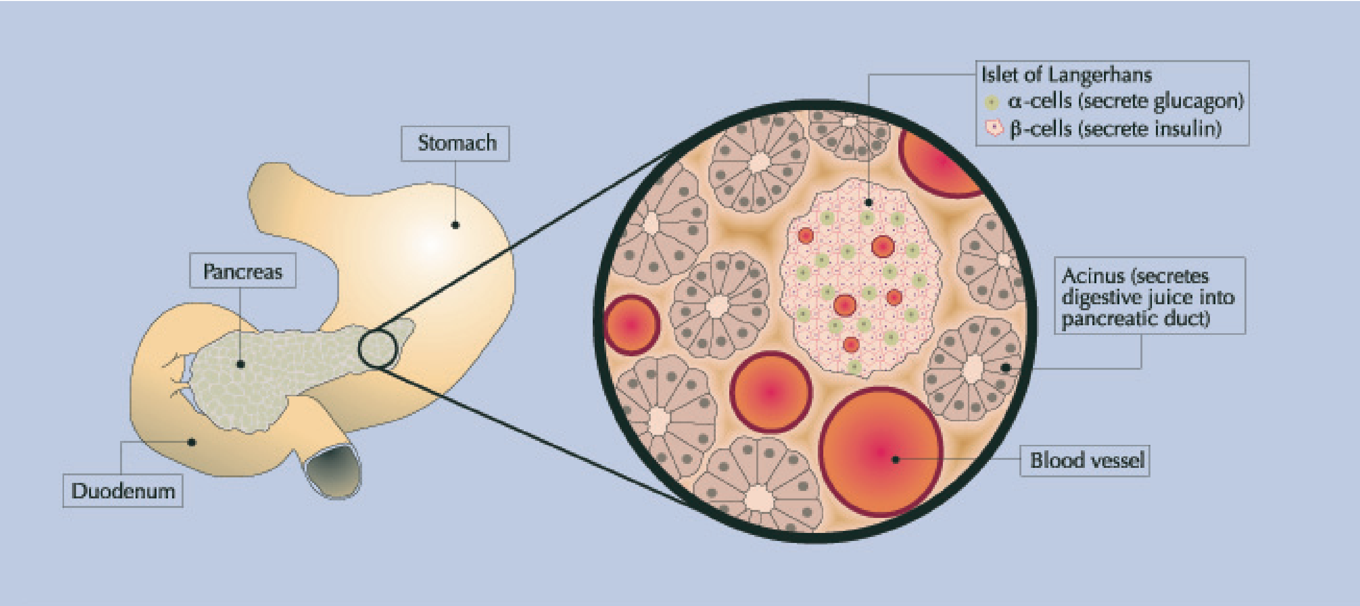
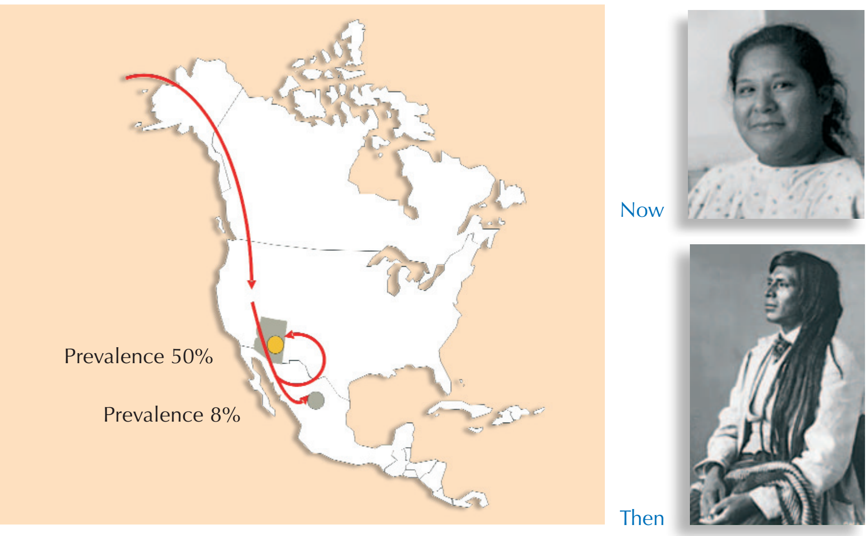


Image courtesy of Dean Madden

Structure of the pancreas

of a Type 2 diabetic patient is almost certain to develop the disease. On the other hand, lifestyle factors such as diet and exercise are also important determinants; in times of scarce food supply, for instance, the incidence of Type 2 diabetes is very low. A good example of the interplay of genetics and lifestyle are the Pima Indians. Those living in Mexico have a diabetes prevalence of about 8%, whereas those who have emigrated to the USA, where the lifestyle is more sedentary and access to energy-dense (fatty) food is easier, have a diabetes prevalence of about 50%.

The most important risk factor for Type 2 diabetes is obesity. Epidemiological studies have shown that, compared to lean individuals, very obese men and women (body mass index >35) have a 60- and 90-fold increased probability of developing Type 2 diabetes, respectively (see figure). In terms of genetics, Type 2 diabetes is a multifactorial disease for which no single gene is responsible.



Incidence of diabetes among Pima Indians: gene-environment interaction

In contrast to patients with overt Type 2 diabetes, patients with pre-diabetes (characterised by insulin resistance) do not exhibit hyperglycaemia when fasting. However, after a challenge like an oral glucose tolerance test (oGTT), during which 75 grams of glucose are ingested, patients exhibit pathologically high glucose levels (see Table 1). These patients, therefore, are characterised as having impaired glucose tolerance.

For a limited period, pancreatic beta cells are able to produce enough insulin to overcome the insulin resistance, so many pre-diabetic patients actually have elevated plasma insulin levels. However, in most patients, the rate of beta-cell death exceeds that of beta-cell formation in the pancreas, resulting in fewer insulin-producing beta cells. When the insulin-producing capacity of the pancreas is overtaken by the increased demand caused by insulin resistance, the patient develops overt Type 2 diabetes.

	Normal	Impaired fasting glucose or glucose tolerance	Overt diabetes
Fasting glucose	<110 mg/dl <6.1 mmol/l	110-139 mg/dl 6.1-7.8 mmol/l	≥140 mg/dl ≥7.8 mmol/l
2h after oGTT	<140 mg/dl	140-199 mg/dl	≥200 mg/dl
	<7.8 mmol/l	7.8-11.1 mmol/l	≥11.1 mmol/l

Table 1: Diagnostic criteria for Type 2 diabetes

Three main factors contribute to hyperglycaemia:

1. Insulin resistance in the muscle tissue, causing the muscles to take up less glucose from the blood.
2. Impaired insulin secretion by the pancreas.
3. Increased glucose production by the liver as a consequence of hepatic insulin resistance.

In the last few years, it has been demonstrated that adipose (fat) tissue and the central nervous system also play important roles in the pathogenesis of Type 2 diabetes.

Diagnosis

Symptoms

Unspecific early symptoms of diabetes include fatigue, a lack of general well-being, or an increased tendency towards infections, e.g. bladder infections. When hyperglycaemia becomes more pronounced, patients lose glucose via the urine, and produce more urine. This leads to the symptoms of overt diabetes, which are typically the initial symptoms of Type 1 diabetes: increased frequency of urination leading to increased thirst, and subsequently to dehydration and weight loss.

Screening

In the early stages of Type 2 diabetes, patients have few or no symptoms, and often go undiagnosed for many years. Unfortunately, diabetic complications (see below) frequently develop during this time. Therefore, it is important to screen those at risk of developing Type 2 diabetes, such as obese people, those with a family history of diabetes, and women who previously experienced gestational diabetes. Screening can be done either by measuring the blood glucose levels while the individual is fasting, or by performing an oGTT (see above). The most important criteria for diagnosing diabetes are shown in Table 1.

The most important measure for monitoring the course of diabetes is glycosylated haemoglobin (HbA1c). The higher the blood glucose value over time, the more non-enzymatic glycosylation of haemoglobin will occur. Because haemoglobin is transported in red blood cells, which have a mean lifespan of about 120 days, the HbA1c value is a reflection of the glucose control over the previous three months. In most assays, an HbA1c value of <6.1% is considered normal. The target value for diabetic patients is an HbA1c of <7.0%, or even <6.5%.

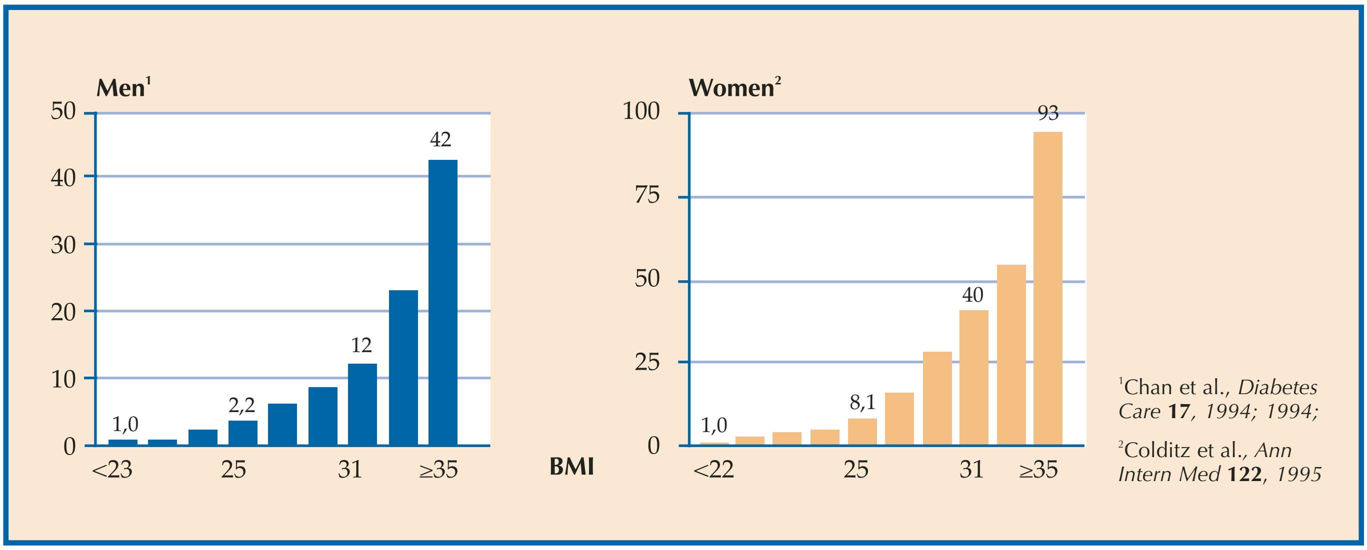
Treatment

The basis of diabetes treatment is educating patients about the pathogenesis of the disease, diabetic complications, dietary and drug treatment, and other aspects of the disease.

All diabetic patients need to be instructed about the appropriate diet and exercise, and the necessity, in most cases, of losing weight. Those Type 2 diabetic patients who manage to radically change their lifestyle and lose significant amounts of weight have a very good chance of ridding themselves of the disease. Unfortunately, only a very small minority of patients manage this.

If the HbA1c value stays above 7.0% despite improved diet and exercise, drug treatment is warranted. Several oral anti-diabetic drugs are currently on the market which target different causes of hyperglycaemia. Metformin reduces hepatic glucose output, sulfonylurea drugs increase pancreatic insulin secretion, and the glitazones reduce peripheral insulin resistance.

If the HbA1c value stays above 7.0% despite treatment with several oral anti-diabetic drugs, insulin therapy is indicated. The first step is often



Obesity as a risk factor for Type 2 diabetes: relative risk for Type 2 diabetes (age corrected)

to treat with long-acting insulin at bedtime. Eventually, many Type 2 diabetic patients will, like Type 1 diabetic patients, require full insulin therapy. This will be either a fixed twice-daily regimen of mixed insulin containing a short-acting and a long-acting insulin, or an intensive regimen with injection of a long-acting insulin at bedtime and/or in the morning, and injections of short-acting insulin with meals. Insulin dose and food intake must be closely matched to prevent either hyper- or hypoglycaemia.

Due to the high risk of cardiovascular problems (see below), it is important to treat not only the glucose disturbances, but also other risk factors of cardiovascular disease such as high blood pressure and high cholesterol levels.

Complications

Due to a high frequency of complications, diabetes significantly reduces life expectancy. Because of complications with the small blood vessels (microvascular disease), Type 2 diabetes is currently the most frequent cause of adult-onset loss of vision (diabetic retinopathy), renal failure (diabetic nephropathy), and amputation (diabetic foot) in the industrialised world. The most frequent microvascular complication is diabetic neuropathy, usually a disease of the distal sensory nerves, which impairs the perception of vibration, temperature, and pain in feet and hands. In later stages, diabetic neuropathy can be characterised by severe pain.

In addition, Type 2 diabetes is associated with complications of the large blood vessels (macrovascular disease), and a two- to five-fold increased risk of cardiovascular disease, mainly myocardial infarctions (heart attack) and strokes.

Outlook

New application methods of insulin – inhaled and oral – are currently being tested in clinical trials, along with drugs with improved efficacy and reduced side-effect profiles.

More important, however, would be preventive measures to tackle the worldwide increase in obesity and diabetes, especially in developing countries in which most of the predicted new cases of diabetes will occur.

REVIEW

This article is suitable for updating secondary school biology teachers on diabetes mellitus, an issue of general interest and social relevance. This disease is becoming more and more common in industrialised countries and even in developing countries.

The text, which is divided into paragraphs to make information retrieval easy, takes into account every aspect of the disease, is written in a plain style, and explains technical terms clearly.

I recommend the use of this material for the teacher as a basis for classroom activities on human physiology and health education. Upper secondary school students would also benefit from using the article as a source of information to work autonomously.

Giulia Realdon, Italy

How do students perceive science and technology?

Svein Sjøberg and **Camilla Schreiner** from the University of Oslo, Norway, explain how they are investigating young people's attitudes towards science and technology.

Introduction

In many highly developed countries, there is a noticeable decline in the recruitment of students to science and technology (S&T) studies. 'Europe needs more scientists' is the title of a report by the High Level Group on Increasing Human Resources for Science and Technology in Europe (EC, 2004). This report examines the condition of S&T in the European Union and pays special attention to the number of people entering S&T education and careers. The title of the report reveals the point: the falling recruitment to S&T studies is seen as a large problem in most European countries. The same tendencies are noted in the USA and in most other countries in the Organisation for Economic Co-operation and Development (OECD).

It is a paradox that the most S&T-driven economies in the world are experiencing a lack of interest in S&T studies and careers among young people. The economic significance to a country of a high number of skilled scientists and engineers is well accepted. But young people do not choose their studies or careers because it is good for the domestic economy. Instead, they base their choices (when they have such choices) on their own interests, values and priorities. It is obvious that S&T studies and jobs no longer have the appeal in wealthier countries that they had some decades ago.

The lack of interest in S&T in schools and further studies is not only a problem for the economy, but also a threat to democracy, as most decisions in modern societies are highly dependent on considerations that involve weighing scientific arguments against value judgements. A scientifically illiterate voting population can be easily manipulated by propaganda.

For these reasons, it is important to understand the S&T-related attitudes, priorities and interests of the young generation: this is what the Relevance of Science Education (ROSE) study aims to do.

Positive perceptions of S&T in society

When we note the lack of interest in S&T studies and careers in some countries, the first and most obvious hypothesis might be that young people in such countries have negative or hostile attitudes towards S&T. Such assertions are often voiced in public debates. S&T is blamed for many of the evils of modern societies, like pollution, destruction of the environment, overuse of natural resources and even modern warfare and conflicts. Do young people really base their attitudes on such assumptions?

Several questions in the ROSE study shed light on this question. The results indicate that there is no general hostility against S&T among young people, neither in rich nor poor countries; generally, positive responses were received to statements such as:

- Science and technology are important for society
- A country needs science and technology to become developed
- Science and technology will find cures to diseases such as HIV/AIDS and cancer
- Thanks to science and technology, there will be greater opportunities for future generations
- Science and technology make our lives healthier, easier and more comfortable
- New technologies will make work more interesting
- The benefits of science are greater

"Science and technology are important for society."

"I like school science better than most other subjects."

Figure 1

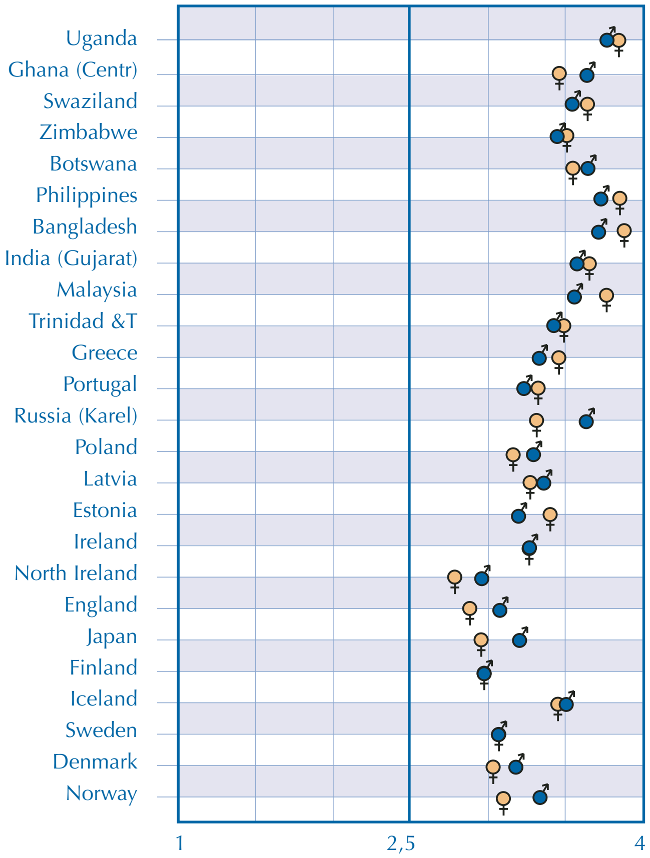
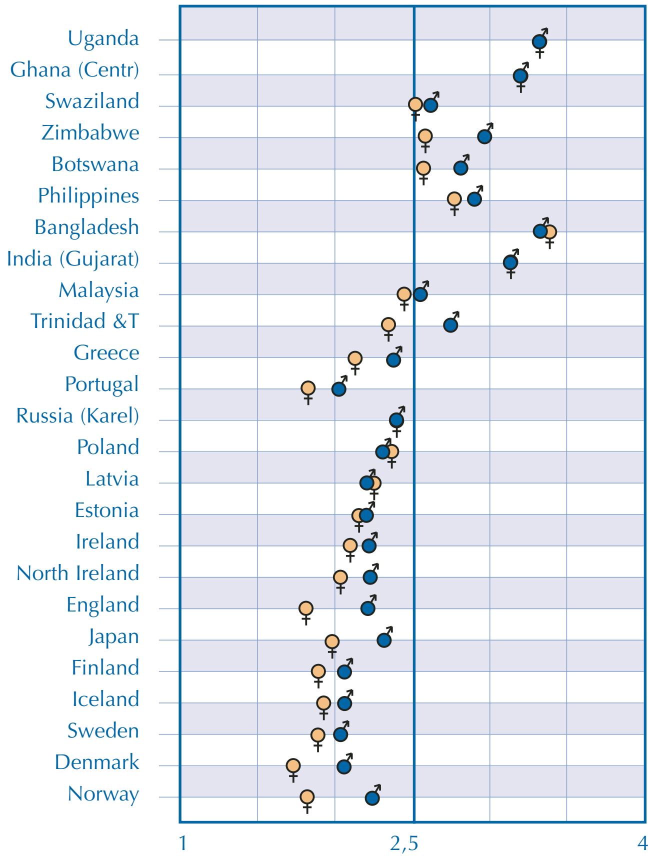


Figure 2



ROSE data showing mean values for girls (open female symbol) and boys (filled male symbol). The scale goes from 1 (disagree) to 4 (agree). Hence, 2.5 is a neutral response, marked with a vertical line. For some countries, only certain regions took part: in Ghana, only the Central region; in Spain, only the Balearic Islands; in Russia, only Karelia. India is represented by the region of Gujarat

than the harmful effects it could have

- Science and technology will help to eradicate poverty and famine in the world
- Science and technology are the cause of the environmental problems.

Most students (aged 14-16) in most countries agree to statements like those listed above, although there are interesting differences between nations and between girls and boys. In general, boys are more positive (or less sceptical?) than girls about S&T, and pupils in developing countries are more positive than pupils in richer countries. But it is important to note that the overall attitude towards S&T is positive.

As illustrated in Figure 1, girls and boys in all countries show pronounced agreement with the statement "Science and technology are important for society". Children in developing countries agree more strongly. Gender differences are rather small.

Problematic attitudes to S&T in schools

Although students in all countries share a positive view of many aspects

BACKGROUND

ROSE (Relevance of Science Education)

ROSE is an international comparative study that investigates the diversity of interests, experiences, priorities, hopes and attitudes that children in different countries bring to school or have developed at school. The underlying hope is to stimulate an informed discussion on how to make science education more relevant and meaningful to students in ways that respect gender differences and cultural diversity. We also hope to shed light on how to stimulate interest in S&T-related studies and careers. ROSE has developed, after consultation with science educators from all continents, an instrument that tries to examine the attitudes of 15-year-old students. The ROSE instrument has around 250 single items – simply worded questions or statements requiring responses on a 4-point Likert scale. This enables the use of standard statistical methods like calculations of means and correlations. About 40 000 students from 35 countries took part in ROSE, and about 10 PhD students from different countries will base their theses on ROSE data. Schreiner & Sjøberg (2004) report fully on the project rationale, development and logistics. Additional information, including reports on data collection from the participating countries, is available on the ROSE website[w1]. Several comparative articles and international reports have been published and more are planned.

of the role of S&T in society, the attitudes to S&T in schools are more mixed.

As Figure 2 demonstrates, there are large differences between how much students in different parts of the world like school science. In general, students in developing countries like school science very much, whereas students in richer parts of the world are more negative. We also note large gender differences: in some countries, girls dislike school science more strongly than do boys. ROSE also includes a series of questions about how students have benefited from school science, but space restrictions prevent us from detailing these here.

Reluctance to enter S&T careers

Many ROSE items ask young people about the plans and visions they have for the future. Here, we only give the responses to two simple questions: whether the student wants to become a scientist (Figure 3), and whether the student wants to work in technology (Figure 4).

As illustrated in Figure 3, there are dramatic differences between the responses from students in rich and in developing countries. In developing countries, students have a strong desire to become scientists, whereas students in most OECD countries are reluctant, with average responses of less than 2 on the 4-point scale. We also note the strong gender pattern, particularly in wealthier OECD countries. In many of these countries, the average response for girls is around 1.5, indicating that most of them strongly reject the idea of becoming scientists.

In Figure 4, we see a similar, but even stronger, pattern: working in technology seems to have a much stronger appeal in developing countries than in rich countries. In many wealthy countries, the average response from boys is close to the neutral line (2.5), but the responses from girls are strongly negative. We also note that in Japan, girls and boys are more negative towards working with technology than are students in any other country.

Conclusions

This short article gives an indication of the data and information emerging from the ROSE study. We have only presented summary statistics for four of the 250 items; more details and advanced analysis will be available on our website[w1]. The first PhD based on ROSE data has recently been presented (Schreiner, 2006), detailing the analysis of the interests young children have in different topics in science and technology. Based on this analysis, a typology of students is suggested.

Through ROSE, we hope to stimulate an informed discussion on important aspects of S&T and its role in society and in education. Researchers from many cultures are involved in the research and discussions about issues of common concern. International cooperation, networking and capacity building are also intrinsically important. Our hope is that S&T education will be an instrument not only to promote material development and well-being, but also to address basic human values.

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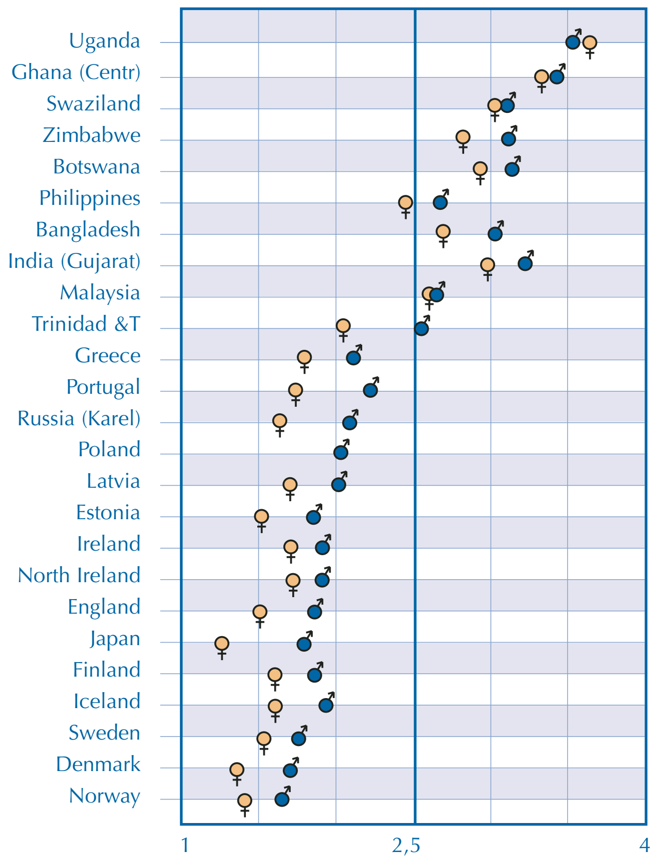
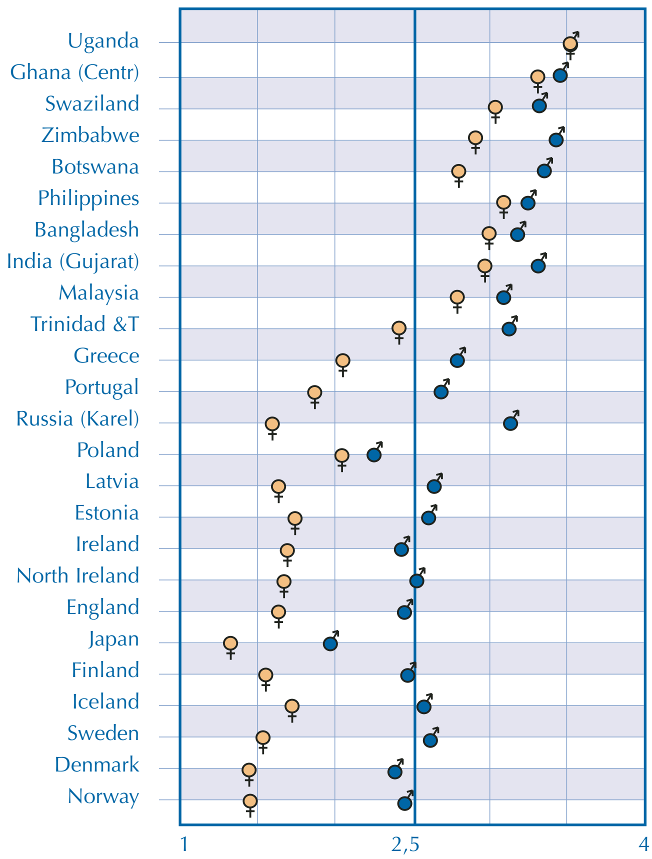
"I would like to become a scientist."

Figure 3



"I would like to get a job in technology."

Figure 4



ROSE data showing mean values for girls (open female symbol) and boys (filled male symbol). The scale goes from 1 (disagree) to 4 (agree). Hence, 2.5 is a neutral response, marked with a vertical line. For some countries, only certain regions took part: in Ghana, only the Central region; in Spain, only the Balearic Islands; in Russia, only Karelia. India is represented by the region of Gujarat

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The sky's the limit

What inspires someone to be a spacecraft designer? And how can you become one? **Russ Hodge** from the European Molecular Biology Laboratory in Heidelberg, Germany, interviews Adam Baker and reveals all.

Imagine a fleet of satellites the size of footballs drifting over the surface of the International Space Station and making repairs, or peering deep into moon craters in search of water. Although most satellites today are large and weigh several tons, space engineering companies across the world are hoping to take advantage of microelectronics and other technologies to make them much smaller. That could dramatically reduce the costs of boosting a cargo into space, which often amounts to more than € 20 000 per kilogram.

This is one of the arguments that people raise against manned spaceflights, says Adam Baker, an engineer and project manager for Surrey Satellite Technology Limited (SSTL) in the UK. "Sending up a normal adult would cost about €1.5 million, just from the weight alone. The real costs are of course much higher, because you also have to send up everything necessary to sustain and protect that person. Imagine everything you'd have to take along on a mission to Mars."


Adam Baker, spacecraft designer

He'd love to see the European Space Agency send a manned mission to the red planet, but it's much more likely that the next generation of spacecraft to go there will be nanorobots carrying miniaturised laboratories. That could yield a wealth of information about the problems humans would face on Mars, especially if the probes returned samples to earth. It's something Adam has thought about a lot; in his last job, he and his colleagues tried to design an engine that could derive its fuel from the Martian atmosphere.

He has had his hand in several other fascinating projects, such as figuring out how to fly a balloon through the clouds of Venus and to keep it aloft for a month. "The surface of the planet is incredibly hot, but 70 or 80 kilometres up, there's a benign atmosphere," Adam says. "We'd like to know what it's like because Venus has been through the worst-case scenario of a runaway greenhouse effect. How did it get that way? We might learn a lot about our own atmosphere."

Flying such a balloon for a month would be tricky, he says, especially since normal power systems – based on solar energy – probably wouldn't work. You couldn't count on enough sunlight getting through the dense atmosphere. So the team looked at other options: a small nuclear reactor, or fuel cells, or even a simple combustion engine. Although the probe has not yet been built, the lessons learned about how to do this at a reasonable cost will be applied to future missions.

The exciting thing about SSTL, Adam says, is that the company can carry out all the stages of a project, from designing something to building and testing it. The main facility in Farnborough, near London, has clean-rooms, thermal vacuum chambers, solar simulators, and everything else you need to reproduce the harsh conditions of space.

Many an engineer has spent a sleepless night worrying that a satellite he or she been building for two years won't succeed. But some important projects have made it from the drawing board into space. While we were talking, for example, an SSTL satellite was tracking a huge fire that had broken out near London. A jet-fuel storage facility in Hemel Hempstead had burst into flames early on a Sunday morning, in an explosion that could be heard 150 kilometres away. Monitoring the fire is just the sort of job for which the Disaster Monitoring Constellation (DMC) – a network of five satellites all built by SSTL – was designed. As a member of the propulsion engineering group, Adam played an important role in developing, building and testing the satellites' engines.

A DMC satellite passes overhead every three or four hours, giving the quick, frequent feedback that is necessary in an emergency – with a single craft, you might only be able to monitor a situation every few days. The cameras on board offer an ideal combination of high resolution and broad coverage: each image encompasses an area 600 by 600 kilometres in size. "The resolution isn't high enough to make out single people," Adam says, "but the cameras are able to operate in the red, green and infrared ranges. That's perfect for studying fires, or vegetation, or the weather. We watched Hurricane Katrina and the 2004 tsunami. You can also watch humans' impact on the environment. We've tracked ships cleaning out their tanks, creating oil slicks."

Here, too, low weight and efficient design significantly reduce a satellite's price tag, putting space within reach of customers who normally couldn't afford to put something into orbit. SSTL has constructed satellites for Nigeria, Turkey and China, and built Algeria's first-ever spacecraft. "This gives countries a foot on the rung of space and space-related applications," Adam says.

So how does a person become a spacecraft designer? Adam remembers some key events from his childhood. When he was young, he lived for a few years in the Far East, experiencing first-hand an incredible boom in technology. That sparked a lifelong interest in engineering.

When Adam was ten years old, NASA's Voyager space probe flew by Saturn on its way out of the solar system. "There was a *National Geographic* lying around with absolutely stunning pictures of the rings. It was amazing to me that we could have a craft up there taking images like that – as if the planet were right next door."

The school that he attended when he returned to the UK didn't offer courses in space science or engineering, but Adam stocked up on physics, chemistry and mathematics. Those subjects come together in materials science – the study of metals and other substances and their applications in areas ranging from electronics to aircraft design. This field was given a huge boost in the 1960s by the American space programme; special alloys of metals, polymers and other materials had to be designed to withstand conditions in outer space. Adam decided that this was what he would study at Oxford University.

Just before leaving school, however, he took part in the UK's first-ever space school, a week-long camp sponsored by Sevenoaks School in Kent – a camp that is still run every year. It gave Adam and a group of other like-minded 17-year-olds the chance to visit a space science lab and attend lectures and workshops by people working in the field. "It was great to hear that there really was a way to get a job in the space industry," he says.

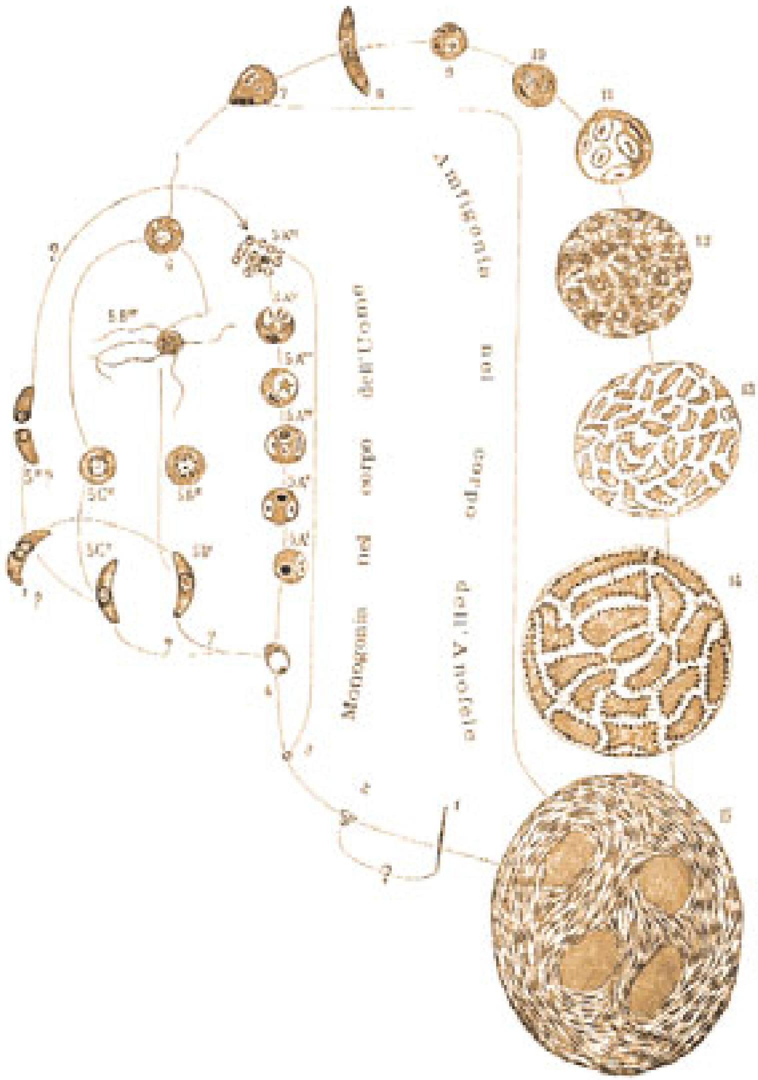
Oxford University had plenty of materials science, but no space programme. Adam spent most of his PhD peering down an electron microscope, almost a bad joke for someone whose dreams lay in the stars. What he was doing was, though, connected to aeronautics: in his dissertation he tried to find a way to make the insides of jet engines out of titanium – which is much lighter than the nickel alloys used in today's engines. The project wasn't entirely successful because the method he used produced forms with erratic shapes. "That's not something you want to have in a jet engine that has to run at extremely high temperatures for billions of hours," he says.

In the meantime, Adam found a new way to keep in touch with outer space. Oxford University encourages its students to join clubs, and if there is none to fit your tastes, you can found your own. So Adam created the university's first space society, and he and his friends started working on rocket engines. "Some of them were really large. We got sponsorship and went to conferences, where we gave talks about what we'd been doing." After such a presentation in 2001, he was approached by representatives from a company that built satellites.

"They said they might have a job," he said. "They warned me that I wouldn't be building things quite as exciting as our work with the club. I said, 'Where do I sign?' Again, they said the work wouldn't be quite as exciting, but the things I would be building would get into space. Again, I said, 'Where do I sign?' The very first day of work they had me assembling a propulsion system for a satellite that is now in orbit for Algeria."

Fighting malaria on a new front

Stéphanie Blandin explains her work on malaria to **Russ Hodge** from the European Molecular Biology Laboratory in Heidelberg, Germany – and describes how she became a molecular biologist.



The closest that many of us will ever come to malaria is a handful of pills prescribed before a trip to a tropical country, or the stories of ancient expeditions wiped out by mysterious fevers. But the disease seems remote only from the comfortable armchairs of the developed world. For much of the rest of the globe, malaria is still a huge problem. It kills millions each year – mostly children in Africa.

Malaria is caused by a single-celled parasite called *Plasmodium*. Scientists believe that the most dangerous form of this organism has been around for about eight million years – ever since humans diverged from apes. The disease probably became a huge problem when humans began clearing land for agriculture, leaving standing pools of water that made ideal breeding grounds for mosquitoes, which transmit the parasite to humans through a bite.

In our bodies, *Plasmodium* infects blood cells and reproduces, bursting out in waves. The surface proteins of the parasite change with each generation, helping it escape our immune system. An infection leads to fever and often death.

The lifecycle of the malarial parasite (Giovanni Grassi, 1854-1925)

Stéphanie Blandin at work

There are two main ways to fight malaria: first, by attacking mosquitoes – destroying the places where they breed or destroying the insects themselves with pesticides (such as the infamous, and now largely banned, chemical DDT). The second approach is to treat infected patients with drugs such as quinine, but *Plasmodium* is developing resistance to drugs. And global warming may bring malaria back to cooler regions where it has been almost entirely eliminated.

So researchers like Stéphanie Blandin, at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, have been putting new kinds of science to work on the problem. Studies of *Plasmodium* may reveal weaknesses in the organism that can be targeted with drugs. Another approach, in which Stéphanie is most interested, might be to take the fight inside the mosquito. Malaria makes the insects ill, too, and curing them would be just as good as stopping the organism in the human body – maybe even better.

Stéphanie has always wanted to be a scientist. Her father is a farmer who raises cattle and grows grain in the Bourgogne region of France; her uncles produce wine; her mother is a nurse. "At home, there were magazines lying around; I particularly remember a magazine about cancer research," she says. "When I was very small, I liked to look at the pictures. I liked the bottles, the beakers and the laboratory equipment. I liked the strange bluish and purple colours – you know, the colours of the gels that we use in experiments. Then when I learned to read, I liked the strange names of the drugs they talked about."

In school, Stéphanie liked mathematics and says she probably would have become a mathematician if she weren't a biologist. She enjoyed the farm and the outdoors and considered going into agricultural science. Both plant and animal science were covered in the *prépa* – a school that some French students attend after high school, to prepare them for the *grandes écoles* where they will learn science and other careers.

Finally, she decided to concentrate on biology. "But first I wanted to see what real-life work in a lab was like. I also wanted to learn better English." Stéphanie spent a few weeks in a laboratory at EMBL. Then when an opportunity opened up to do a practical period in the lab of Max Cooper at the University of Alabama, she jumped at the chance to go to the USA. Cooper was working on a fascinating problem: how molecular signals trigger generic cells to become specialised immune system cells. After six months in Alabama, she was hooked.

Stéphanie seems entirely at home in front of the microscope, mounting a slide and adjusting the focus with a quick twist of her hand. She steps back and lets me take a look. A few days ago, a mouse was bitten by *Anopheles* mosquitoes; we are looking at samples of its blood. The view is full of pearly globes – red blood cells – and when Stéphanie tells me what to look for, even I can see that the mouse has malaria. Some of the cells are cluttered with black spots, caused by a dye that marks the presence of the parasite.

The hardest part of her job is to infect 'cute white mice' with malaria, she says. "But it's necessary. If you have ever seen a child suffering from this horrible disease... that sight stays with you. The fact that the parasite is developing resistance to the drugs puts millions more people at risk and we are going to need new ways to fight it. It makes you work harder and helps you to make some of these difficult choices."

Now that she has shown that the mice have been infected, Stéphanie will try to infect a new round of mosquitoes. She divides the insects into three hand-made cups that she designed herself – "mosquito houses" – because there are slight differences between the three groups. She will let them all feed on the infected mice – which have been briefly put to sleep –

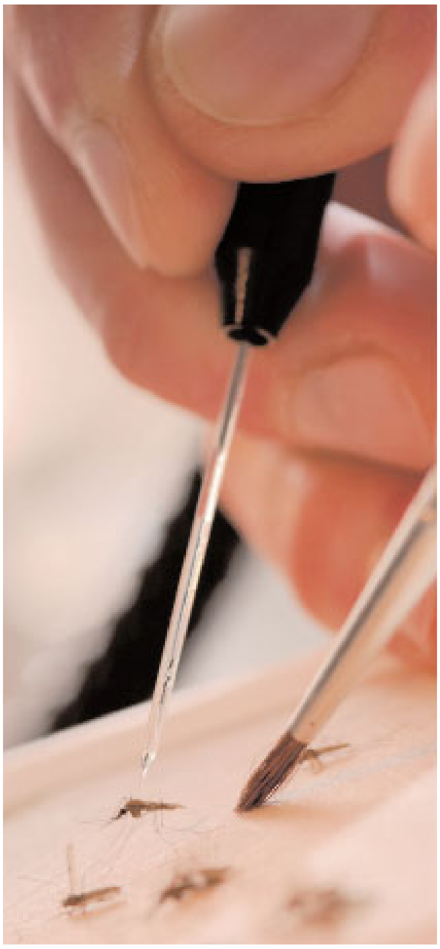
hoping to see differences in their ability to transmit the disease.

"When I began working in this area, almost nothing was known about the mosquito immune system – it wasn't even certain that they really had one," Stéphanie says. "There were good reasons to think that they might, because some other insects are known to have a basic immune system, and mosquitoes are related to them through evolution. Some flies, for example, produce proteins that protect them from some types of bacteria. Elena Levashina, my supervisor in the lab, had found two types of molecule called thioester-containing proteins [TEPs] in the mosquito. My job was to try to find more, and to discover whether they had anything to do with a mosquito immune system."

Some mosquitoes seemed to be able to battle malaria: researchers had discovered a strain of *Anopheles* that was unable to transmit the disease. "This unusual strain is so close to the normal, disease-carrying type of mosquito that we think only a few mutations in genes – maybe even only one – protects it," Stéphanie says. "A single protein might be killing the parasite in the mosquito body."

Within two years, Stéphanie and her colleagues had found over a dozen other potential immune-system molecules. Early studies showed that TEPs helped mosquito cells kill bacteria – could the molecules also help in the fight against malaria? "You can't study parasites and mosquito cells in the test tube," Stéphanie says, "so we had to go directly to studies in the mosquito body." The team discussed how to do these experiments, but they knew they were running up against the limits of gene technology.

"In other organisms, there are methods that let you shut down molecules or switch them on," Stéphanie says. "This kind of genetic engineering is very useful to investigate such questions – you could take the immune strain and then shut down one of its



Working with mosquitoes

proteins. If the mosquito could then transmit malaria although it hadn't been able to before, we'd know that this particular molecule was helping to protect it."

Unfortunately, these methods hadn't yet been developed to work in the mosquito. A new method was being used in worms and other organisms to shut down specific proteins; it involved injecting animals with a slightly altered version of one of their own molecules. To create proteins, cells make a template molecule called RNA. Scientists had discovered that injecting cells with a modified version of the template for a specific protein would block the production of that protein. So Stéphanie tried the same method (called RNA interference, or RNAi) in the mosquito, and discovered that it worked very well. Then she could inject mosquitoes with modified RNA, shutting down specific TEPs, and hoping to knock out the immunity of mosquitoes resistant to malaria.

"I did exactly what I am showing you now," she says. In her first 'mosquito house', she has controls – normal insects that should transmit malaria. The second and third houses hold mosquitoes that are normally resistant. But she has injected them with RNA one-by-one under the microscope, blocking crucial immunity proteins. Each of her two experimental strains has had a different TEP shut down. She hopes that at least one of the two altered types of mosquitoes will now be able to transmit the disease.

When the feeding is done, she returns the sleeping mice to their cage and the well-fed mosquitoes to their shelf. "Now the parasite has to grow and develop in the mosquito," she says. "We have to wait several days. The first time we did this, I was pretty excited."

The one thing Stéphanie likes most about science is the freedom. You can establish your own rhythm and work the hours that you choose – normally a lot. She likes to come by in the evening: quiet hours, when most people have gone home – that's when she gets the most work done. Often she comes in at noon and stays in the lab until two or three a.m. "It makes things a bit hard when your partner is also a scientist," Stéphanie says; her husband also works at EMBL. "You have to try to find a common schedule."

A few days after my first visit, she goes into the cold room next to the lab of Fotis C. Kafatos, where she has worked for the past few years. The mosquitoes she infected a few days ago are on ice. Below a certain temperature, the insects enter a dormant state in which they can survive a few days. She will now dissect them and search for traces of *Plasmodium*.

With a few deft movements under the microscope, she removes the mosquito's mid-gut, a stringy white tissue that looks like a very tiny version of our own intestines. The meal of blood passes through the mid-gut as the mosquito digests its food, and it's also here that the parasite starts its invasion. *Plasmodium* parasites in the blood squeeze through the cells that line the gut and travel through the mosquito body to reach the salivary glands, where they can infect a new animal or a human when the mosquito next feeds.

Her test has been successful. Stéphanie finds traces of the live parasite in strains of mosquitoes that normally can defeat *Plasmodium*. By shutting down a single type of TEP, she has succeeded in transforming non-infectious *Anopheles* into carriers of malaria.

"Obviously what we want to do is the opposite," she says. "Now that we know this particular protein, TEP1, is vital to killing the parasite, we can look for ways to introduce it into mosquitoes that otherwise transmit the disease." It will probably be many years, she says, before this work will result in a cure for malaria. That might take the form of a 'smart spray' that strengthens the mosquito immune system, or even result in genetically modified mosquitoes that might one day be released into the environment. Before any of that happens, of course, scientists will have to know a lot more about *Anopheles* mosquitoes, and will only intervene after careful studies and with the full consent of affected countries.

No one knows where the next major breakthrough in the fight against malaria will come from. But in the past, the key battles against the disease have been won by taking the fight to the mosquitoes. As long as the disease exists, and they are able, insects will continue to transmit malaria. That's more than enough reason, Stéphanie and her colleagues think, to attack the problem with all the tools available to today's molecular biologist.

REVIEW

This article talks about a scientist who works in a molecular biology lab, trying to find a cure for the deadly disease of malaria. The end result is a story any scientist – or anyone thinking about becoming a scientist – should read. It is interesting, optimistic and sends a message of hope for a better world. At the same time, it raises many important questions.

As the story unfolds, the reader gets a general overview of the specifics of the disease: how it is caused, how it is spread, what efforts have been used to battle it so far, and what the present research focuses on. Although much of this information can be found in many good biology schoolbooks, it is presented here in an interesting and readable fashion.

When you read about the scientist in the article, you get a positive view of what scientists do: they have the opportunity to work in research centres around the world carrying out fascinating projects; they use modern scientific techniques; they are free to design their own (admittedly quite heavy) work schedule; and most importantly, their personal contribution can lead to discoveries of worldwide significance, which could save the lives of millions, especially children.

Perhaps what makes this article unique is that it effortlessly raises a number of topical issues, which concern not only the scientific society but also governments, organisations and the general public. In a very short historical account of the appearance of malaria, the author hints that perhaps it was human action thousands of years ago that allowed the disease to evolve from a rare one to a major killer. In modern times, human action resulting in global warming might even bring the disease from distant tropical countries right to the doorstep of the developed world. The issue of the use of lab animals in research is also briefly addressed. In addition, it is suggested that scientific discoveries should only be exploited after careful examination of all their implications.

This article could be used in various ways as a teaching aid. Apart from its obvious use as a source of scientific information for the teacher, it could be used as an alternative form of teaching tool. For example, the teacher could give it to the students and ask them to complete a worksheet to collect scientific information and obtain an insight into how real-life scientists design their research.

Michalis Hadjimarcou, Cyprus

Those who can, teach

Adrian Dow originally wanted to be a bank manager but is now a mathematics teacher. He explains to **Marianne Freiberger** how his enthusiasm for teaching developed – and what his plans are for the future.

When Adrian Dow left his native Trinidad in 1992 and came to the UK to complete a mathematics degree, he was firmly set on going into banking. "Bank director was very high on the list. […] But during the lectures, I used to try to think of better ways of putting mathematical concepts across. Also, the idea of having a positive impact on the world around me suddenly became really important to me. I'd always liked the idea of working with young people, and at school I was good at explaining things to others, so I eventually decided to try and go into teaching."

A voluntary teaching stint turned Adrian's interest into a passion. He absolutely loved working with kids, but it was not all positive. "Talking to kids about how they felt they were being taught and the methodology behind the teaching raised a lot of questions. The teacher didn't manage to infect them with any kind of enthusiasm and it became clear to me that there had to be better ways than that."

But was Adrian himself enthusiastic about mathematics at school? "No, it really came about when I was doing my degree.
I came to love mathematics for what it is, for its beauty. And I wanted to show the kids that wherever you look, be it music, philosophy or nature, you get a hint of mathematics. I think this is what's lacking in a lot of mathematics teaching."

In his first school, in London, he spent four years putting his theories into practice. He greatly enjoyed his time there and felt that his teaching methods were successful, but it was time for a change. "I had always said that if I could teach for free, I would. It's a very rewarding job, and there are many places in the world where the education systems suffer from severe lack of funding. So teaching with the Voluntary Service Overseas [VSO] really appealed."

The big wide world

The VSO is an international development charity which sends skilled volunteers to countries where their help is needed. Adrian started at a school in a remote village called Bartica, in Guyana, South America. Surrounded by unspoilt nature, this was a far cry from busy London, but that was not the only difference. "In the school, everything was different from what you'd expect in England. There wasn't enough chalk, there weren't enough blackboards. The roofs were leaking, and kids were sitting four or five to benches that were designed for two. And there were no complaints! There isn't a social system out there that looks after people, and the children know that school is their only ticket to success."

But despite the enthusiasm, school had to compete with families' more pressing, economic, concerns. "Amongst the older students, girls often outnumbered boys three to one, because the boys had to go out to work – sifting river beds in remote areas for specks of gold. It's a quick buck, but a hard and even dangerous one, as malaria is rife. We tried to get the parents not to sacrifice their sons' education. It's hard to break the cycle, but sometimes we were successful."

Two of the classes that Adrian taught were due to take their final examinations at the end of his stay in Guyana. To prepare them, Adrian set up voluntary Saturday lessons. The turnout was overwhelming. "On the first day, 75 kids turned up! We kept on going like that for 62 Saturdays: rain or shine, the kids would come. That really spurred me on to work with them, and sometimes we'd organise cricket games after the lesson and turn the mathematics lesson into a full day event."

The hard work paid off: that year, the school achieved its highest ever grades in mathematics.

Gear change

But what next? Adrian returned temporarily to London and there, the head teacher in his previous school had a proposition that kept Adrian in the country for another four years. "An initiative, called the Behaviour Improvement Programme, was just starting. Truanting, lack of discipline and even violence was, and still is, a big problem in some schools. So the government had decided to invest money to find a way of addressing the problem.

"As a 'behaviour improvement project manager', I started by looking at the various sanctions for students, talking them through behavioural issues, but especially using restorative justice. This is about getting the kid and the teacher, or the kid and the kid, to talk about the problem they have with each other. That very quickly proved to be a successful strategy. It injects a human element into the process and gives students – and teachers – the opportunity to identify the problem themselves, to explain their behaviour or to apologise."

And it wasn't only the kids who had something to learn. Adrian organised a few sessions with teachers. "We talked about how the children mirror you. So if you shout to communicate, don't be surprised if they shout back at you."

On the whole, Adrian feels that the behaviour improvement project is on the road to success. "Of course we didn't manage to solve all the problems, but what our strategies do very well is to differentiate those students who present a permanent problem from those who have the odd bad day."

But in a world where many kids face distressing family problems, and in which drug abuse and youth offending is rife, is there any virtue in learning mathematics? "Questioning the world around you, questioning life, is at the heart of mathematics. There are a lot of life lessons in mathematics, apart from the obvious 'it'll help you understand your bank statements' ones. How much of that is actually expanded on in a classroom is another question. I wish we had a slower system in which there was time to expand on the background of things, to talk about their beauty and meaning, but there just isn't enough time."

Sun, sea and more school

Now Adrian feels that it's time to return to Trinidad. Ultimately, he wants to set up his own school. "First, I have to get into the education system over there, and then see whether the state would support me, or whether I'd have to go private and, in that case, see how I can make it affordable for people."

"I'd like to set up a teaching environment in which you can explore things and delve into the children's questions rather than rush through a syllabus. Most of all, I'd like to teach the kids to be inquisitive, to nurture their interest in the world. I often say to them 'well, this is Pythagoras' Theorem, what's yours going to be?' I'd like to have the best of both worlds, in which the teaching is enjoyable for the teacher and the workload is manageable, and where the kids are inquisitive and keen to interact. It's a really idyllic vision. Many teachers have told me that it just doesn't exist, but I think you have to go out there and create it."

Resources

More information about the Voluntary Service Overseas is available at: www.vso.org.uk

More information on the UK Behaviour Improvement Programme is available at: www.dfes.gov.uk/behaviour improvement/

Marianne Freiberger is co-editor of *Plus Magazine* (www.plus.maths.org), a free online magazine which aims to introduce readers to the beauty and applications of mathematics. This article was first published in *Plus* in a longer form (www.plus.maths.org/issue37/interview).

Deep Impact

Films about science or even pseudo-science can be powerful tools in the classroom. **Heinz Oberhummer** and **Markus Behacker** from the Cinema and Science project provide a toolkit for using the film *Deep Impact*.

In the classroom, a scene or clip from a popular film or documentary about science or even pseudo-science can be used to stimulate discussion and raise interest in scientific subjects. The Cinema and Science (CISCI) website[w1], due to launch in December 2006, will describe a wide variety of film scenes, providing explanations and background information to help teachers prepare inspiring, film-based lessons.

This article on the film *Deep Impact* provides a sample of the content being developed by CISCI, including explanations for pupils and background information for teachers.

Deep Impact

The young astronomer Leo Beiderman discovers a comet. In an attempt to destroy it, a shuttle is launched to place nuclear bombs on the comet; when these are detonated, they succeed in splitting the comet in two. The larger piece misses earth, but the smaller piece lands in the sea, creating a tsunami. In preparation for the impact, a limited number of citizens are sheltered in special bunkers, ready to rebuild society after the catastrophe has passed. The people are selected by lottery together with 200 000 scientists, doctors, soldiers and other officials.

Scene 1: Comet produces mega-tsunami

As the comet passes through the atmosphere, friction with the air causes it to become a giant fiery ball. When it hits the ocean, it produces a mega-tsunami, with waves around 400 metres high. The tsunami reaches and devastates New York City and Washington, DC, and floods vast coastal areas.

Basic explanation

Comets consist of ice and dust and are therefore often called 'dirty snowballs'. They come from far out in the solar system. Asteroids, on the other hand, are rocks from a region between the planets Mars and Jupiter. Sometimes a comet or asteroid may hit earth. If it lands in the ocean, a series of gigantic waves are produced: a tsunami.

In this scene, a gigantic tsunami is produced when the comet hits the ocean. The tsunami, several hundred metres high, devastates New York City and other coastal areas. Given the size of the comet, several kilometres in diameter, the severity of the tsunami is realistic.

Advanced explanation

Comets

Comets consist of ice and dust and are therefore often called 'dirty

BACKGROUND

Cinema and Science (CISCI)

The CISCI project involves ten partners from Europe and the USA, and is part of the larger NUCLEUS project funded by the European Commission. The planned 160 content units will cover physics, biology, chemistry, mathematics, informatics and other science subjects and will be available on the CISCI website[w1] in English and the languages of the CISCI partners.

snowballs'. They originate from a far region of the solar system called the Oort cloud. When comets approach the sun, they heat up and emit particles from their surface (shown in the film as mini-eruptions). These particles are then dispersed by wind from the sun, forming the characteristic comet tail. Comets often have two distinct tails pointing in slightly different directions: one made of dust and the other of gas.

Oort cloud

The Oort cloud was named after the Dutch astronomer Jan Hendrik Oort and is about 50000 to 100000 kilometres further from the sun than earth. The Oort cloud consists of trillions of comets, left over when our solar system was formed.

Tsunami

The Japanese word 'tsunami' is written as two characters. The character 'tsu' means harbour, while the character 'nami' means 'wave'. The name comes from the experience of Japanese fisherman who returned to their harbour to find it totally devastated, although they had noticed nothing out at sea.

The height of a tsunami in open water is often less than one metre, although it may achieve a height of 30 metres or more as it approaches the coast. A tsunami may be produced by earthquakes, landslides, volcanic eruptions and impacts from comets or asteroids. The most common cause is an undersea earthquake. Through the sheer weight of water, the waves can pulverise all objects in their path, reducing buildings to their foundations. Even large objects such as ships and boulders can be carried several kilometres inland. After all, one cubic metre of water has a mass of one ton. Water, travelling at the speed shown in the film, acts as a solid body on impact.

Scientific description

Scientists have used computer simulations to describe an asteroid or comet, 1.4 kilometres in diameter, landing in the sea about 600 kilometres offshore. Such an event happens on average once every 1.8 million years. The simulation produced the following results:

- The released energy would correspond to about 275 000 megatons of TNT, or 27 500 hydrogen bombs.
- The asteroid or comet would completely evaporate upon impact.
- A crater about 12 kilometres wide and reaching 5000 metres below the water surface would be created.
- About 1 cubic kilometre of water vapour would evaporate together with the debris of the comet or asteroid, creating a huge cloud.
- A gigantic tsunami would be produced, flooding coasts and reaching a height of about 120 metres, about 10 times higher than the Asian tsunami on 26 December 2004. In the film, the tsunami is about 400 metres high.

A comet moves with an average velocity of about 40 kilometres per second (14400 kilometres per hour). As the comet moves at a low angle across the sky, we can draw a comparison with the velocity of a passenger aeroplane, which has a speed of about 800 kilometres per hour.

The comet moves 180 times faster (14400/800) than the aeroplane. A passenger aeroplane can be observed moving across the sky for about 6 minutes, or 360 seconds. The comet would cross the sky in about 360/180 = 2 seconds. The time taken for the comet to move across the sky in the scene, therefore, is too slow.

To summarise, the *Deep Impact* scene showing the comet is not quite realistic. However, the tsunami and its devastating effects in the scene are essentially scientifically correct.

Web references

w1 – The CISCI website can be found at www.cisci.net

Resources

Deep Impact sites

The Internet Movie Database: www.imdb.com/title/tt0120647/

Wikipedia:http://en.wikipedia.org/wiki/Deep_Impact_%28film%29

Amazon (DVD: *Deep Impact*, Special Edition, Dream Works Home Entertainment): www.amazon.co.uk

Amazon (DVD: *Deep Impact*, Paramount): www.amazon.com

Comet sites

Wikipedia: Scientific description of comets: http://en.wikipedia.org/wiki/Comet

Views of the Solar System: introduction to comets, including images: www.solarviews.com/eng/comet.htm

Views of the Solar System: film about the history of comets: www.solarviews.com/cap/comet/vcomet.htm

Windows to the Universe: educational site about comets: www.windows.ucar.edu/tour/link=/comets/comets.html

NASA/ESA Hubble Space Telescope site: video clips about comets: www.spacetelescope.org/bin/videos.pl?searchtype=free search&string=Comet

Oort cloud sites

Wikipedia: scientific description of the Oort cloud: http://en.wikipedia.org/wiki/Oort_cloud

Views of the Solar System: introduction to the Oort cloud: www.solarviews.com/eng/oort.htm

Sites about comet or asteroid impacts

Wikipedia: scientific description of an impact: http://en.wikipedia.org/wiki/Impact_event

Earth Impact Effects Program: an interactive website to estimate the environmental consequences of impacts on earth: www.lpl.arizona.edu/impacteffects/

Solar System Collision: an interactive website to estimate the effects of impacts on different planets: http://janus.astro.umd.edu/astro/impact/

Tsunami sites

Wikipedia: scientific description of tsunamis: http://de.wikipedia.org/wiki/Tsunami

Tsunami!: questions and answers about tsunamis: www.ess.washington.edu/tsunami/

Asian Tsunami Videos.com: amateur videos of the 2004 Asian tsunami: www.asiantsunamivideos.com

Heinz Oberhummer is the co-ordinator of CISCI, and is based at the Vienna University of Technology, Austria.

Table 1: *Deep Impact* details

Title	*Deep Impact*
Release year	1998
Film producer	DreamWorks SKG, Paramount Pictures, Zanuck/Brown Productions
Director	Mimi Leder
Scientific subject and topic	Physics and astrophysics

Table 2: Scene 1 details

DVD	*Deep Impact*, Special Edition, DreamWorks Home Entertainment
Time interval	Track 27, 01:39:05 - 01:41:55
Scientific keywords	Comet, asteroid, planet

Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life

by Eva Jablonka and Marion J. Lamb

Reviewed by Bernhard Haubold, Fachhochschule Weihenstephan, Germany

In *The Origin of Species*, published in 1859, Charles Darwin described evolution as a process subject to diverse influences. Natural selection, of course, leads to adaptation in a manner similar to the changes elicited by breeders of pets or livestock. However, organisms might also display neutral characteristics, which have no effect on their fitness. In addition, and rather surprisingly for the modern biologist, Darwin went along with the conventional wisdom of his day and believed acquired characteristics to be heritable. Since then, genetics and computers have been the decisive additions to evolutionary thought. Their combination has led to a distinctive reinterpretation and refinement of Darwin's great idea. In 1976, the UK evolutionary biologist Richard Dawkins succinctly stated the resulting new paradigm in the preface to his influential book, *The Selfish Gene:* "we are survival machines – robot vehicles blindly programmed to preserve the selfish molecules known as genes." From this point of view, the sequence of the human genome published in 2001 holds the promise of revealing the entire software that comes with the human hardware.

Darwin's open-mindedness about the possible forces of evolution is the starting point for *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life* by the evolutionary biologists Eva Jablonka and Marion J. Lamb. Their book is aimed at anyone interested in evidence that undermines a strictly gene-based perspective , as the authors hope to convince their readership that "DNA is not the be all and end all of heredity". Ever since that winter day in 1953 when Francis Crick told astonished lunch guests at the Eagle pub in Cambridge that he and Jim Watson had just solved the secret of life by unravelling the double helical structure of DNA, this molecule has, to all intents and purposes, been the 'be all and end all of heredity'. For biologists brought up in the growing excitement of molecular biology that culminated in the Human Genome Project, the supremacy of DNA is part of a shared culture that has become so entrenched that it is hard even to recognise. But Jablonka and Lamb make a convincing and level-headed case for a more pluralistic view of evolution and heredity. The authors avoid the antagonistic tone of *The Selfish Gene* school of debating and patiently explain the nuts and bolts, as well as the implications, of the four dimensions of evolution that they consider important. In each of these dimensions, they present up-to-date ideas but at the same time remind the reader of classical observations that would have undermined the 'DNA as software' metaphor had their significance been fully acknowledged.

The first dimension they discuss is the genetic. A central tenet of contemporary evolutionary thinking is that mutations, the raw material of evolution, are random. In other words, it is believed that there is no code for changing the code. Jablonka and Lamb introduce the reader to the debate about non-random, adaptive mutations among microbiologists during the late 1980s and 1990s. More persuasive, however, is their insistence on the significance of the well-known fact that cells can alter their own DNA through various mechanisms, including somatic mutation and selective amplification.

The second dimension is the epigenetic, which encompasses all those characteristics of cells and organisms that are heritable without being written into a genome's DNA sequence. Although liver and brain cells contain the same DNA, they have very different heritable morphologies and functions. Behaviour constitutes the third dimension. The behaviour of the young is guided in non-genetic ways by that of their parents. Finally, symbolic inheritance systems, foremost among them language, make up the fourth dimension.

Having described their four-dimensional model of evolution, Jablonka and Lamb continue by showing how these dimensions interact. As before, it is classical work that is most illuminating. For example, the authors cite Waddington's experiments from the 1940s with heat-shocked *Drosophila* which demonstrated the phenomenon of 'genetic assimilation'. Here, selecting for an inducible phenotype leads to it becoming constitutive and stably heritable after only a few generations.

Today, genetic assimilation as well as many other genetic phenomena are understood in molecular detail and the reader is given some of this information where appropriate. The moderately technical nature of these passages is mitigated by careful avoidance of unnecessary jargon. In addition, each chapter concludes with a delightful dialogue in which the themes introduced in the main section are playfully varied. This makes the book not only thought-provoking, but also fun to read. We may be blind robots, but some of these robots are perceptive enough to see the limited fruitfulness of this point of view. I thoroughly recommend Jablonka and Lamb's book to anyone interested in an exciting alternative.

Details

Publisher: MIT Press

Publication year: 2005

ISBN: 0262101076

The Ancestor's Tale: A Pilgrimage to the Dawn of Life

by Richard Dawkins

Reviewed by Bernhard Haubold, Fachhochschule Weihenstephan, Germany

There is a natural way to tell a tale: begin at the beginning and end at the end. Standard biographies, for example, start with the forebears, in many cases the grandparents, and end with the protagonist's death. So the end is clear, but the beginning is potentially fraught with the difficulty of deciding which ancestors to describe. After all, one person has two parents, four grandparents, and 2^{n+2} n-great-grandparents. An elegant technique to avoid the thicket of ancestors is contained in the Bible, in which Luke, the biographer of Jesus, tells the genealogy of his subject by starting with Jesus and ending with Adam. As a man of his time, Luke only mentions the fathers, thereby converting an exponentially growing, unmanageably large bi-parental genealogy into a lean uni-parental genealogy.

In contrast to human individuals, two animal or plant species are usually derived from a single ancestral species. Biological species therefore naturally form uni-parental genealogies. In his latest book, *The Ancestor's Tale: A Pilgrimage to the Dawn of Life*, Oxford biologist Richard Dawkins takes advantage of this fact by giving a popular but richly detailed account of evolution starting at the end and time-travelling backwards to the beginning of life.

Today, the inversion of the arrow of time has a strong tradition among evolutionary biologists. If we start with, say, three copies of the human alpha-haemoglobin gene and look back in time, we will reach a point at which two of the three genes were derived from a common ancestral gene. At that point, two alpha-haemoglobin lineages fuse. Such a fusion is also known as a coalescence event, and hence the corresponding theory is called coalescent theory. Moving further back in time, we reach a point where the last two remaining lineages fuse in another coalescence event. This is known as the most recent common ancestor of the genes. It is of fundamental importance for evolution, since any mutation that happened further in the past affected all genes equally and hence is invisible in the present copy of the genes.

Consequently, there is no use in pursuing the history of a sample of genes beyond their most recent common ancestor. Similarly, there is no sense in telling the history of life beyond the last common ancestor of all creatures alive today. So, as with biographies, the end of the story is clear, while the beginning is less clear, because evolution has as many ends as there are extant species. But of course, we are mainly interested in ourselves and this is where Dawkins starts his magnificent account.

Moving backward in time, we are joined along our lineage by 39 other branches of the tree of life. These include, among others, apes, monkeys, rodents, marsupials, birds, amphibians, fish, protostomes, sponges, fungi, plants, Archaea, and, finally, Eubacteria. At each of these 'rendezvous', the joining branch is displayed together with a time estimate and a description of the biology of the newly arrived pilgrims. The title of the book alludes to Chaucer's 14th century *Canterbury Tales,* which recounts a pilgrimage to the English town. Along the way, the pilgrims are encouraged by their host to wile away the time by each telling a tale. In *The Ancestors's Tale,* Dawkins plays host to the increasingly numerous organisms on their pilgrimage from the present to the past. The real charm of the book lies in the tales he puts into their mouths, beaks, and probosces.

These are lucid essays that take the reader through the great ideas in evolutionary biology. For example, the gibbon's tale explains the reconstruction of phylogenies, following the genealogy of 24 different manuscript versions of the *Canterbury Tales.* The mouse's tale takes issue with the popular analogy between the genome and an organism's 'blueprint', and clarifies that it is misleading to think of a genome as a description of its host organism. The lamprey tells a tale of gene duplication in general and of globin duplication in particular. It is a thought that needs some getting used to, that the human alpha-haemoglobin gene is much more closely related to the chimp alpha-haemoglobin than it is to the human beta-haemoglobin.

The peacock's tale is, of course, about sexual selection and it challenges the reader to contemplate why we are naked (hairless) apes, walking on two legs with heads often too big for our own good. The fruit fly gracefully shows off its developmental master genes, the Hox genes. Originally discovered in the fruit fly, these have now been found in almost all animals, including mammals. The velvet worm's tale is about the radiation of all extant animal forms during the 'Cambrian Explosion' some 500 million years ago, which wasn't so explosive after all. In the epilogue to this tale, Dawkins treats us to a succinct account of the so-called molecular clock hypothesis, which posits that genes accumulate mutations at a roughly constant rate. And on the pilgrimage goes, until it is finally joined by the Eubacteria. There, the tale is by *Thermus aquaticus,* the bacterium which contains a DNA polymerase known to molecular biologists as Taq polymerase. This heat-stable enzyme is the basis of the polymerase chain reaction, with which any region in a genome can be amplified million-fold, thereby greatly facilitating a wide range of genetic engineering tasks.

Until quite recently, Luke's backward approach to genealogy has largely been confined to evolutionary biologists. In picking it up, Dawkins has found a new plot to the oldest story around. It is this originality, combined with the playful but precise descriptions of many of the best ideas in contemporary biology, that makes this book a joy to read.

Details

Publisher: Orion Publishing Group

Publication year: 2004 (hardback) or 2005 (paperback)

ISBN: 0297825038 (hardback) or 0753819961 (paperback)

DNA interactive

Reviewed by Dean Madden, National Centre for Biotechnology Education at the University of Reading, UK

This award-winning yet inexpensive educational DVD contains numerous short interviews with scientists, many of them Nobel laureates, who have played a major role or continue to work principally in human molecular biology. There are also computer animations showing key techniques and processes. Video clips are grouped in several ways to facilitate their use, e.g. by theme or by interviewee. The material is aimed mostly at 16- to 19-year-old biology students.

Many, if not most, of the clips have been culled from a five-part Channel 4/PBS television series made to coincide with the 50th anniversary of the discovery of the DNA double helix. That series of five 50-minute programmes, *DNA – The story of the pioneers who changed the world*, is available on two DVDs from the production company, Windfall Films Ltd.

The most spectacular and impressive sequences in *DNA interactive* are undoubtedly the molecular animations showing DNA replication, coiling and protein synthesis. These were created by Drew Berry at the Walter and Eliza Hall Institute in Melbourne, Australia. Coupled with the possibility of choosing the level of sophistication of the accompanying spoken commentary, these superb clips form an extremely useful addition to teaching resources.

Other animations taken from the television series vary in quality, and some, such as that showing simple DNA replication, are clearly intended for a different, general audience. Indeed, the voiceover indicates the DVD makers' recognition of the replication clip's shortcomings – the DNA molecules consist simply of bases with no sugar-phosphate backbones. Some of the other explanations are disappointing, such as that of DNA microarrays, which really leaves the viewer none the wiser.

The principal feature of the *DNA interactive* DVD is its interviews with scientists who were and are at the forefront of molecular genetics. Where else could you find Francis Crick, James Watson, Maurice Wilkins, François Jacob, Benno Müller-Hill, Sydney Brenner, Paul Berg, Wally Gilbert, Herb Boyer, Stanley Cohen, Kary Mullis, Alec Jeffreys, Svante Pääbo and the other creators of molecular genetics talking about their work? It is a shame that the DVD was not produced five or ten years ago, before several of the pioneers of molecular biology had died.

Be warned that many of the DVD's 200 clips are little more than short 'sound bites', and that to be used effectively in an educational context, they would require supporting materials. Fortunately, the producers have realised this: there is a complementary website at the Dolan DNA Learning Center which presents a great deal of additional, highly valuable, educational material.

Details

PAL, Region 2 version

Dolan DNA Learning Center

Windfall Digital, London, UK

Publication year: 2003

ISBN: 0971058822

Sponsors

The *DNA interactive* project was funded mainly by the Howard Hughes Medical Institute. Additional funding came from the Alfred P. Sloan Foundation, Channel 4 television and the University of North Carolina, Chapel Hill.

Ordering

The PAL DVD with English commentary may be ordered direct from Windfall Digital, 1 Underwood Row, London N1 7LZ, UK: www. windfalldigital.com

An NTSC, Region 1 DVD with an American voice-over is also available to educational institutions at a discounted price, directly from the Dolan DNA Learning Center: www.dnai.org

Information on *DNA – The story of the pioneers who changed the world* can be found on the Windfall Films Ltd website: www.windfallfilms.com

Note that a Region 1 DVD may not play on some European DVD players, or may require that you reset the region on your computer's DVD player. Often the region coding can only be changed a limited number of times, after which it is necessary to wipe the computer's hard drive. It is therefore advisable to purchase a DVD with the correct region setting (1 = USA; 2 = Europe).

Resources

The complementary website at the Dolan DNA Learning Center can be found at www.dnai.org. Registration is required to access teachers' resources.

The Elements of Murder: A History of Poison

by John Emsley

Reviewed by Tim Harrison, University of Bristol, UK

When is a chemistry textbook not a chemistry textbook? The answer to this riddle is *The Elements of Murder: A History of Poison.* Most people would think that a book about the toxicity of the elements arsenic, antimony, mercury, lead and thallium would be fairly heavy going, but this book reads more like a novel than a chemistry text.

The book gives a great deal of information on the history of the use of these materials, the concentrations of toxic metals in the human body and in a variety of foods, and the effects of these elements on the body. However, this book is much more than that. John Emsley's work is full of the interesting snippets of information that would switch on the most disinterested of school students on the last lesson on a sunny Friday afternoon. It is a 'must read' for any chemistry teacher who wants to enthuse and excite his or her students and is not afraid to stray from the more orthodox chemistry curriculum.

Included throughout are many nuggets of information that would be a delight for school students. For example, in the Middle Ages, antimony was used as a cure for constipation. Swallowing 'perpetual pills' (small balls of antimony) irritated the gut sufficiently to expel its contents. The balls of antimony were recovered from the excrement, washed and reused. As Emsley reports, the balls were passed down through generations! Another and more recent story refers to a common chemical that students are used to handling in school practicals: copper sulphate. The authors relates the story of three Canadian teenage girls who stole some copper sulphate from their school and decided to murder a classmate by adding it to a blue drink. Fortunately, their attempt was unsuccessful, mainly because seven girls (including two of the poisoners!) shared the drink and were treated at their local hospital. The girls were brought to trial in 2003. Another interesting anecdote relates to the authenticity of a batch of fake Scotch whisky. A comparison of levels of trace metals in the fake and the genuine whisky did not provide the necessary evidence. However, a thorough examination of the foil bottle caps gave the game away: the caps on the fake whisky contained over four times as much antimony as those on the genuine article.

Although several of the examples of poisoning may be known to many science teachers, such as mercury poisoning of fishermen's families around Minamata Bay in Japan, or the arsenic content of Napoleon's hair, there are many other interesting stories in *The Elements of Murder.* Included amongst these are the arsenic eaters of the Styrian Alps in Austria: the men ate arsenic trioxide like salt to improve their breathing at high altitudes, and their wives ate it to become more desirably plump and to give them rosy cheeks. In another example, Emsley describes how antimony hit the headlines in the 1990s in the UK, when it was linked with sudden infant death syndrome (SIDS). It was proposed that the antimony oxide added to foam mattresses in cots as a fire-retardant was being converted to the gas stibine by the fungus *Scopulariopsis brevcaulus*, and that stibine was a major cause of SIDS. This was subsequently proved to be wrong.

Taking a look back in history, Emsley examines the role of these five elements in the madness of Isaac Newton, the strange death of King Charles II, the deaths of Mozart, Beethoven and Handel, and the poisoning of Pope Clement II, as well as the use of thallium by Saddam Hussein. Whole chapters are dedicated to the more famous poisoners in UK history such as Graham Young, Florence Maybrick and George Chapman.

The poisonous nature of some of the other elements in the Periodic Table is also discussed: the final chapter deals briefly, but informatively, with barium, beryllium, cadmium, chromium, copper, nickel, potassium, selenium, sodium, tellurium and tin.

The glossary adds a little more depth to the science behind the poisons, while the bibliography, sorted by element, gives plenty of direction to those who wish to pursue their research further.

The author, John Emsley, spent 20 years as a researcher and lecturer in chemistry before becoming a freelance Science Writer in Residence at Imperial College, London, and then at the University of Cambridge, UK. He won the Science Book prize for his *Consumer's Good Chemical Guide: A Jargon-Free Guide to the Chemicals of Everyday Life* in 1995 and was awarded the German Chemical Society's Writer's Award in 2002.

Other books written or co-written by Emsley include:

- Emsley J (2004) *Vanity, Vitality, and Virility: The Science behind the Products You Love to Buy.* Oxford, UK: Oxford University Press
- Emsley J (2003) *The Elements* (Oxford Chemistry Guides). Oxford, UK: Oxford University Press
- Emsley J (2000) *The 13th Element: The Sordid Tale of Murder, Fire, and Phosphorus.* New York, NY, USA: John Wiley & Sons
- Emsley J (2000) *The Shocking History of Phosphorus: A Biography of the Devil's Element.* London, UK: Macmillan
- Emsley J (1998) *Molecules at an Exhibition: Portraits of Intriguing Materials in Everyday Life.* Oxford, UK: Oxford University Press
- Emsley J, Fell P (1999) *Was It Something You Ate? Food Intolerance, What Causes It and How to Avoid It.* Oxford, UK: Oxford University Press

Details

Publisher: Oxford University Press

Publication year: 2005 (hardback) or July 2006 (paperback)

ISBN: 0192805991 (hardback) or 0192806009 (paperback)

Nano: the Next Dimension
Nanotechnology

Reviewed by Tim Harrison, University of Bristol, UK

Nano: the Next Dimension is a short television documentary featuring several leading physical scientists discussing nanotechnology and its applications – amongst these are Nobel laureates Jean-Marie Lehn and Sir Harry Kroto.

The film employs stunning graphics to give a good mental picture of the nano-scale, and descriptions of the quantum tunnelling effect and Werner Heisenberg's Uncertainty Principle. The ways in which European nanotechnology research could be used are discussed: these include using nano-tubes as ballistic conductors for the replacement of copper wires, increased memory capacity for computers, and applications in biological systems. The film includes a good video clip of the formation of nanotubes. Other experiments show the application of nano-particles for scratch-proof surface protection, as a hydrophobic surface of ceramic sinks, and to make walls graffiti-proof. The printing of music CDs onto flexible plastic polymers and the manufacture of molecular robots are also touched upon.

The film also features the application of nanotechnology to AIDS research. In an early AIDS screening method, negatively charged HIV antibodies were attracted to positively charged iron-based nano-particles. Any HIV particles were attracted to the antibodies, and since the iron-based nano-particles could be magnetised, both the particles and the virus could be removed using a magnetic field.

Nano: the Next Dimension is available in DVD format but only in English.

Nanotechnology is a short film aimed more specifically at younger students than its predecessor *Nano: the Next Dimension*. The film employs many of the same stunning graphics and examples as its predecessor, but delivers the information using a pair of school students who are preparing a presentation on nanotechnology. To help the students, a couple of atoms are magnified a billion times to lead the youngsters through the marvels of nanotechnology. The film features the students interviewing several scientists in the laboratory to discuss applications of nanotechnology, rather than using a 'talking heads' approach.

Nanotechnology is available on DVD in twenty languages (either through subtitling or dubbing).

The overall aim of both films is to increase awareness of nanotechnology and the European research in this field. In this, they succeed. Science teachers wishing to update themselves on this area will be able to make good use of these DVDs. Whether the films would be used in schools in which science is traditionally taught is much harder to say. *Nanotechnology* could be used as part of a science careers programme, but unfortunately all the scientists featured are male and so the film presents fewer role models for young women.

The superb graphics on the DVDs could be used in lessons on structure and bonding or, for older students, as part of a lesson on electron microscopy. Due to the multilingual nature of the *Nanotechnology* DVD, it may be a useful resource for science teachers who do cross-curricular work.

Details

Nano: the Next Dimension

Commissioned by: The European Commission

Produced by: Ex-Nihilo, France

Publication year: 2002

Nanotechnology

Commissioned by: The Research Directorate-General of the European Commission

Produced by: Wajnbrosse Productions

Publication year: 2003

Ordering

Both films are downloadable or available free of charge as DVDs, along with a brochure, *Nanotechnology: Innovation for tomorrow's world* (3.8 MB), and can be ordered online at: www.cordis.lu/nanotechnology/src/pressroom_films.htm

Resources

The European Commission on Nanotechnology homepage is: www.cordis.lu/nanotechnology/

The commentary from *Nano: the Next Dimension* is available at: http://europa.eu.int/comm/research/conferences/2002/pdf/presspacks/1-3-nano-new-dimension-script_en.pdf

Free image databases

The worldwide web is a wonderful source of information, but sometimes the sheer amount of content can be overwhelming. Where do you start looking?
In each issue of *Science in School,* we will suggest useful websites for particular purposes.

Are you looking for a good picture to use in a worksheet, an overhead or a poster? You need it to be good quality, but you don't want to pay to use it. Here is a selection of our favourite free image databases (you may even recognise some of the pictures).

The ECOD-BIO picture pool contains almost 500 varied biological images: www.picturepool.ecod-bio.org

The Multimedia Gallery of the European Space Agency (ESA) contains over 3000 images and videos, as well as other types of visual material about space: www.esa.int/esa-mmg/mmghome.pl

Interactions.org, a website designed for communicators in particle physics, has an extensive database of beautiful images: www.interactions.org/imagebank

Lightsources.org provides news, information and educational materials about the world's light-source facilities. Its database has a good variety of images: www.lightsources.org/imagebank

The www.freeimages.co.uk database provides over 2500 images covering a wide range of subjects, including science.

If you use images from the databases listed above, it is advisable to check the conditions under which the images may be reproduced.

To suggest types of websites that you would like us to review, or to tell us about your own favourite websites, email editor@scienceinschool.org. In the subject field of the email, please include the text 'Website review'.

Shipwreck: science to the rescue!

Answers to comprehension questions on page 27

1. *The hull timbers of both the* Vasa *and the* Mary Rose *have been found to contain about 2 tonnes of sulphur, as the element S. If 1000 kg sulphur in the wood were in the form of the pyrite, FeS_2, how much sulphuric acid ($H_2SO_4(aq)$) would be produced when all the pyrite is fully oxidised?*
   Two pathways are common: to hydrated iron(II) sulphate:

   $$FeS_2(s)+{}^7/_2O_2+(n+1)H_2O \rightarrow FeSO_4{\cdot}n(H_2O)(s)+H_2SO_4(aq)$$

   or to goethite, alpha-FeOOH (as in rust):

   $$FeS_2(s) + {}^{15}/_4O_2+{}^5/_2H_2O\_ \ FeOOH(s)+2H_2SO_4(aq)$$

Answer: 1000 kg S corresponds to 15.6 kmol FeS_2. If hydrated iron(II) sulphate is the end product, 1.5 tonnes sulphuric acid would form. If goethite, alpha-FeOOH, forms, the amount would be double: 3.1 tonnes sulphuric acid.

2. *Sodium hydrogen carbonate (sodium bicarbonate, $NaHCO_3$) has been added to the re-circulated sprayed conservation solution of the* Mary Rose *to keep its pH about 7. How much sodium hydrogen carbonate would be needed to neutralise the acid formed in Question 1 (from oxidised pyrite containing 1000 kg sulphur)?*

Answer: To neutralise 1.5 tonnes sulphuric acid, 2.6 tonnes sodium bicarbonate would be required; 3.1 tonnes of sulphuric acid would require 5.2 tonnes of sodium bicarbonate.

3. *Crystalline pyrite has a volume of 40 Å^3 per FeS_2 unit and expands dramatically when oxidised. For example, the volume per formula unit of the crystalline hydrated iron(II) sulphate melanterite, $FeSO_4{\cdot}7(H_2O)(s)$, is 243.5 Å^3 and of rozenite, $FeSO_4{\cdot}4(H_2O)(s)$, 162.7 Å^3. Also natrojarosite,*

   $NaFe_3(SO_4)_2(OH)_6$, with a volume of 266.0 Å^3 per formula unit, is commonly found on the Vasa's wood. Estimate how many times the volume will increase when a pyrite crystal oxidises and a) $FeSO_4{\cdot}7(H_2O)(s)$, b) $FeSO_4{\cdot}4(H_2O)(s)$ or c) $NaFe_3(SO_4)_2(OH)_6$ salts crystallise as products. What effects could these processes have if they took place inside the wood structure?

Answer: When solid $FeSO_4{\cdot}7H_2O(s)$ precipitates, the volume increases with a factor of 12.2 for $FeSO_4{\cdot}7(H_2O)(s)$; 8.1 times for $FeSO_4{\cdot}4H_2O(s)$; and 6.7 times for $NaFe_3(SO_4)_2(OH)_6$. This can cause outbursts of salts through the wood surface, or crack the wood structure from within.

4. *In a chemistry textbook, look up a schematic molecular orbital energy level diagram for the oxygen molecule O_2 in its ground state. Explain how uptake of energy from light can produce singlet oxygen, ${}^1O_2$, with all electrons paired.*

Answer: The O_2 molecule is paramagnetic with the two outermost electrons unpaired, one in each of two degenerate (with same energy) anti-bonding molecular π-orbitals formed by combining the p-orbitals of the O atoms. With an energy uptake of ~92 kJ mol^{-1} from photons of light, the two outermost electrons can be paired (a 400-nm photon has energy of 300 kJ mol^{-1}). The energy uptake process usually needs a sensitiser (e.g. light-absorbing dissolved organic matter). This excited singlet ${}^1O_2$ (one single arrangement in space for a pair of electrons) oxygen molecule is a diamagnetic but reactive short-lived species, even though its energy is only sufficient for mild oxidation (Stumm W, Morgan J (1996) *Aquatic Chemistry* (3rd ed). New York, NY, USA: Wiley-Interscience).

A cocktail of nucleic acids: celebrating the double helix

Dean Madden and **John Schollar** from the National Centre for Biotechnology Education at the University of Reading, UK, suggest a recipe for a cocktail containing deoxyribose nucleic acid (DNA). This drink has novel features of considerable biological interest.


The DNA cocktail

By combining elements from Cambridge, London and the Ameri-cas, this red, white and blue drink pays tribute to all of those who worked on the double helix. A hint of pineapple juice helps to celebrate what Francis Crick called 'The Golden Helix'.

Equipment & materials

From England:

- 8 frozen strawberries (about 68 g) – the variety 'Cambridge Favourite' is naturally the most appropriate.
- London dry gin – the strongest you can find. This is necessary to precipitate the DNA. *N.B. Chill this gin in the freezer for at least 2 hours before preparing the drink.*

From the Americas:

- 60 ml fresh pineapple juice. This must be fresh as protease activity is required to degrade the histones associated with the DNA.
- Blue curaçao[1].
- Lime juice and icing sugar, to decorate.

Also required:

- A blender[2]
- Large test tubes or boiling tubes, for serving.

Method

1. Moisten the rim of a large test tube with lime juice then dip the rim into icing sugar.
2. Add about 10 ml[3] of blue curaçao to the tube.
3. Tilt the tube then with great care, pour about 20 ml[3] of ice-cold gin down the side of the tube to form a layer above the blue curaçao.
4. Blend the strawberries and pineapple juice for 10 seconds, then drop the purée on top of the gin. Wisps of strawberry DNA will precipitate into the gin.

Discussion

Others have suggested (unpublished data) that thin helical twirls of lime peel may be used to decorate the rim of the tube. More enterprising drinkers have tried to recover the nucleic acid from the gin, using a swizzle stick. We are not aware of the details of the results of these investigations.

Most of the 'DNA' in the gin is probably pectin, although the method described here is strikingly similar to the 'Marmur preparation' used by molecular biologists throughout the world to prepare DNA.[4]

It has not escaped our notice that this cocktail contains significant amounts of alcohol and should, therefore, be consumed only by adults and in moderation.

We are much indebted to Peter Finegold for suggesting that we create a cocktail to celebrate the 50th anniversary of the double helix in 2003.

1 *If it proves difficult to form distinct layers of liquids, dissolve a little sugar in the curaçao.*

2 *A Waring blender, as used by Fred Hershey and Martha Chase, who in 1952 proved conclusively that DNA was the genetic material, seems an appropriate model. Hershey AD, Chase M (1952)* Journal of General Physiology **36**: *39-56*

3 *Adjust these volumes for smaller tubes.*

4 *Marmur J (1961)* Journal of Molecular Biology **3**: *208-218*

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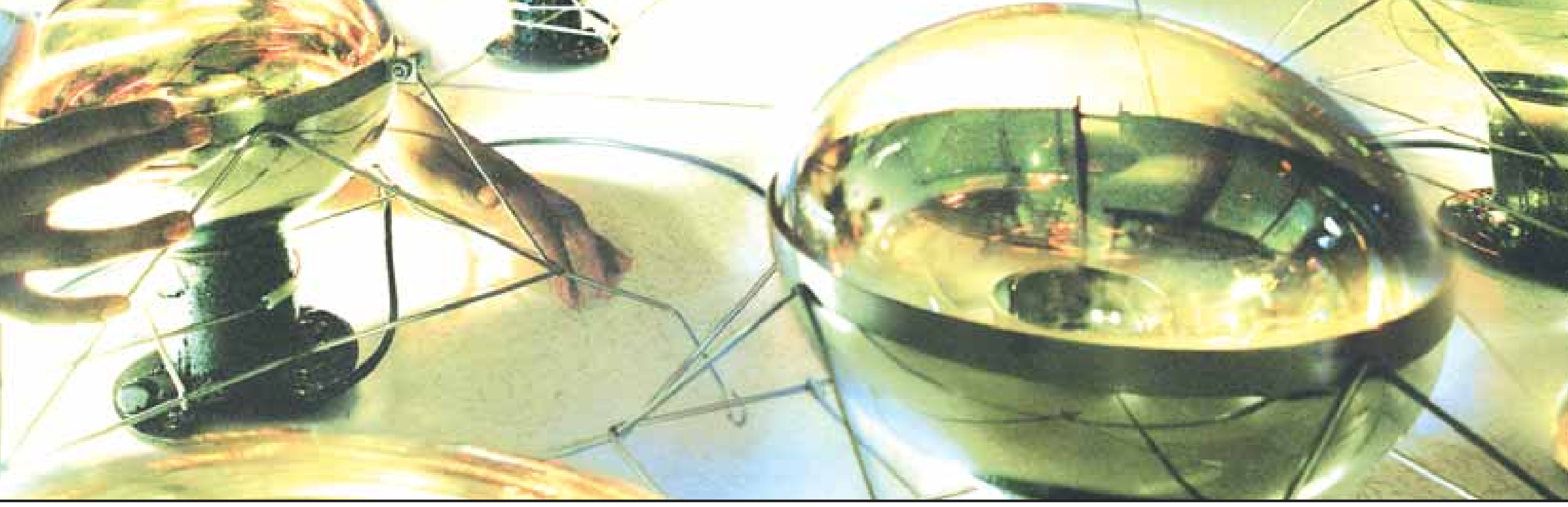

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