Autumn 2008 Issue 9

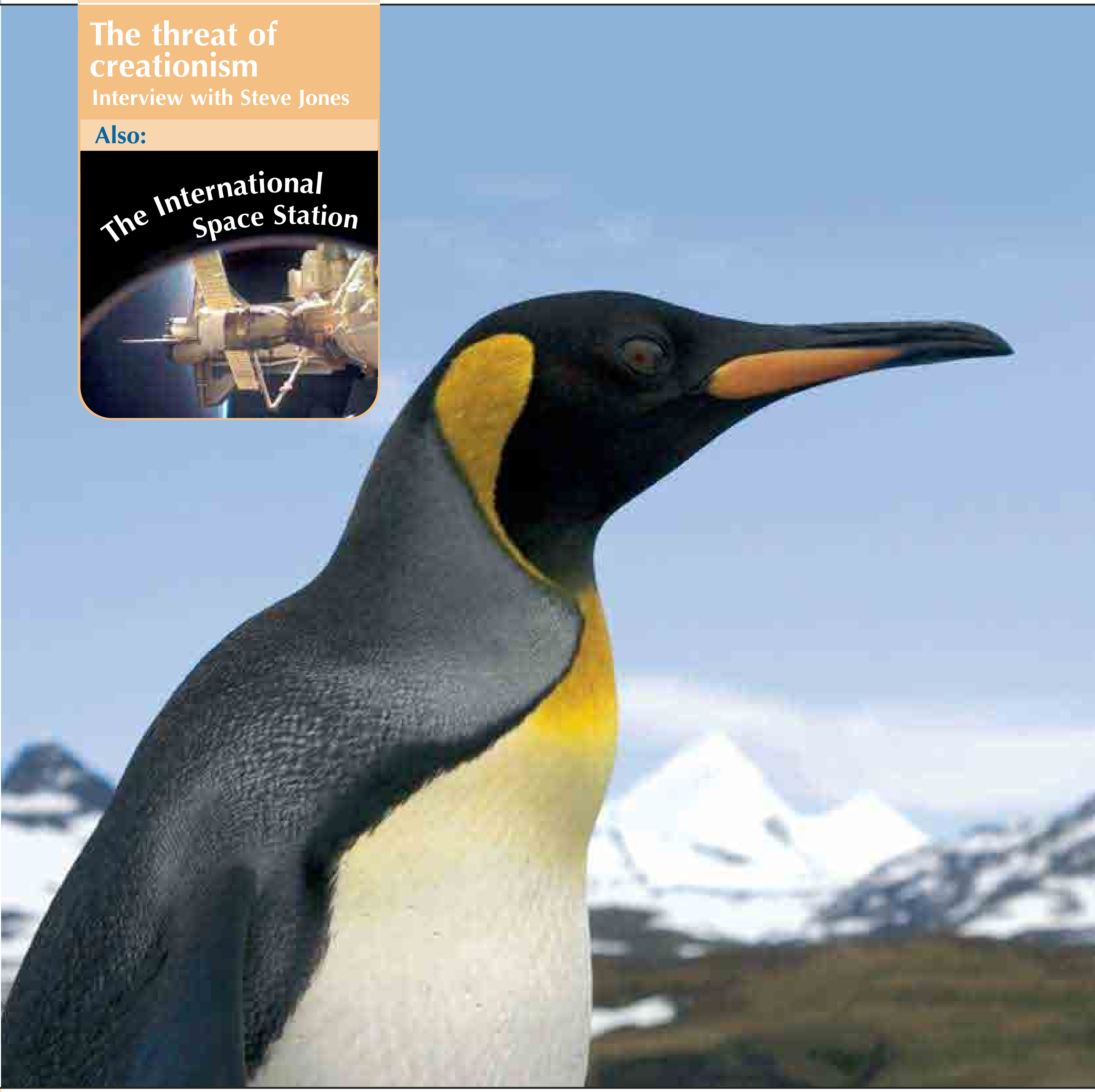
SCIENCE in SCHOOL

In this Issue:

The threat of creationism

Interview with Steve Jones

Also:



Highlighting the best in science teaching and research

About *Science in School*

***Science in School* promotes inspiring science teaching by encouraging communication between teachers, scientists and everyone else involved in European science education.**

***Science in School* addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge research. It covers not only biology, physics and chemistry, but also maths, earth sciences, engineering and medicine, focusing on interdisciplinary work.**

The contents include teaching materials; cutting-edge science; education projects; interviews with young scientists and inspiring teachers; European education news; reviews of books and other resources; and European events for teachers.

***Science in School* is published quarterly and is available free online; free print copies are distributed across Europe. Online articles are published in many European languages; the print version is in English.**

Credits

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We welcome articles submitted by scientists, teachers and others interested in European science education. Please see the author guidelines on our website for details.

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Science in School is the **only** European journal aimed at secondary-school science teachers across Europe, and across the full spectrum of sciences. It is freely available on the web and over 30 000 full-colour printed copies are distributed each quarter.

The target readership of *Science in School* includes everyone involved in European science teaching, including:

- Secondary-school science teachers
- Scientists
- Science museums
- Curriculum authorities

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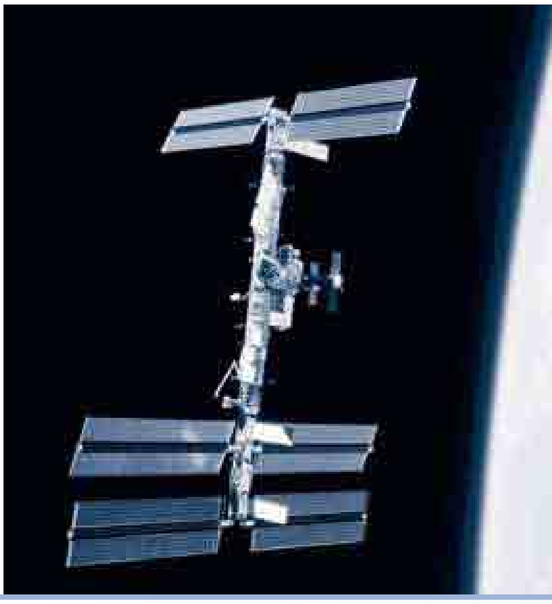
Welcome to the ninth issue of *Science in School*



"Before I start, I'd like to mention two things: half of what I'm telling you will be wrong; and I don't even know which half." This introduction by renowned molecular biologist Ueli Schibler to his students illustrates a discomforting aspect of science. The only way to find out which half is wrong and which is right, is by disproving existing 'truths' and replacing them with new ones. To do this takes inventive, creative minds with a curiosity about questions such as "what if…?" Challenging young people to tackle these questions and inspiring them to see the beauty of science, rather than being discouraged by it, is the difficult but important task of the science teacher.

Having worked as a developmental biologist, I made the move into science journalism and publishing with the firm belief that science is exciting – all science, that is, not just biology. Being exposed to a wide variety of topics and satisfying my own curiosity is one of the joys of my job, and I hope to convey this excitement to others. How better to do this than through *Science in School*, which aims to overcome the frontiers between subjects and countries, researchers and teachers?

Space – the final frontier? Not any more, now that nations have transcended their frontiers to build the International Space Station (ISS) in the shared pursuit of scientific knowledge. Shamim Hartevelt-Velani and Carl Walker take us on a two-part journey to this orbiting laboratory – find out more in the next issue!

The main purpose of the ISS is research – in which even students can take part, for example through the ESA Success contest. Cornelia Meyer is one of the lucky ones. She wants to test the idea that life on Earth may have arrived on board a meteorite.

Does that sound like a silly idea? Perhaps, but its feasibility can be scientifically tested. Unlike creationism, that is – or so says Steve Jones, our featured scientist, who strongly favours evolution as the only scientific explanation for the origin of biological diversity. What is your opinion? Why not debate this topic further in our online discussion forum?

From the origins of life, via its evolution, to its extinction: a fate that woolly mammoths met about 6000 years ago. Caitlin Sedwick describes how a computer model is helping scientists to investigate why. A warming climate seems to have destroyed much of the mammoths' habitat, with humans hunting the woolly giants into extinction.

Are you concerned about the warming of our own habitat? In the third article in our series on climate change, you can even try modelling this phenomenon yourself, with the help of Dudley Shallcross and Tim Harrison. If modelling sounds too dry, and you'd prefer something more hands-on, take a look at this issue's laboratory activities for the classroom. Anna Lorenc introduces urease from soya beans as a model for explaining enzymes, while the sugar detection experiments by Fred Engelbrecht and Thomas Wendt are a great way of demonstrating some of the problems faced by people with diabetes every day.

As the Assistant Editor of *Science in School*, I hope to inspire young people to be curious about the world. Science is all around us, and it can be a lot of fun. With your help, we can get this message across to many more students. We look forward to your feedback and contributions, since you as readers and teachers know best how *Science in School* can be useful to you.

Marlene Rau
Assistant Editor of *Science in School*
editor@scienceinschool.org

Forthcoming events

4 December 2007 – 30 September 2008

Explor@dome, Paris, France

Exhibition: Bougez Vert: the development of sustainable transport

This exhibition invites pupils and teachers to address environmental questions related to transport. It offers an interactive and pleasant way to test their knowledge and develop an understanding of sustainable development. Among the many hands-on exhibits are the energy bike and interactive exhibits that produce hydrogen for a fuel cell or allow visitors to investigate different ways to move around a city.

Scientific and multimedia workshops are also available for children aged 7-14.

More information: www.exploradome.com

Contact: Eloise Soucours (eloise@exploradome.com)

6-11 September 2008

University of Liverpool, UK

Science festival: BA Festival of Science

Organised by the British Association for the Advancement of Science (BA), this week-long event is the biggest celebration of science, engineering and technology in Europe. There are events for everyone: talks, plays, debates, hands-on activities and more. In special events for young people, school groups can explore Earth's atmosphere, discuss important issues with eminent scientists or investigate the best material to make a successful catapult.

More information: www.the-ba.net/festivalofscience

19-28 September 2008

Norway

Science festival: Norwegian science week

School students, teachers and the general public are invited to take part in the Norwegian science week. Learn about and experience science through science fairs, demonstrations, lectures, performances, exhibitions and discussions, as well as tours, information stands, and cultural and hands-on activities. Nearly all events are free of charge.

As part of the science week, school classes are invited to carry out a project about solar energy and write a report on the results. See www.miljolare.no

More information: www.forskningsdagene.no/artikkel/vis.html?tid=30355

29 September – 1 October 2008

European Molecular Biology Laboratory, Heidelberg, Germany

Training course: 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 three-day course is designed to enable the participating teachers to explore a range of activities, which they can practice in the lab and then take back to the classroom.

The course is open to 20 European high-school science teachers and is run in English. The course, including course materials, catering and accommodation, is free of charge; participants are expected to meet their own travel costs.

More information: www.embl.de/ells

Contact: ells@embl.de

1-3 October 2008

Laboratori Nazionali di Frascati, Italy

Training course: Incontri di Fisica

Organised by INFN Laboratori Nazionali di Frascati, Incontri di Fisica is a three-day training course for secondary-school science teachers and people involved in science communication. The goal is to provide teachers with further professional training, and to encourage interactive and hands-on contact with the latest developments in physics, as well as direct contact between teachers and researchers.

The programme includes plenary sessions, working groups, discussions, and visits to experimental areas. There will be lectures on the new frontiers of physics, including the Large Hadron Collider (LHC), cosmology, and nuclear energy, as well as a consideration of science and society. In small groups, participants will work on physics experiments typical of the research of Istituto Nazionale di Fisica Nucleare (INFN) and Laboratori Nazionali di Frascati.

The course is free and is run in Italian. The registration deadline is 30 May 2008.

More information: www.lnf.infn.it/edu/incontri/2008/

Contact: sislnf@lnf.infn.it, or tel: +39 (0)69 403 2423/2942/2552/2643

23-26 October 2008

Urania conference centre, Berlin, Germany

Science teaching festival: National Science on Stage festival

About 250 science teachers from Germany and other European countries will participate in the first national Science on Stage festival in Berlin, Germany, organised by Science on Stage Germany and THINK ING. Participants will present teaching projects and experiments in a fair and discuss innovative methods in workshops and round tables. The festival programme also includes scientific talks, exhibitions at the science and research institutes in Berlin, and stage performances.

Interested teachers are invited to visit on the open days, on 24 and 25 October from 11am to 5pm, in the Urania conference centre. The conference language is English and admission is free of charge. To register, please write a short email, including your name and institution.

More information: www.science-on-stage.de

Contact: info@science-on-stage.de

24-25 October 2008

Deutsches Museum, Munich, Germany

Workshop: Genlabor & Schule IV

Science teachers, research scientists and representatives of learned societies, governments, companies and foundations are invited to attend the next Genlabor & Schule workshop. This two-day event consists of lectures, discussion workshops and panel discussions.

Genlabor & Schule is a network of learning laboratories for the molecular life sciences in Germany, coordinated by the German Society for Biochemistry and Molecular Biology (Gesellschaft für Biochemie und Molekularbiologie, GBM).

The event will run in German and participation costs €40.

More information: www.gbm-online.de/Arbeitskreise/AkOe/Genlabor_Schule_IV/impressum.htm

28 October, 5 November, 12 November 2008

DECHEMA, Frankfurt, Germany

Open day: Science days (Wissenschaftstage)

School students, their teachers and interested members of the public are invited to participate in one of three days of chemical demonstrations, lectures and experiments. Visits to the laboratories of the Karl Winnacker

Institute are also possible. The science days are organised by the German Chemical Society (Gesellschaft Deutscher Chemiker, GDCh) and the German Society for Chemical Engineering and Biotechnology (DECHEMA).

All events are free of charge and are held in German. Please register in advance.

More information: www.dechemax.de/wita08

Contact: presse@dechema.de, tel: +49 (0)69 7564 375/296, fax: +49 (0)69 7564 272

13 November 2008 – May 2009

Competition: The chemical detective (Mit Chemie auf Spurensuche)

The ninth DECHEMAX school competition will start in November 2008. In the first round, teams of three to five students from Years 7-11 answer weekly questions on the Internet about biology, biotechnology and chemistry. Teams that pass the first round can take part in the second – experimental – round. There are certificates for all successful teams, and attractive prizes for the winners.

The competition is run in German. Registration opens online on 1 October: www.dechemax.de/anmeldung

More information: www.dechemax.de

Contact: dechemax@dechema.de, tel: + 49 (0)69 7564 164/172

12-14 December 2008

Engineering Department, University of Cambridge, UK

Training course: Cambridge Update

All practising teachers of physics are invited to take part in a course run by the UK's Institute of Physics. Through a series of talks and workshops, participants will learn about recent developments in physics and the applications of physics, try new practical techniques and find out about developments in physics education.

The course costs £130 (residential) or £70 (non-residential). There is a discount for members of the Institute of Physics.

Flyers and application forms will be sent to UK schools early in September. Schools from outside the UK who would like to be informed about the course should get in contact.

Contact: Leila Solomon (leila.solomon@iop.org)

Until 15 January 2009

Germany

Competition: Siemens school competition

This year's Siemens school competition in science, engineering and mathematics is all about water. How can we reduce our water consumption? How can we avoid water pollution? What technologies are available for acquiring drinking water and treating sewage? Students in Years 11-13 are invited to compete.

The deadline for registration is 31 October 2008. The submission deadline is 15 January 2009. The competition language is German.

More information: www.siemens.de/generation21/schuelerwettbewerb

15-17 February 2008

London, UK

Training course: Physics in Perspective

This study course for 6th formers and college students (aged 16-19) offers insights into the many aspects of modern physics, including cutting-edge physics topics, technological applications, as well as some 'fun' physics. The programme of six lectures is designed to counteract misconceptions that physics is a dry, narrow subject concerned only with certainties and remote concepts, and to demonstrate how physics is used to help us understand our environment, our planet and our universe.

Organised by the UK's Institute of Phyiscs, the course costs £20.

Contact: Leila Solomon (leila.solomon@iop.org)

All year

CERN, Geneva, Switzerland

Training course: CERN high-school teacher programme

CERN, the world's largest particle physics laboratory, organises one-week courses for secondary-school physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students aged 13-16.

The courses cover (at an introductory level) particle physics, cosmology, detectors, accelerators and applications. Teachers have the opportunity to visit CERN's experimental installations. Each course is aimed at teachers from a particular European country and is run in the national language.

The courses are free of charge, but the participants are expected to pay for their travel expenses and accommodation.

More information: http://education.web.cern.ch/education/

Contact: Mick Storr (mick.storr@cern.ch)

All year

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. Secondary-school students isolate plasmid DNA from bacterial cultures and digest it with restriction enzymes. The resulting DNA fragments are separated and visualised by gel electrophoresis.

The workshops are for secondary-school students who already have the necessary theoretical background and are over 17 years of age. The workshops are free of charge, are in German or English (on request), and have a maximum of 20 participants. Teachers are invited to get in touch to arrange a workshop for their class.

More information: www.schullabor.ch

Contact: Gesche Standke (gesche.standke@novartis.com)

All year

Schools and other venues in the UK

Roadshow: Cool Seas

Run by the Marine Conservation Society, the Cool Seas Roadshow visits primary and junior schools throughout the UK. It entertains and educates school children about the importance of conserving the UK's spectacular marine wildlife, using life-size inflatable models of whales, dolphins, sharks, turtles and seals in dynamic presentations given by a marine wildlife education specialist. The roadshow involves a full day of presentations to different classes, and costs either £175 or £350, depending on how much the school can contribute.

Each school that is visited receives printed materials and web-based resources, including an activity booklet for each student, and a poster for every classroom. The curriculum-linked, web-based resources can be viewed here: www.mcsuk.org/coolseas

The roadshow is also suitable for public events outside school, so if you are planning an environmental event or have a large and suitable audience in mind, please get in touch.

More information: www.mcsuk.org
Contact: info@mcsuk.org

All year

10 locations around the UK

Training courses: Science continuing professional development

The national network of Science Learning Centres, set up by the UK Department for Skills and Education and the Wellcome Trust, provides continuing professional education for everyone involved in UK science education, at all levels. With nine regional centres and a national centre in York, access to innovative and inspiring courses is within reach across the UK. The centres not only deliver hundreds of courses, but also act as a focus for all the science learning activities in their region.

More information: www.sciencelearningcentres.org.uk

Contact: enquiries@national.slcs.ac.uk

All year

Glasgow Science Centre, Glasgow, UK

Free teacher visits

Teachers, classroom assistants, nursery teachers and technicians are invited to visit the Glasgow Science Centre, free of charge, to explore and investigate what is on offer.

More information: www.glasgowsciencecentre.org

Contact: +44 (0)871 540 1003

All year

Many Scottish venues, UK

Roadshow: Science Circus

Glasgow Science Centre's outreach team brings all the fun of the science centre directly to schools and community groups throughout Scotland thanks to its lively travelling Science Circus. Science Circus activities consist of amazing live science shows and interactive exhibits delivered at your venue.

More information: www.glasgowsciencecentre.org

Contact: +44 (0)871 540 1004

All year

Pembrokeshire, Wales, UK

Field trip: Rockpools

The Pembrokeshire Darwin Science Festival invites all primary schools in Pembrokeshire to book a rockpool ramble and identification field trip. The course is aimed at Key Stage 2 pupils (ages 8-11), takes half a day and is led by three qualified marine scientists. Cost: £250 with a bus or £170 without a bus. Maximum 30 children.

More information: www.darwincentre.com

Contact: Marten Lewis (M.B.Lewis@pembrokeshire.ac.uk)

All year

Pembrokeshire, Wales, UK

Workshops: Primary school

The Pembrokeshire Darwin Science Festival offers a double workshop visit for a maximum of 30 Key Stage 2 pupils (ages 8-11), costing £200. The group is split into two workshops, which run simultaneously:

- Plankton/microscopy identification workshop
- Energy workshop using dynamos, solar panels and a steam engine as hands-on props.

Also available are three 90-minute workshops, each for a maximum of 20 pupils and costing £120:

- Oil-spill workshop for Key Stage 2 pupils (ages 8-11)
- Climate-change workshop for Key Stage 2 pupils (ages 8-11)
- Marine-litter workshop for Key Stage 1 pupils (ages 4-7).

More information: www.darwincentre.com

Contact: Marten Lewis (M.B.Lewis@pembrokeshire.ac.uk)

All year

Paris-Montagne, Paris, France

Science Academy

Throughout the year, Paris-Montagne runs an outreach programme in all Parisian suburbs and in the Lyon area. The science academy is for high-school students who are interested in science but not confident enough to enrol for undergraduate studies, due to social and cultural hindrances. The organisation offers students personal tutoring and the possibility to discover the world of research by meeting researchers in various fields and by carrying out their own research in real laboratories during their holidays (100 labs, from three hospitals and a dozen universities and research institutes, participated in April 2008). The most dedicated participants in the programme are offered the chance to take part in a summer camp during the Paris-Montagne science festival in July, and also to attend other scientific summer camps in Europe (including Petnica, Kut Diak and Visnjan).

Since its creation in 2006, nearly 300 high-school students have participated in the science academy, and each year around 1500 participants visit the Paris-Montagne science festival.

More information:
www.scienceacademie.org

All year

Portugal

School visits: MIT professors go to Portuguese secondary schools

Ciência Viva is organising short talks by MIT professors in Portuguese secondary schools, as part of a co-operation between the Massachusetts Institute of Technology and Portuguese universities in the areas of bio-engineering, sustainable energy and transport systems. The students have direct contact with MIT professors and can discuss their ideas and ask questions about these important engineering areas.

Schools are selected based on their motivation for participating in the programme and on the projects they have developed in the areas of science and engineering.

More information:
www.cienciaviva.pt/divulgacao/mit

Contact: mit@cienciaviva.pt

All year

INTECH, Hands-on Interactive Science and Discovery Centre, Winchester, UK

Free teacher visits

Teachers are invited to visit INTECH, the hands-on interactive science and discovery centre, free of charge, or to attend a teacher preview session to discover what is available for school visits and workshops.

More information: www.intech-uk.com

Contact: Angela Ryde-Weller (AngelaRydeWeller@intech-uk.com)

If you organise events or competitions that would be of interest to European science teachers and you would like to see them mentioned in *Science in School*, please email details – including date, location, title, abstract, price, language, registration deadline, website and contact email address – to editor@scienceinschool.org.

Interview with Steve Jones: the threat of creationism

Steve Jones talks to **Vienna Leigh** about the startling re-emergence of creationism in Europe, how teachers can help, and why he will never argue with a creationist.

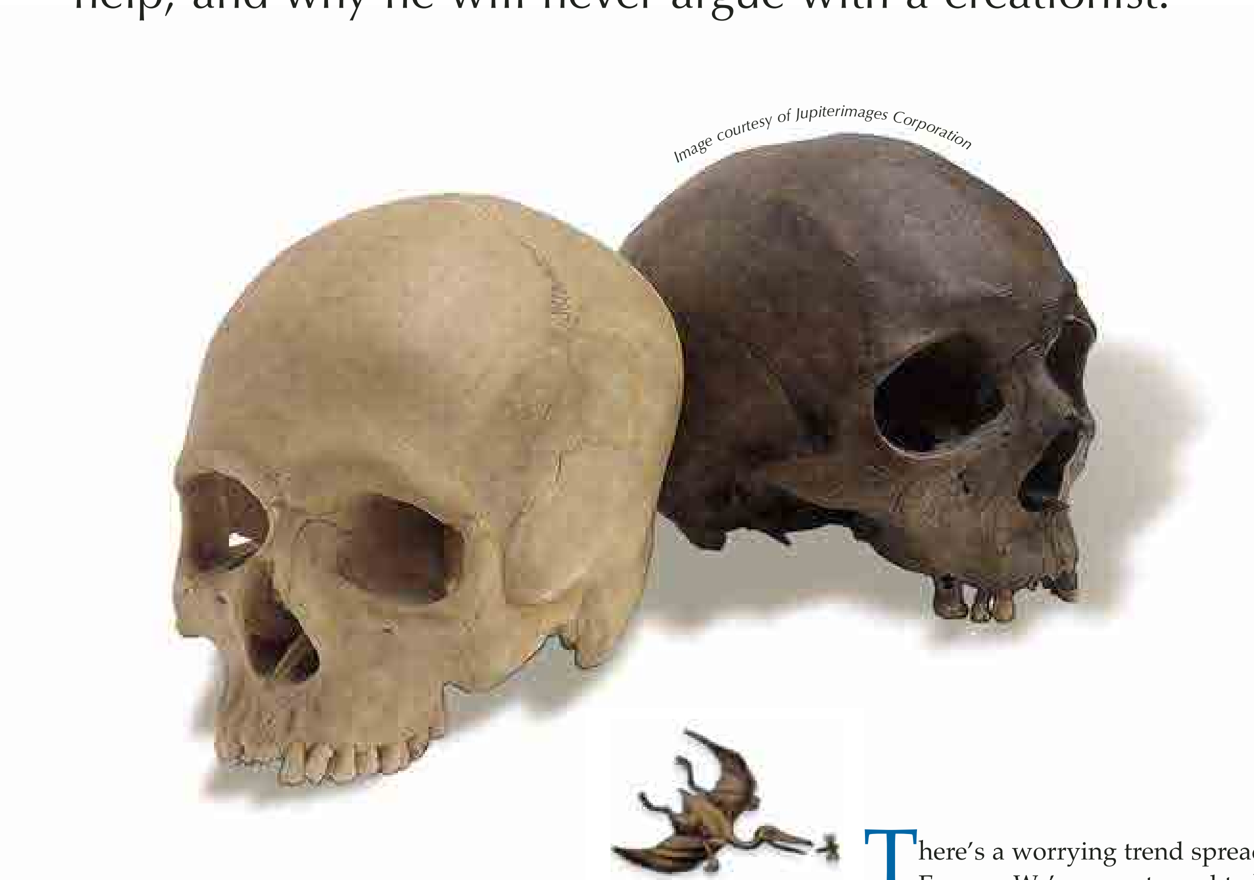
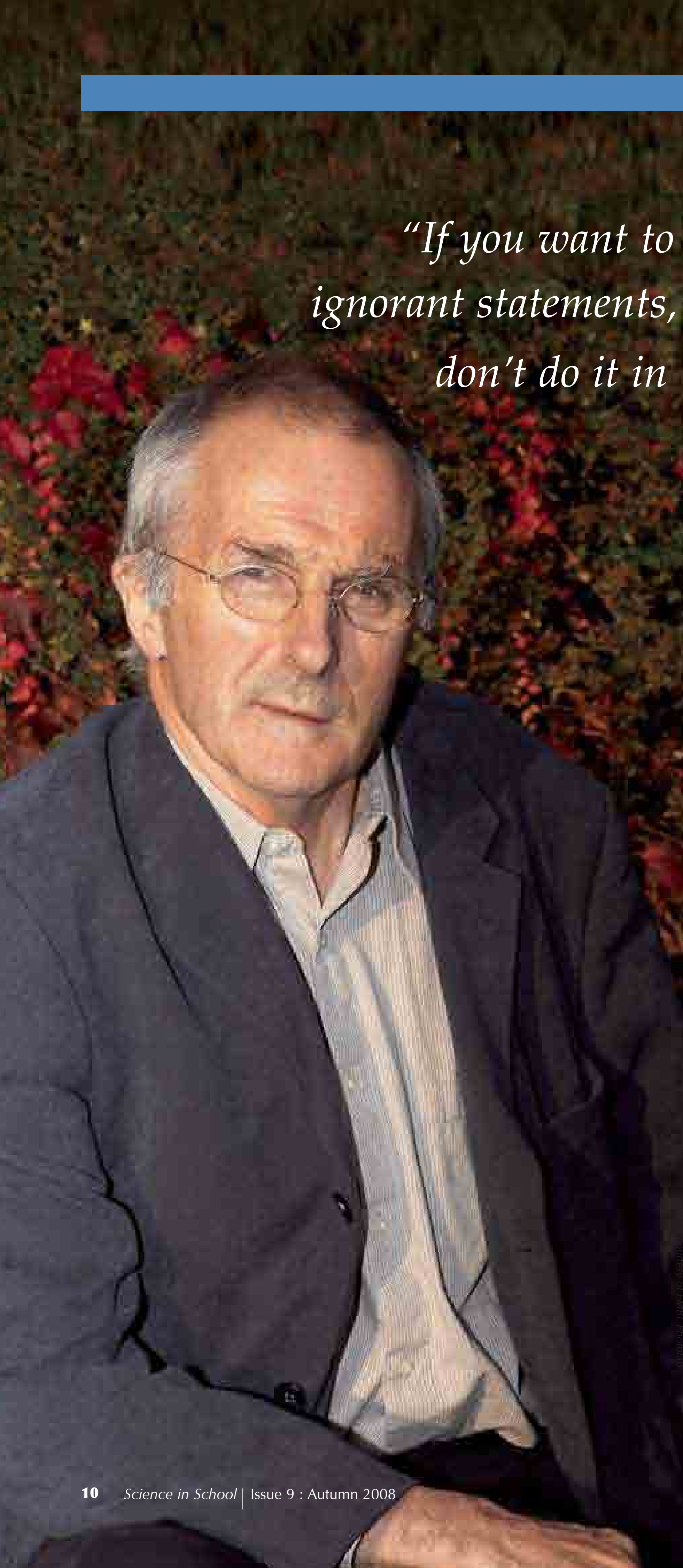


Image courtesy of Jupiterimages Corporation

There's a worrying trend spreading across Europe. We're accustomed to hearing about the fiery debate surrounding the teaching of evolution in the USA, especially but not exclusively in the Bible belt. But in November 2006 in an article in *Nature*, Almut Graebsch and Quirin Schiermeier expressed concern that the teaching of alternative theories in schools is not just an issue across the Atlantic (Graebsch & Schiermeier, 2006).

They're not the first to notice this. In 2006 the Royal Society, the UK's national academy of science, launched an attack on creationism, concerned that the idea was gaining a foothold in schools and universities across the country. They enlisted Steve Jones, Professor of Genetics at University College London (UCL), to give



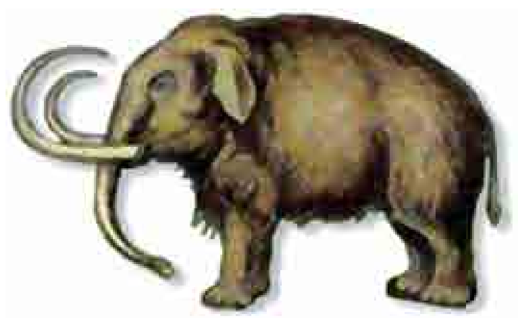
"If you want to go around making ignorant statements, don't do it in a biology lesson."

his public lecture, 'Why evolution is right and creationism is wrong'.

Steve, author of several popular books on genetics, including *In The Blood* and *The Language of the Genes*, lectures widely about evolution in schools, universities, conferences and research institutes. He's concerned – and absolutely baffled – by the growing influence of creationist groups in Europe.

"It's a mystery," he says. "In the 30 to 40 years I've been talking to audiences about evolution, I'd never once had a question about creationism. In the last few years, though, such questions have become completely commonplace."

Steve estimates that he has lectured more than 100 000 school pupils during his career, and is UCL's representative at the London Science Learning Centre, which provides in-career training to science teachers[w1]. He has also featured extensively on BBC radio, presented a six-part TV series and appeared on various other TV programmes, as well as writing for the press on scientific issues, with a regular column in *The Daily Telegraph*, 'View from the Lab'.



"It's very alarming. Graebsch and Schiermeier's article cites examples of schools in Germany where creationism is being taught and, more notably, Italy, where in 2004 education minister Letizia Moratti caused a furore when she removed the theory of evolution from the curriculum. In Britain, the pro-creationist group Truth in Science sent information packs to every secondary school in the country at the end of 2006. Polish European parliament member Maciej Giertych organised a workshop for parliamentarians entitled 'Teaching evolution theory in Europe: is your child being indoctrinated in the classroom?'. In October 2007, Miroslaw Orzechowski, Poland's former deputy education minister, told the newspaper *Gazeta Wyborcza*: "The theory of evolution is a lie. It is an error we have legalised as a common truth."

The creation-evolution debate divides opinion about the origins of life; those who have a faith-based belief trust that life appeared in, as Steve puts it, "some magical, non-scientific means sometime in the fairly recent past", as opposed to the scientific consensus supporting evolutionary biology. Although many religions have reconciled their beliefs to evolution, there are still many creationists, most prevalent in more conservative regions of the USA, who believe that evolution is contradicted by the stories found in their respective religions. "Creationism is wrong because all its claims fly in the face of everything we know about science," explains Steve. "But people expect – and fear – too much. They want answers to questions which are not open to scientific enquiry, like 'is there a God?', or 'what does it mean to be human?'."

The debate isn't new. Evolutionary ideas such as common descent and the transmutation of species have existed since at least the 6th century BC, but as biological knowledge grew in the 18th century, such ideas developed, challenging the thought that the natural world was fixed by God's will. It was the publication of English naturalist Charles Darwin's 1859 book, *On the Origin of Species*, which established evolution by common descent as the dominant scientif-

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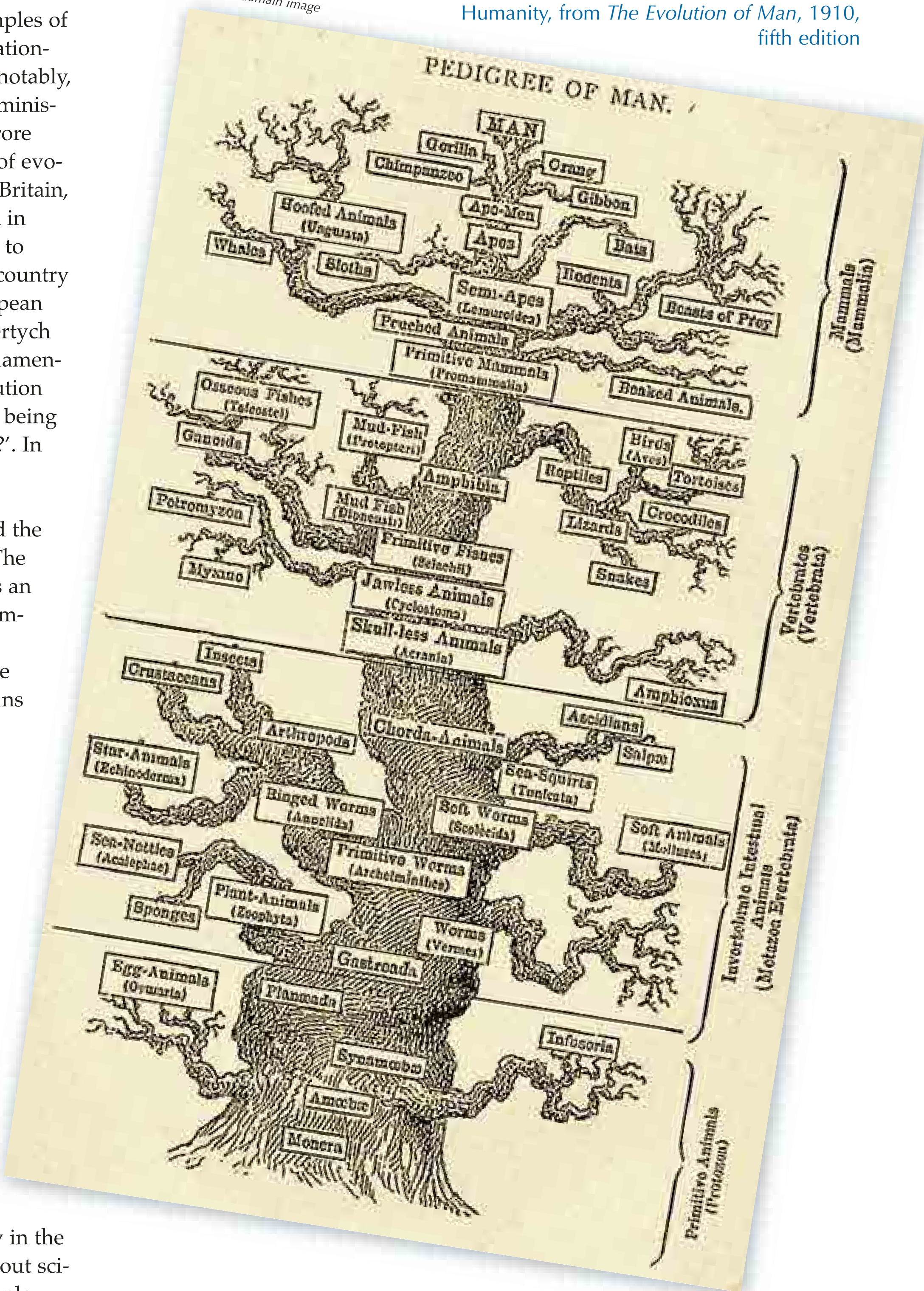
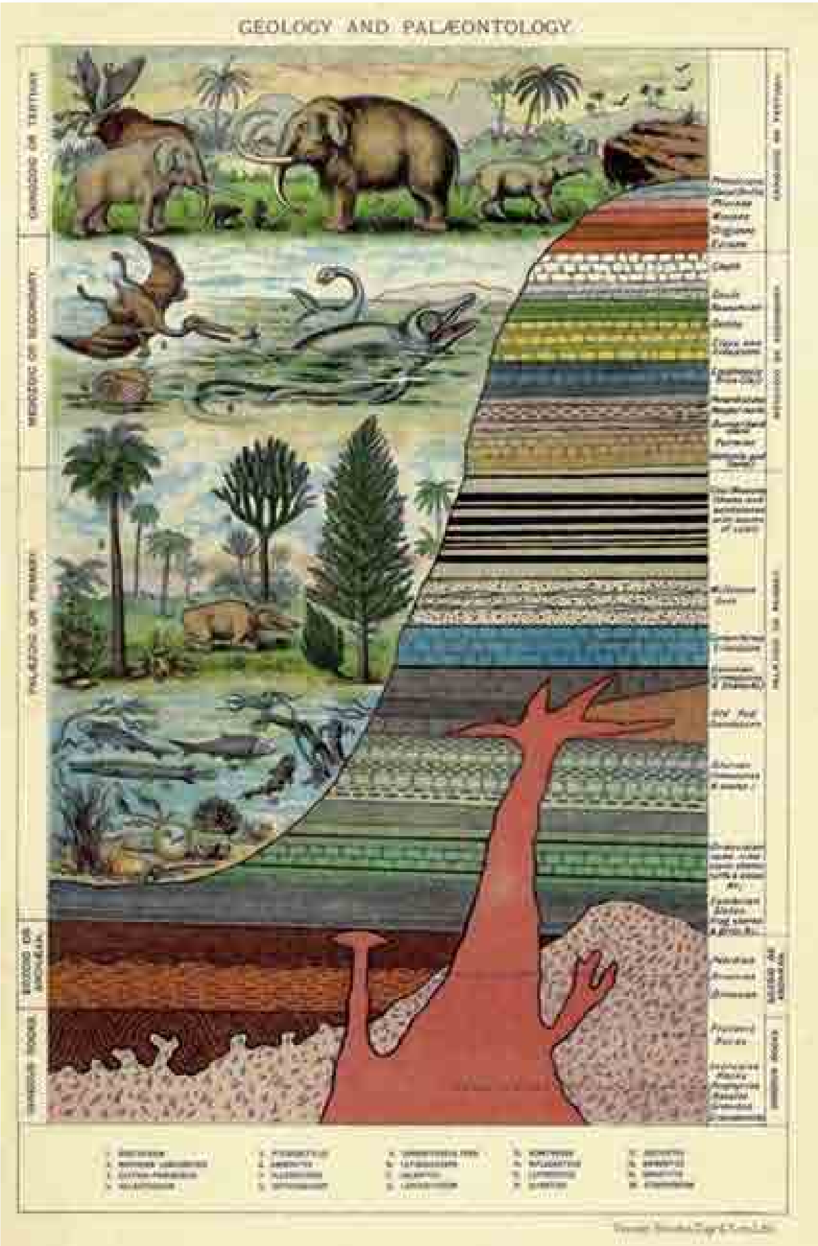


Ernst Haeckel, Genealogical Tree of Humanity, from *The Evolution of Man*, 1910, fifth edition



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Formation of different rocks and evolution of life on Earth. Published c1880

ic explanation of diversification in nature.

"The Victorians had a horror of evolution at first, thinking it makes us less than human, but in fact it makes us *more* human – we're the only animals that have developed art, history, speech – all those things. We *are* very similar to chimps, but in every way that's important, we're completely different," says Steve.

"But by 1870, just over a decade after Darwin's book came out, the uproar had subsided. Most churchmen were educated people and could see that they could accept evolution and that it had nothing to do with their religious belief. The two things simply don't clash. Science is far too powerful to bother with ridiculous, untestable theories."

But why, after 150 years of evolution being recognised as the best explanation for the development of life on Earth, providing a clear understanding of the processes that account for the variety of organisms, and being taught as an essential part of biology and science courses, is pressure from somewhere – maybe simply political correctness – leading even decision-makers to change policies?

"It was the late 1960s when creationism started coming back into fashion, and then was triumphant very gradually. It was mainly as a result of the fear of modern biology, but sometimes because of the false claims of many scientists. But now, I don't know why it should be so rampant suddenly."

Of course it's fair to show both sides of a coin, but to hold up a religion-based theory as an alternative to scientific fact can be damaging.

"I'm not against [teaching creationism at school] as such," says Steve, "but it should be taught in theology lessons. If you want to go around making ignorant statements, don't do it in a biology lesson."

Steve calls creationism 'anti-science'. "I will never debate with a creationist," he says. "They think that 2 + 2 = 5; or, at a push, as a compromise, 4.1. I'm entirely sure that 2 + 2 = 4. There's nothing to discuss. If they won't accept the physical facts of life, we have nothing to talk about. I don't care what they *believe*, unless they've got some evidence, which they haven't."

"It's a mystery to me how any scientist can believe in creationism," he says. "In Europe you don't get the [same attitudes] about it that you get in the USA, but there is a more sophisticated line of argument; 'creationism with a college education'. It's the 'intelligent design' argument –

that organisms must have been designed by something, because they're so complex. But Darwin showed that evolution is a factory for making almost impossible things."

So how can scientists and teachers help? "Teachers feel that evolution isn't just another part of biology – they think it's something special, something they have to be careful about. I'm tempted to say they should make evolution boring. They should present it as something that's simply part of biology, a fact, rather than something that's debatable and controversial and somehow 'sexy'.

"Another problem is that evolution is very badly taught, largely because teachers have been taught it badly, and it's not well-presented in textbooks," he adds. "The rest of biology is done very well, but when it comes to evolution, it's very unclear. There are the old, traditional examples – the peppered moth, antibiotic resistance, and Darwin's finches – but there are no new examples. Teachers aren't taught what modern evolutionary biology is.

"Darwin didn't think he would ever see evolution happening – he thought of it as a historical thing, a model that brought together many apparently unrelated facts into one seamless whole – but of course we *can* see it happening. In the brief history of HIV, we have the perfect example of the whole of the Darwin machine unfolding its powers in front of our eyes. He would have been delighted to see the workings of evolution so starkly exposed."

Editor's note

What do you think about Steve Jones' opinions? For example, do you agree that evolution is badly taught at school? That creationism is anti-science? Why not join the *Science in School* discussion forum and leave your comments online: www.scienceinschool.org/forum

BACKGROUND

A history of creationism

By Dean Madden from the National Centre for Biotechnology Education, University of Reading, UK.

Public domain image

Charles Darwin, English naturalist (1809-1882). Engraving from *The Century Magazine*, New York, January 1883

When Darwin was an undergraduate at Cambridge University, UK, his future career was strongly influenced by several scientists, notably geologist Adam Sedgwick and John Henslow, the botanist who suggested that Darwin should accompany Captain FitzRoy on the *HMS Beagle*. As was required of Cambridge dons at that time, the two scientists were ordained church ministers. They were also deeply committed Christians. Yet even they, some 30 years before *Origin of Species* was published, doubted the literal truth of the Bible. In England, general acceptance of Darwin's theory of evolution was rapid, and the Anglican church soon came to terms with it. Elsewhere in Europe and America, religious opposition was muted: typically the debate was not whether natural processes or the Christians' God had created living things, but whether the creation was a result of a supernatural influence working through nature or the result of natural processes ('what happened?' not 'whodunnit?').

The Catholic hierarchy has generally been conservative, but the overwhelming weight of evidence was such that in 1996, Pope John Paul II issued a letter in which he said that the work of scientists worldwide: "... leads us to recognise in the theory of evolution more than a hypothesis" (unlike many modern creationists, John Paul understood the difference between a mere hypothesis and a scientific theory). Today, mainstream Christians are not usually biblical literalists, and leaders in both the Catholic and Anglican churches have recently reaffirmed their opposition to the teaching of creationism in science lessons (Thavis, 2006; Bates, 2006).

continued overleaf

BACKGROUND (CONTINUED FROM PAGE 13)

In August 2006, an analysis of people's acceptance of evolution was published by the journal *Science* (Miller, 2006). Thirty-two European nations plus the USA and Japan were compared in the report. The study showed that Icelanders, Danes, Swedes, French, Japanese and Britons were among those most likely to accept that humans evolved "*… from earlier species of animals*". Individuals with a strong belief in a personal god and who prayed frequently were significantly less likely to accept the concept of evolution. In the USA and Turkey, where strong religious beliefs are common and evolution education has been politicised, people were least likely to accept evolution.

Throughout the western world, particularly in Europe, secular modernity has long been seen as a consequence of urbanisation, increased wealth and better education. Sociologists have speculated that, as the religious become increasingly conscious of their unusual identity in a secular society, they may become more entrenched in their views. Such entrenchment may also be true of those of no faith, living in predominantly religious societies. This may account for the increasingly polarised debate over the teaching of evolution that has been noted by several observers, including Steve Jones.

The emergence of much modern opposition to the teaching of evolution worldwide can be traced back to the pioneering days of the USA, when settlers from different religious backgrounds, unable to rely upon an established church hierarchy, found it necessary to develop their own 'do it yourself' churches. This, coupled with a highly decentralised education system, largely run by elected amateurs in 17 000 school districts, has led to several instances where school boards have tried to prevent the teaching of evolution or to promote the teaching of religion. These have often been challenged in the courts.

The most famous remains the Scopes 'monkey trial' of 1925, which was held in Dayton, Tennessee, USA. By the mid-1920s, six of the Southern states had already passed anti-evolution laws. The Scopes trial was a publicity stunt concocted by local businessmen to boost Dayton's flagging economy: the trial would be the first in the USA to be broadcast live on the radio. When he was approached by several businessmen, twenty-four-year-old John Scopes agreed to their request to stand trial. Everyone knew that Scopes was likely to be convicted of teaching evolution, although in reality he may only have used a book that included evolution, and may not have taught the subject. The American Civil Liberties Union (ACLU), which backed Scopes' defence, planned to appeal to the US Supreme Court in the hope of obtaining a judgement which clarified the rights of the individual over those of the government.

Although Scopes was convicted, the ruling was soon overturned on a technicality, robbing the ACLU of its chance to take the case further. The ban on evolution education remained, and the amount of evolution taught in US schools declined over the next 35 years, so that evolution was absent from almost all US school biology textbooks in the early 1960s. The Sputnik scare of 1957 prompted a re-think of US science education, and evolution returned to the textbooks, notably the new high-school texts produced by the Biological Sciences Curriculum Study. When the Tennessee law and others like it were eventually declared unconstitutional in the 1960s, the anti-evolutionists were forced to adopt a different strategy. This approach was necessitated by the USA's separation of church and state, which does not permit the teaching of religion *as religion* in publicly funded schools. Throughout the 1970s and early 1980s, 'creation science' was their preferred mechanism.

Public domain image; image source: Wikimedia Commons

'Creation science' attempted to suggest that scientific evidence supported biblical events, and demanded that equal time be given to creationism and evolution in the classroom. Most of the highly selective interpretations of evidence were obvious nonsense. For instance, it was suggested that humans initially escaped the biblical flood by climbing to the tops of mountains. Dinosaurs, however, were less successful and trilobites even less so – this accounted for the relative positions of fossils in rock strata. Several court judgements, notably in Arkansas and Louisiana, ruled out the 'equal time' argument. Creationism was deemed a religious idea by the US Supreme Court, not a scientific one, and therefore it could not be taught in US schools.

Recently, the plain creationism of Scopes's time and 'creation science' of the late 20th century have been replaced by 'intelligent design' (ID), a strategy promoted by the US Discovery Institute, which aims to "… replace materialistic explanations with the theistic understanding that nature and human beings are created by God".

The ID movement generally avoids any reference to a god however, and presents its ideas as rational alternatives to accepted scientific understanding, which should therefore be entitled to equal treatment in (US) science classrooms. Consequently, 'Teach the controversy' became the new slogan of the anti-evolutionists.

Perhaps because of its appeal to fairness and its superficially scientific approach, the ID movement's influence, unlike that of similar efforts in the past, has been felt far beyond its native USA. Well-organised, often generously funded and sometimes politically endorsed campaigns have influenced school education not only in countries such as Poland and Turkey, where religion and politics are closely associated, but also in more secular societies including France, Germany and Italy. Early in 2004, for example, Italy witnessed the removal of the theory of evolution from the middle-school curriculum, ostensibly because students 'were confused by it'. Almost two years later, after a 'Darwin Commission' had reported, a weakened account of evolution was re-introduced, omitting any reference to human origins.

This and similar events, such as the Dover School Board trial in the USA, led the Interacademy Panel on International Issues to issue a statement on the teaching of evolution in June 2006[w2]. "Theories about the origin and evolution of life on Earth...", it said, were being "…confused with theories not testable by science". It noted that all forms of life on Earth continue to evolve, a fact which "...palaeontology and the modern biological and biochemical sciences are describing and independently confirming with increasing precision. Commonalities in the structure of the genetic code of all organisms living today, including humans, clearly indicate their common primordial origin". Similarly, the Council of Europe has issued a strongly worded statement in support of teaching evolution[w3].

What will the next challenge from the creationists be? In Louisiana, USA, groups hostile to evolution have adopted a subtle new tactic, which appears to encourage a cherished feature of science. They have proposed and passed a law which requires 'academic freedom' to promote "... critical thinking skills, logical analysis, and open and objective discussion of scientific theories being studied, including, but not limited to, evolution, the origins of life, global warming and human cloning". Critics fear that this law and others will allow creationism in by the back door.

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Graebsch A, Schiermeier Q (2006) Anti-evolutionists raise their profile in Europe. *Nature* **444**: 406-407. doi: 10.1038/444406a. Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2008/issue9/stevejones), or subscribe to *Nature* today: www.nature.com/subscribe

Miller JD, Scott EC, Okamoto S (2006) Public acceptance of evolution. *Science* **313**: 765–766. doi: 10.1126/science.1126746. Supporting online material: www.sciencemag.org/cgi/content/full/313/5788/765/DC1

Thavis J (2006) Intelligent design not science, says Vatican newspaper article. *Catholic News Service*, 17 January. www.catholicnews.com/data/stories/cns/0600273.htm

Web references

w1 – For more information about the Science Learning Centre network and the courses they offer for UK-based teachers, see: www.sciencelearningcentres.org.uk

w2 – In 2006, 67 members of the InterAcademy Panel on International Issues, a network of science academies from around the world, issued a joint statement 'On the Teaching of Evolution'. See: www.interacademies.net/CMS/About/3143.aspx

w3 – The Council of Europe has issued a statement entitled 'The dangers of creationism in education'. See: http://assembly.coe.int/Main.asp?link=/Documents/AdoptedText/ta07/ERES1580.htm

Resources

The UK Department for Children, Schools and Families (formerly the Department for Education and Skills) provides guidance on the place of creationism and intelligent design in science lessons. See: www.teachernet.gov.uk/docbank/index.cfm?id=11890

The *Big Picture* is a free magazine-style publication from the Wellcome Trust for post-16 students and their

REVIEW

One of the most important (and for some, the most controversial) scientific discoveries of all time was unveiled to the public 150 years ago next year. The seminal text, *On the Origin of Species by Means of Natural Selection*, was published in 1859, and its author, Charles Darwin, would be celebrating his 200th birthday next year. Plans are advanced for celebrations around the world to mark Darwin 200. The celebrations have already begun, as 1 July 2008 marked the 150th anniversary of Darwin and Wallace announcing their theory.

Steve Jones is one of the best-known of modern geneticists, both through his academic achievements and his popularity as a communicator of science. In this article he confirms his acceptance of the Darwinian theory of evolution, and also presents some of his arguments against creationism.

Perhaps this thought-provoking article will re-open a debate for some readers; for others it may inspire them to re-appraise the scientific method in contrast with anti-science.

The article could be used in biology (while teaching evolution), theology or religious studies (in a consideration of creationism) or in English lessons (as the basis of a debate or comprehension exercise).

Marie Walsh, Republic of Ireland

Public domain image; image source: Wikimedia Commons teachers. The *Big Picture* on evolution is available to download (as a PDF document) or to read on screen and is supported by additional resources for teachers. See: www.wellcome.ac.uk/Professional-resources/Education-resources/Big-Picture/Evolution/index.htm

The Understanding Evolution website from the University of California, Berkeley (USA), provides authoritative, up-to-date information about evolutionary mechanisms, theory, evidence and modern research. The site includes numerous resources for teaching about evolution (aimed at a US audience). See: http://evolution.berkeley.edu

For an open-access article about the status of evolution and creationism in US schools, see:

Berkman MB, Pacheco JS, Plutzer E (2008) Evolution and creationism in America's classrooms: a national portrait. *PLoS Biology* **6(5)**: e124. doi:10.1371/journal.pbio.0060124

The 2005 Eurobarometer survey examined European attitudes to science and technology. In particular, see Section 3.3, 'Science, Faith and Luck':

European Commission (2005) Special Eurobarometer 224: Europeans, science and technology. http://ec.europa.eu/public_opinion/archives/ebs/ebs_224_report_en.pdf

A popular, readable and up-to-date account of evolution is:

Jones S (2001) *Almost like a whale: The Origin of Species updated*. London, UK: Black Swan. ISBN: 055299958X

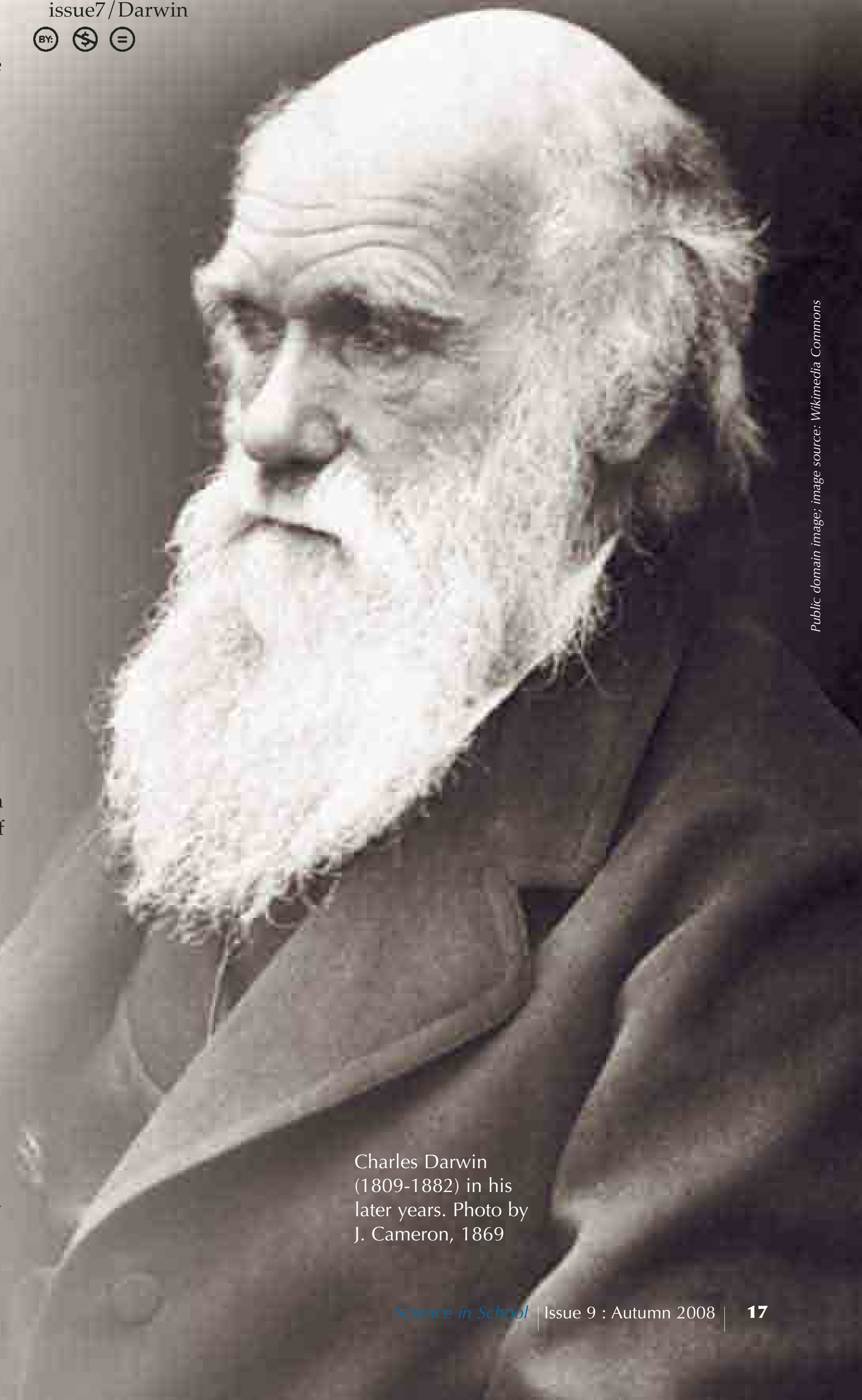
Some other recent popular books are:

Carroll SB (2008) *The making of the fittest: DNA and the ultimate forensic record of evolution*. London, UK: Quercus. ISBN: 9781847244765

Shubin N (2008) *Your inner fish. A journey into the 3.5 billion-year history of the human body.* London, UK: Allen Lane. ISBN: 9780713999358

For a review of a book describing the development of Charles Darwin's *The Origin of Species* and its wider impact, see:

Madden D (2007) Darwin's *The Origin of Species*. *Science in School* **7**: 67. www.scienceinschool.org/2007/issue7/Darwin



Charles Darwin (1809-1882) in his later years. Photo by J. Cameron, 1869

Public domain image; image source: Wikimedia Commons

What killed the woolly mammoth?

Climate change is nothing new. **Caitlin Sedwick** describes how a computer model is helping scientists to explain the extinction of the woolly mammoth.

Forty-two thousand years ago, during the last glacial advance of the Pleistocene epoch, woolly mammoths thundered across the frozen steppes of the Eurasian continent. The huge beasts thrived on the arid tundra of the last ice age, having adapted to temperatures that would chill the toes off any hairless ape. Yet, by the middle of the Holocene epoch, 6000 years ago, the glaciers had retreated and the Eurasian woolly mammoth was on the verge of extinction. They were ultimately done in, say David

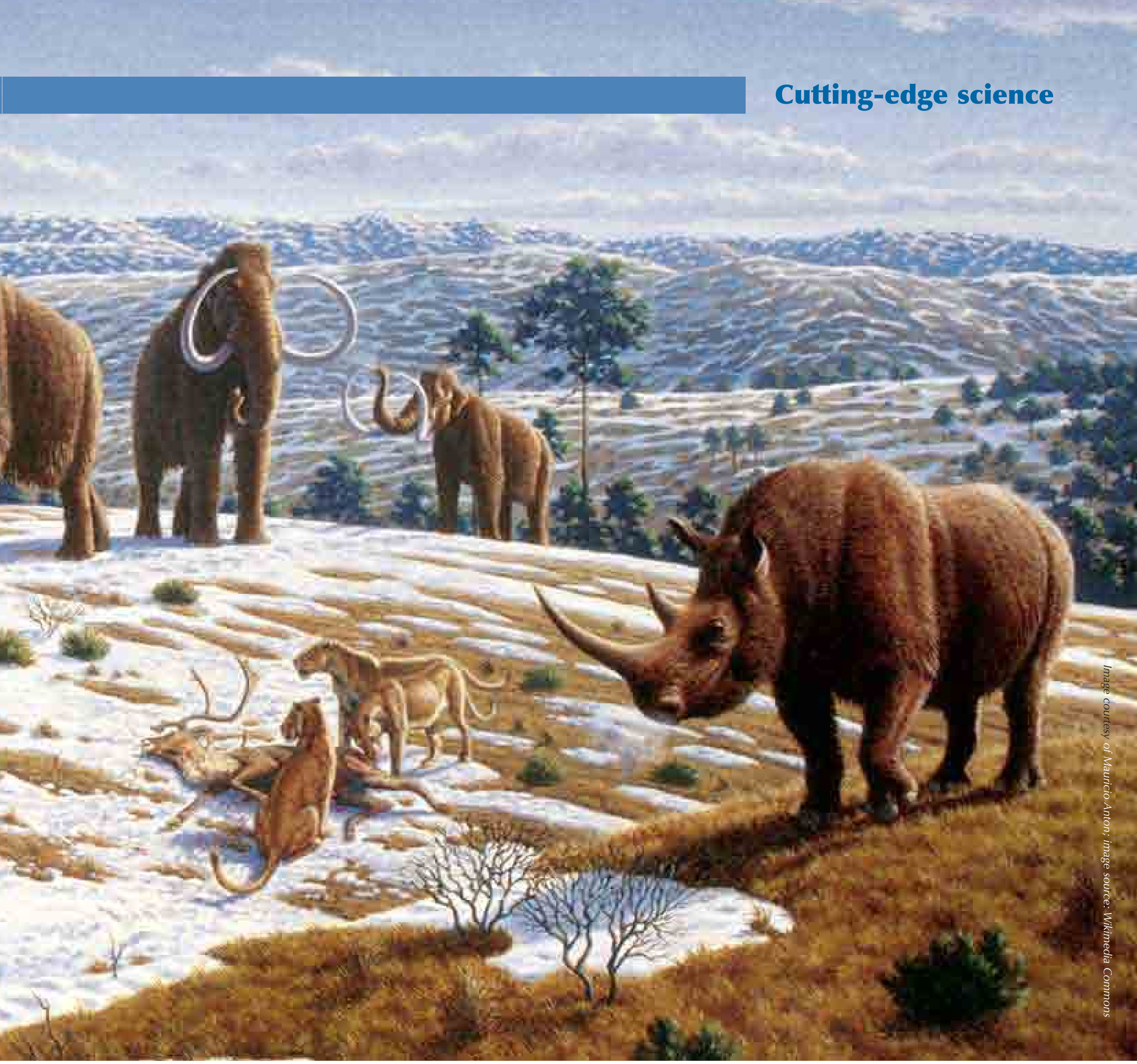


Image courtesy of Mauricio Anton; image source: Wikimedia Commons

Woolly mammoths were driven to extinction by climate change and humans

Nogués-Bravo and colleagues, by climate change – with a helping hand from humans.

Ever since Mikhail Adams retrieved the first fossilised woolly mammoth remains from Russia in 1806, scientists have debated what happened to this ancient relative of the Asian elephant (Gross, 2006). Did it die out because its habitat disappeared, as the planet's climate warmed and vegetation and precipitation patterns changed? Or did human interlopers on the Eurasian plains hunt it to extinction? It's a difficult question to untangle, because the retreat of the glaciers at the end of the Pleistocene era not only changed the animals' habitat but also allowed primitive human bands to migrate north from southern Eurasia, probably hunting whatever game they encountered during their journey. Whereas previous attempts to explain what happened to the mammoths were largely descriptive inferences based on available data, Nogués-Bravo et al (2008) used the data to generate quantitative estimates of the interplay between the mammoth's disappearing range and warming versus hunting.

To study the factors that may have contributed to the mammoth's demise, the authors modelled the climate in the regions inhabited by the mammoth during several periods of the last ice age. Their model related the fossil record – showing the distribution and age of mammoth remains – to simulated maps of the highest mean temperature, the lowest mean temperature, and average rainfall conditions on the Eurasian supercontinent for three periods during the last glacial advance in the Pleistocene (42 000, 30 000, and 21 000 years ago) and to a point in the interglacial in the middle of the Holocene era (6000 years ago). Next, they applied their climatic models to the Eurasian supercontinent 126 000 years ago (the previous time the planet had warmed between glacial advances). Together, these data allowed the group to estimate the characteristics and extent of the animals' favoured habitat at the periods studied.

The authors' findings suggest that mammoths experienced a catastrophic loss of habitat: as the last glaciers retreated and the planet warmed, 90% of the animals' former habitat disappeared. Prime mammoth habitat progressively shrank from 7.7 million square kilometres 42 000 years ago (in the midst of the last glacial advance) until just 0.8 million square kilometres remained 6000 years ago. The animals were restricted to isolated tracts spotted across Eurasia and tiny patches squeezed up against the northern coastal edges.

Although the near obliteration of their habitat would have placed great pressure on the species, the situation appeared even more dire during the previous glacial retreat 126 000 years ago, when only 0.3 million square kilometres of prime habitat existed. At that time, the species probably teetered on the brink of extinction, as geographically isolated groups experienced declines in genetic diversity and fitness. Even so, the mammoths had managed to survive that crucible. What was different about the Holocene? The remaining mammoth herds faced a foe that hadn't existed 126 000 years ago: human hunters.

Humans evolved to their modern form during the Pleistocene and migrated north with the final retreat of the glaciers, hunting mammoths as they advanced. By the middle of the Holocene, mammoth populations

REVIEW

When the summary of a scientific paper is written in such a pleasant, simple and friendly way, it is an excellent teaching resource for a natural science or English-language teacher. It can be used in secondary schools by biology and earth science teachers, who can exploit it in an interdisciplinary way, possibly involving the English-language teacher in a CLIL activity (a European project aimed at teaching different subjects in a foreign language).

The topic is interesting for every student who remembers the film *Ice Age*[w1], the style is witty and precise at the same time, and the logical development of the text is easy to follow. Moreover, the article content is a perfect example of the scientific method at work (observation, modelling, prediction) in the context of evolution.

Teachers could use the article to discuss climate change in geological eras and in the last two centuries, as well as methods of modern climatology and palaeontology. The article can also be used to link history and scientific subjects (earth science, biology, mathematics) for an interdisciplinary approach to the study of prehistory and cultural evolution.

The language of the article is plain enough to propose some comprehension questions such as:

1. Eurasian woolly mammoths became extinct about:
   a) 126 000 years ago
   b) 42 000 years ago
   c) 21 000 years ago
   d) 6000 years ago.
2. What happened 126 000 years ago?
   a) the Earth's climate became warmer
   b) the glaciers retreated
   c) woolly mammoths flourished in Eurasia
   d) modern humans hunted woolly mammoths.
3. David Nogués-Bravo and his colleagues:
   a) first discovered fossilised woolly mammoths
   b) made descriptive inferences about the woolly mammoths' extinction
   c) built mathematical models of climate changes in the last ice age
   d) are going to unearth fossils in the Eurasian continent.

The reading activity could be completed by building a geological timeline with the students (I performed an activity like this with a toilet paper roll in the school courtyard: every sheet of the paper symbolised a certain time period).

Finally, the article has a format that is easily handled by teachers and it is a good starting point for further activities in the exciting field of Earth's history. The format is suitable for a single lesson.

Giulia Realdon, Italy

were so vulnerable that it would not have taken much hunting pressure to push them to extinction. The authors' most optimistic estimates of mammoth population size and density suggest that if each human killed just one mammoth every three years, the species would become extinct. More pessimistic estimates suggest that the loss of as few as one mammoth every 200 years (per human in its territory) might have sealed the animals' fate.

Other evidence may yet be uncovered that would support the authors' contention that mammoth populations made vulnerable by climate change were finished off by human hunting. For example, the authors' habitat models suggest new areas on the Eurasian continent where mammoth fossils may be found. Expeditions to these locations could determine whether mammoth populations lived there, and provide more evidence to help researchers continue the shift from qualitative to quantitative interpretations of the data.

This article was first published in PLoS Biology *and is reproduced with kind permission.*

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These references are freely available online.

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Nogués-Bravo D et al (2008) Climate change, humans, and the extinction of the woolly mammoth. *PLoS Biology* **6(4)**: e79. doi:10.1371/journal.pbio.0060079

Web references

w1 – For details of the film *Ice Age*, see the Internet Movie Database: www.imdb.com/title/tt0268380

Resources

For more accurate accounts of the decline of mammoth populations than is provided in the film *Ice Age*, see two BBC TV documentaries:

The last episode of *Walking with Cavemen*. See the Internet Movie Database: www.imdb.com/title/tt0370053 and the BBC website: www.bbc.co.uk/sn/prehistoric_life/tv_radio/wwcavemen

Walking with Beasts. See the Internet Movie Database: www.imdb.com/title/tt0286285 and the BBC website: www.bbc.co.uk/sn/prehistoric_life/tv_radio/wwbeasts

Both are available on DVD.

A very good BBC Radio 4 programme on the fate of mammoths can be heard online. See: www.bbc.co.uk/radio4/science/frontiers_20020515.shtml

Image courtesy of Mauricio Anton; image source:Wikimedia Commons

Detecting sugar: an everyday problem when facing diabetes

Fred Engelbrecht and **Thomas Wendt** from the ExploHeidelberg Teaching Lab describe some experiments on sugar detection to demonstrate the problems that people with diabetes face every day.

Image courtesy of iStockphoto

Diabetes, a disease of modern civilisation

The monosaccharide glucose is the most important source of energy in the living eukaryotic organism and is used by cells in aerobic or anaerobic respiration. It also serves as a precursor in the production of proteins and in lipid metabolism. Therefore, it is a central molecule in several metabolic pathways and its concentration in the bloodstream must be tightly regulated by insulin and glucagon.

Diabetes mellitus (or simply **diabetes**) is a syndrome characterised by disordered glucose metabolism and overly high blood sugar levels (hyperglycaemia). This is due either to low levels of the hormone insulin or to an abnormal resistance to the effect of insulin coupled with levels of insulin secretion that are too low to compensate for the resistance.

There are two major forms of diabetes: Type 1 and Type 2. Although they have different causes, patients with either form are unable to produce sufficient insulin in the beta cells of the pancreas to prevent hyperglycaemia.

Type 1 diabetes comprises about 10% of all diabetes cases in Europe, and is characterised by the loss of the pancreatic beta cells, usually by autoimmune destruction. Since Type 1 diabetes often affects patients at a young age, it is also named juvenile diabetes. It is the more severe form of the disease because there is no treatment. Instead, patients must adjust their lifestyles, for example by improving their diet, taking regular exercise and monitoring their blood sugar levels. Additionally, subcutaneous injections or the continuous delivery of insulin by a pump into the blood circulation system are necessary to avoid coma or death.

Type 2 diabetes is due to insulin resistance or reduced insulin sensitivity in the target tissues, combined with insufficient insulin secretion. The lowered response of the body tissues to insulin almost certainly involves the insulin receptors in cell membranes. This causes the body to need abnormally high amounts of insulin to maintain normal blood sugar levels, and diabetes develops when the beta cells cannot meet this demand. Type 2 diabetes, commonly known as adult-onset diabetes, usually appears after the age of 30. In most cases, it is connected with obesity and too little physical exercise; changing to a healthier lifestyle can improve the condition or in some cases even cure it. See Dugi (2006) for more details of diabetes.

People affected by either type of diabetes need to learn how to live with the symptoms of the disease. These include frequent urination, increased thirst and, consequently, increased fluid intake. Since large numbers of children are affected by diabetes, it is essential to teach students about the disease from an early stage. Diabetes sufferers need to learn how to minimise their symptoms or even prevent the disease by eating a healthy diet and taking enough exercise. Healthy children should understand the needs of their affected friends.

We have therefore put together some experiments to enable students to detect carbohydrates. One series of experiments detects whether or not a solution contains starch, proteins, or sugars such as glucose, lactose or

BACKGROUND

ExploHeidelberg

The ExploHeidelberg[w3] is an informal learning and interactive science centre. It consists of three different components: an interactive exhibition, a media lab and a biotechnology teaching lab.

In the interactive exhibition, about 50 exhibits challenge visitors to experience optical, acoustic and mechanical phenomena. The pedagogical concepts and design of the interactive exhibition are developed in close collaboration with the University of Education Heidelberg[w4]. Trainee teachers and staff members from the physics department are involved as exhibition scouts, and in designing exhibits and developing workshops, teacher training and research projects.

The teaching lab offers middle- and high-school students the opportunity to perform biotechnology experiments in full-day practical courses that are not possible in the classroom.

A media lab with 12 workstations, webcast facilities and a video imaging workstation complements the study centre.

The interactive exhibition and the media lab are open daily to the general public and focus on interesting the visitor in life sciences in general. The teaching lab offers school and university students, teachers and trainee teachers special courses related to the school curriculum, giving an insight into modern biotechnology techniques. Participants can choose from one-day courses on handling DNA or proteins and specialised one-week courses involving sophisticated techniques that are usually only taught at university level.

Image courtesy of Thomas Wendt

Fehling's reaction (left), Lugol's reaction (middle), protein assay (right)

sucrose. Once the sugars are identified, further experiments determine, using an enzymatic reaction, which samples contain lactose or glucose. The principle of these experiments is the same as in assays to determine blood glucose levels for the diagnosis of diabetes, or to measure glucose and/or lactose levels, for example in fruit juices, milk and dairy products. These experiments, therefore, give students an idea of how diabetes sufferers can monitor their sugar status.

Experiment 1: Detection of sugar, starch and protein

Students receive five samples, labelled A to E, which contain starch, protein (bovine serum albumin), the monosaccharide glucose, or the disaccharides lactose or sucrose. All solutions are at a concentration of 0.1% in water. You could also test samples of colourless glucose-containing energy drinks (e.g. Powerade®-Lemon). Using different reagent solutions, students should determine which of the five samples contain sugar, starch or protein.

For a class of 30 students working in pairs, you will need the following solutions:

- Fresh Fehling's solution, made by mixing equal volumes of light blue Fehling's I solution (7 g $CuSO_4 \cdot 5\,H_2O$ dissolved in 100 ml distilled water) and colourless Fehling's II solution (35 g $C_4H_4KNaO_6 \cdot 4\,H_2O$ and 10 g NaOH dissolved in 100 ml distilled water). The solution should be mixed shortly before it is needed.
- Lugol's solution, made by dissolving 1 g iodine (I_2) and 2 g potassium iodide (KI) in 50 ml distilled water.
- Coomassie Brilliant Blue dye for the Bradford assay is commercially available, for example from Biorad[w1].

a) Detection of a reducing sugar (Fehling's reaction)

1. Pipette a 1 ml sample of solutions A to E into each of five different reaction tubes and heat the contents to 60 °C in a water bath for 2 min.
2. Add 16 µl of the deep blue fresh Fehling's solution to each reaction tube and incubate the tubes at 60 °C for a further 10 min, or until a colour reaction is observed and a precipitate forms.

The solutions containing reducing sugars like fructose, glucose or lactose should turn red and develop a red precipitate (the dissolved copper (II) ions are reduced to insoluble copper (I) oxide), whereas there should be no colour change with sucrose or starch. The protein solution should turn pale violet.

b) Starch detection (Lugol's solution)

1. Pipette a 500 µl sample of solutions A to E into each of five new reaction tubes.
2. Add 50 µl of Lugol's solution to each tube and observe the colour reaction.

Lugol's solution is an indicator to test for starch. The dye will stain starch as it interacts with the coiled structure of the polysaccharide, giving rise to a deep blue colour. It will not react with monosaccharides (glucose) or disaccharides (lactose or sucrose).

c) Protein detection

The protein assay is based on the Bradford dye binding procedure that measures the colour change of the Coomassie Brilliant Blue dye when it binds to protein.

1. Pipette a 20 µl sample of solutions A to E into each of five new reaction tubes, then add 800 µl deionised water and 200 µl Coomassie Brilliant Blue dye (Bradford reagent).

Image courtesy of iStockphoto

Table 1: Example of results obtained in Experiment 1

	Fehling's reaction	Lugol's reaction	Protein assay	Compound
Solution A	**Red precipitate**	Brown	Brown	Reducing Sugar
Solution B	Blue solution	**Dark blue**	Brown	Starch
Solution C	**Red precipitate**	Brown	Brown	Reducing Sugar
Solution D	Violet solution	Brown	**Blue**	Protein
Solution E	Blue solution	Brown	Brown	Sucrose

2. Mix the reagents, leave the reaction for 5 min, and observe the colour reaction.

In the presence of protein, the solution will turn blue (this can be measured in a photometer at 595 nm). The samples containing sugar or starch will not change colour.

Safety note: The Biorad protein assay solution contains methanol and phosphoric acid and should, therefore, be used with caution.

Results and interpretation

Solution B gives a positive reaction with Lugol's solution, thus revealing it to contain starch. Solution D gives a positive result with the Bradford assay, revealing itself to be a protein solution. Solutions A and C give a red precipitate during the Fehling's reaction, and can therefore be identified as the reducing sugar samples glucose and lactose (although it is not possible at this stage to tell which is which). The remaining solution, E, shows no reaction in any of the tests and must therefore be the sucrose solution.

Experiment 2: Enzymatic determination of sugar

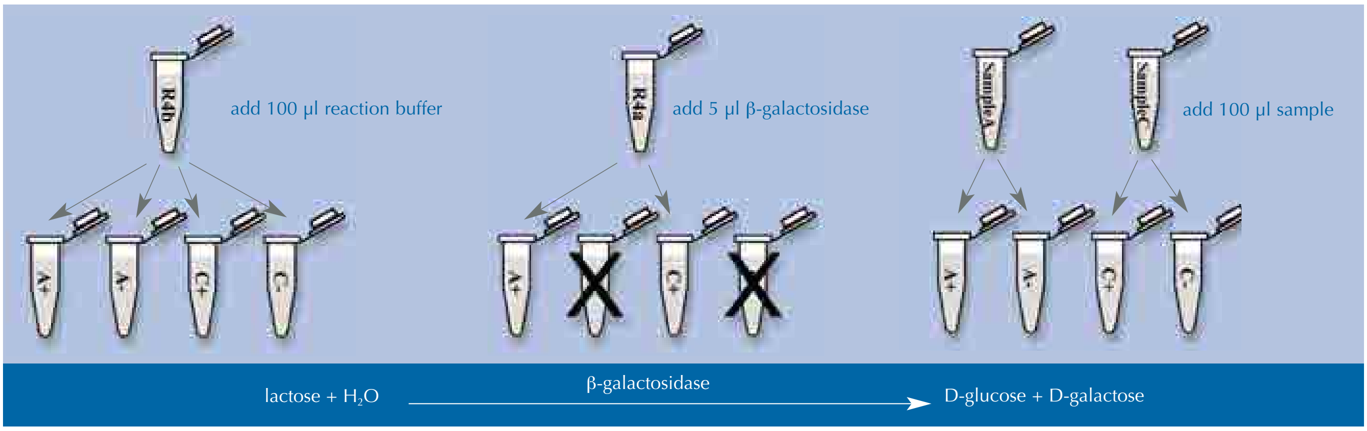
In this second experiment, the two remaining solutions A and C are tested again, to see which of them contains lactose and which glucose. For this experiment we use a commercially available kit, EnzyPlus EZS 962+ lactose/D-glucose, which can be purchased from BioControl[w2]. The procedure is similar to that routinely used by diabetes patients to monitor their blood glucose levels. The standard protocol for the product has been modified and downscaled, so that a larger number of experiments can be performed with the reagents provided. One kit provides enough materials for 20 pairs of students.

The principle of the test is as follows (see figure below):

- The disaccharide lactose is hydrolysed by the enzyme β-galactosidase to D-galactose and D-glucose (Step 1 in the diagram below).
- In the presence of ATP, D-glucose is specifically phosphorylated by the hexokinase to glucose-6-phosphate; simultaneously, adenosine-5'-diphosphate (ADP) is formed (Step 2).
- The glucose-6-phosphate is oxidised by the glucose-6-phosphate dehydrogenase to gluconate-6-phosphate.

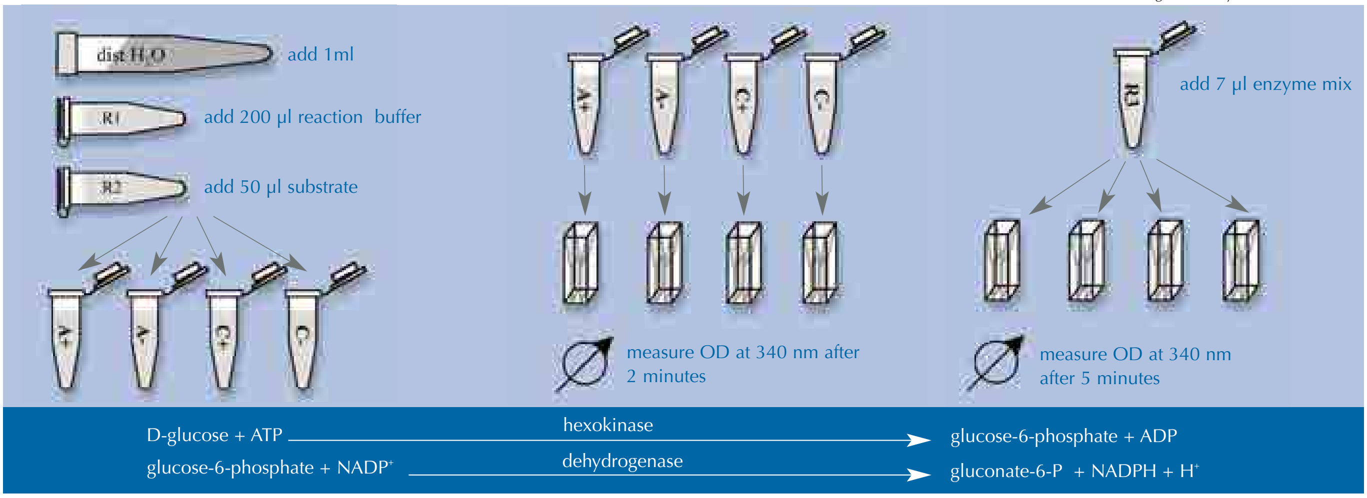
Step 1: Hydrolysis of lactose

Image courtesy of Thomas Wendt



Step 2: Detection of glucose

Image courtesy of Thomas Wendt



- During this reaction, $NADP^+$ is reduced to NADPH. The amount of NADPH formed in this reaction is stoichiometric to the amount of lactose and can be measured photometrically by the increase in absorbance at 340 nm.

To perform the reaction:

1. Take four 1.5 ml reaction tubes and label them A+, A-, C+ and C-. Put 100 µl reagent buffer R4b (phosphate buffer pH 6.6) into each tube, and add 5 µl β-galactosidase solution R4a into tubes A+ and C+ (but not tubes A- or C-).
2. Add 100 µl of solution A to tubes A+ and A- and 100 µl of solution C to the tubes labelled C+ and C-.

Note: In the remaining steps of this experiment, all four samples are treated identically.

3. Leave all samples for 30 min at 37 °C in a water bath while lactose hydrolysis occurs.
4. After the incubation, add 1 ml distilled water, 200 µl reaction buffer R1 and 50 µl reagent R2 (containing ATP and NADP, respectively) to all four reaction tubes and mix thoroughly.
5. Transfer 1 ml of each reaction mixture into separate photometer cuvettes and measure the optical density at 340 nm (OD_{340}) after 2 min.
6. To each cuvette, add 7 µl enzyme mix R3 containing the hexokinase and the glucose-6-phosphate-dehydrogenase, incubate for a further 5 min, and measure the absorption at 340 nm again.

Table 2: Example of results obtained in Experiment 2

<table>
<tr><th></th><th>First measurement (OD_{340})</th><th>Second measurement (OD_{340})</th><th>Result</th></tr>
<tr><td>**Sample A +**</td><td>0.09</td><td>2.43</td><td rowspan="2">Glucose</td></tr>
<tr><td>**Sample A -**</td><td>0.09</td><td>2.37</td></tr>
<tr><td>**Sample C +**</td><td>0.10</td><td>1.43</td><td rowspan="2">Lactose</td></tr>
<tr><td>**Sample C -**</td><td>0.09</td><td>0.10</td></tr>
</table>

Image courtesy of iStockphoto

Results and interpretation

All four samples should give low absorption values when first measured, indicating the absence of NADPH. The second measurement (after addition of the enzymes) should allow solutions A and C to be distinguished. Since solution A gives positive results independently of whether or not β-galactosidase had been added, it can be concluded that it contains glucose. In contrast, a change in the absorption of solution C should only be measured in the presence of β-galactosidase (C+), indicating that it contains lactose.

During the practical, participants get basic information on diabetes and the problems that patients with diabetes face. To monitor their blood glucose level, patients use a test-strip glucose-monitoring system that acts like a black box but is based on the principle used in Experiment 2. Performing such experiments may raise awareness of diabetes and of how the disease can be survived or prevented through lifestyle changes.

The experiments described here can be safely performed in normal school laboratories, since the reagents used are not hazardous materials in the sense of the Hazardous Substances Regulations (EC Regulation 67/548/EEC). The level of sodium azide, the preservative in the reagents, is below the lowest level of toxicity for a preparation, according to the Directive 1999/45/EC.

References

Dugi K (2006) Diabetes mellitus. *Science in School* **1**: 61-65. www.scienceinschool.org/2006/issue1/diabetes/

Web references

w1 – Biorad: www.bio-rad.com

w2 – BioControl: www.rapidmethods.com

w3 – ExploHeidelberg: www.explo-heidelberg.de

w4 – University of Education Heidelberg: www.ph-heidelberg.de

REVIEW

In this article, Fred Engelbrecht and Thomas Wendt address the important topic of diabetes and propose two experiments to give an insight into the main components of food and into the science behind glucose test strips commonly used by diabetes patients.

The style of the text, clear and appropriate, is easier in the first part (about diabetes); the experiments are a bit more challenging, giving teachers the opportunity to use the different sections at different secondary-school levels.

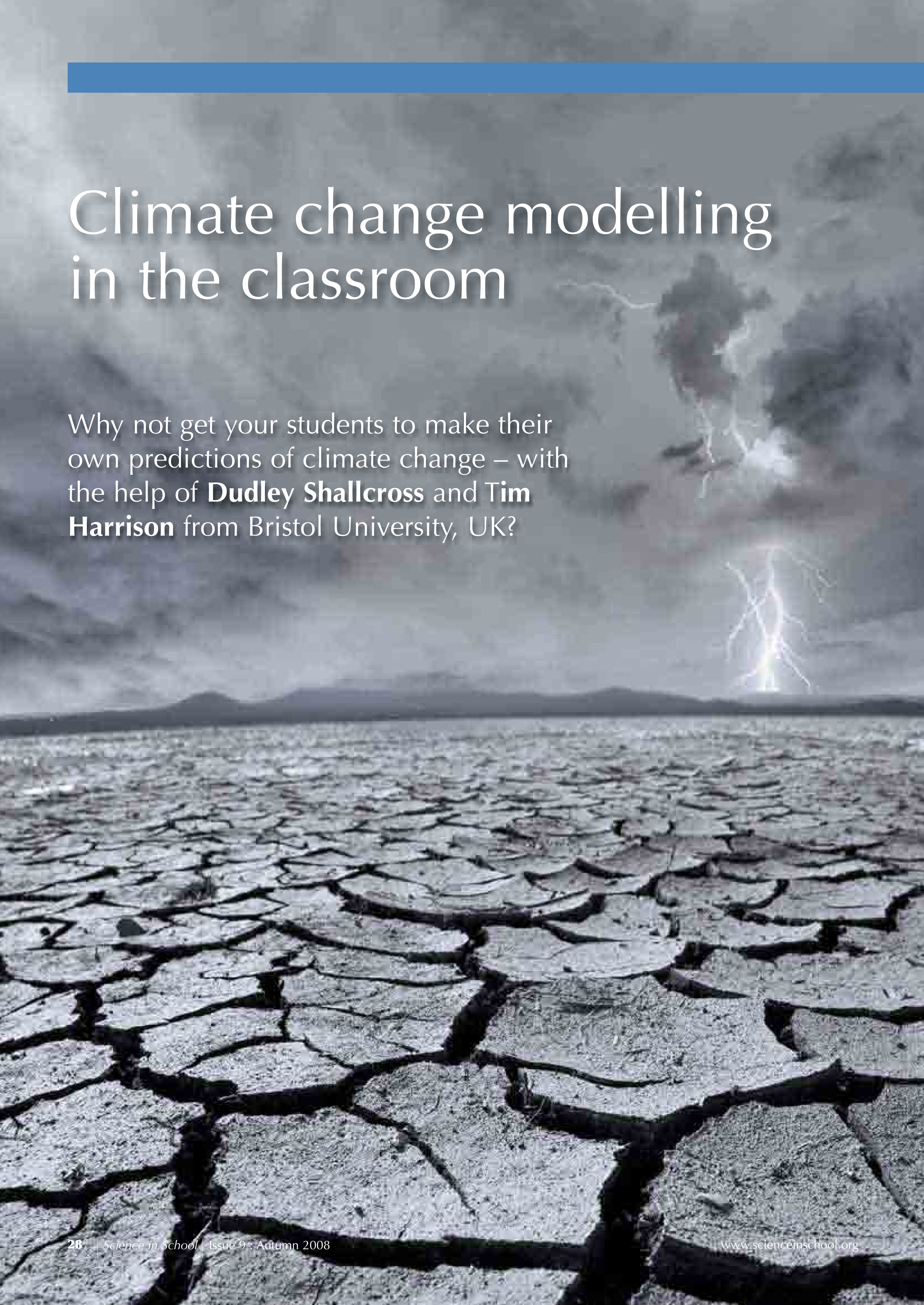
The article can be used in the biology, chemistry and health education curricula, with the possibility of an interdisciplinary approach to the issues related to diabetes, for example linking biochemistry, biology and health education. Given the widespread nature of this disease, the text is useful as a starting point to promote active citizenship and full social inclusion of diabetic students.

The article could be used to address the topics of carbohydrates and proteins; metabolism (biochemistry); the digestive system (biology); food and health (health education); and laboratory training (chemistry).

The first part can be used to test the comprehension of diabetes, the second part to test the comprehension of technical issues. Example questions include:

1. Which of the following features is not typical of diabetes mellitus?
   a) High blood glucose level
   b) Insufficient insulin production or resistance to the effect of insulin
   c) Low blood glucose level
   d) Frequent urination and increased thirst.
2. The data shown in Table 2 mean that:
   a) Glucose needs β-galactosidase to produce NADPH
   b) Lactose needs β-galactosidase to produce NADPH
   c) Lactose doesn't need β-galactosidase to produce NADPH
   d) Glucose needs glucose-6-phosphate dehydrogenase to produce $NADP^+$.

Giulia Realdon, Italy



Climate change modelling in the classroom

Why not get your students to make their own predictions of climate change – with the help of **Dudley Shallcross** and **Tim Harrison** from Bristol University, UK?

Image courtesy of iStockphoto

Climate change and global warming are 'hot' topics and deserve an important place in the school science curriculum.

But how do we predict how our climate is going to change? It seems timely to introduce students to simple climate modelling. In this article, we demonstrate that students can use a straightforward spreadsheet to investigate the major factors that affect Earth's climate.

A first attempt to model the climate

The simplest model of the climate is one in which incoming solar energy is equal to outgoing terrestrial energy emitted from the planet, i.e. an 'energy in equals energy out' model. In this article, the term 'energy' really means energy flux, i.e. energy per second. We know from measurements that the energy from the Sun reaching the top of the atmosphere (per second), termed the solar constant S, is 1370 Wm^{-2}.

We start by calculating the average surface temperature of Earth, T_E. If we take the radius of a perfectly spherical Earth to be R_E, in this very simple model we can see that Earth absorbs solar radiation over an area πR_E^2 (i.e. a flat disc of atmosphere) but emits energy from an area $4\pi R_E^2$ (i.e. from the entire surface).

(a) Energy in = energy out

and using the Stefan-Boltzmann Law (see box)

(b) Energy per unit area per unit time x total area $_{(disc)}$ = energy per unit area per unit time x total area$_{(sphere)}$

(c) $1370 \times \pi R_E^2 = \sigma T_E^4 \times 4\pi R_E^2$

Rearranging the equations gives:

$$\sigma T_E^4 = \frac{1370 = S/4}{4}$$

$$T_E^4 = \frac{1370}{(4 \times 5.67 \times 10^{-8})}$$

$$T_E = 279 \text{ K } (6\ °C)$$

where σ is the Stefan-Boltzmann constant ($5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$).

BACKGROUND

Essential background physics

Black body radiation and the Stefan-Boltzmann Law

All bodies radiate energy as electromagnetic radiation. A black body absorbs all radiation falling on it. It emits radiation as a function of its surface temperature.

The Stefan-Boltzmann Law describes the total energy, I, emitted by a black body at any temperature, T, by:

$I(T) = \sigma T^4$ *Equation 1*

where:

I is the energy per unit area emitted per second (Wm^{-2})

T is the absolute temperature (K)

σ is the Stefan-Boltzmann constant ($5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$).

At first glance, this looks like a sensible figure for such a crude model, although of course the actual average surface temperature of Earth is known to be 16 °C. (There are several ways to work it out, such as by splitting Earth into latitude bands, working out the average temperature per band and summing and averaging all of these.) The problem with this very simple model, though, is that some solar energy is not absorbed by Earth, but is instead reflected back out to space by clouds and ice.

Approximately 24% of the incoming energy is reflected by clouds and another 6% is reflected by the surface, e.g. by ice. This gives a total reflectivity of Earth – known as the albedo (A) – of 30% or 0.3. Therefore, the left-hand side of equation (c) must now be re-written as 0.7 x 1370 x πR_E^2 and the calculation of T_E becomes:

$$T_E^4 = \frac{1370 \times 0.7}{(4 \times 5.67 \times 10^{-8})}$$

$$T_E = 255\ \text{K}\ (-18\ °\text{C})$$

This value is obviously far too low, and leads naturally to the question: why is Earth so warm? In order to answer this question we need a slightly more complex model.

The one-layer atmosphere model of Earth

If we assume that the atmosphere is made up of a single layer of miscible gases, we can create a more accurate model that students can use with a spreadsheet. In this model, allowances are made for absorption by the atmosphere of the incoming visible light from the Sun and absorption of the outgoing infra-red light emitted from Earth.

The figure below summarises the elements of the model. F_S is the solar constant divided by 4 (S/4), which arises from the difference between incoming energy spread over a disc, πr^2, and outgoing energy radiated from the surface of a sphere, $4\pi r^2$ (the assumption made in the first model). The incoming energy from the Sun is then $F_S(1\text{-}A)$, where A is the albedo – the portion reflected back to space. This incoming energy is in the UV and visible regions. τ_{VIS} is the proportion of this incoming energy that is not absorbed by the atmosphere: if the atmosphere absorbs it all, τ_{VIS} is zero; if the atmosphere absorbs none of it, τ_{VIS} is one. Hence the energy reaching the surface of the planet is $F_S(1\text{-}A) \times \tau_{VIS}$.

Earth will behave similarly to a black body and will emit the energy denoted as F_g from its surface. This terrestrial radiation is centred in the infra-red region of the spectrum.

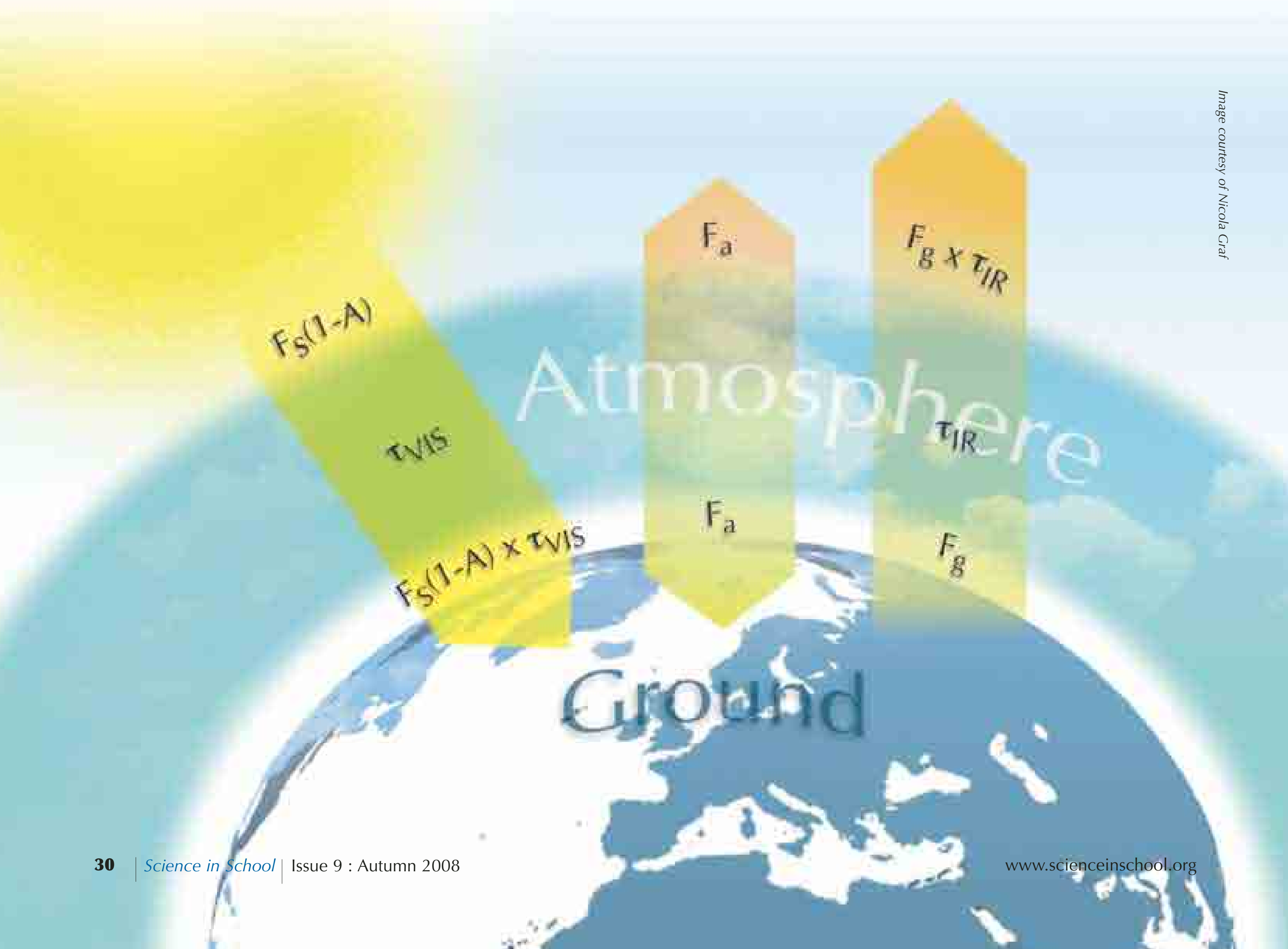
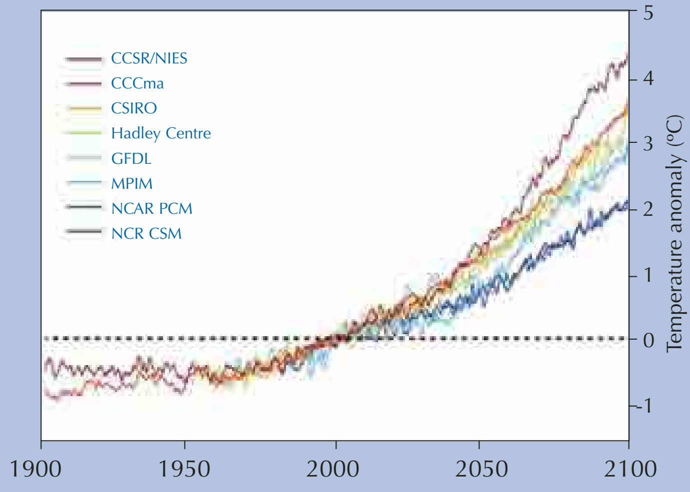


Image courtesy of Nicola Graf

Images courtesy of Robert A. Rohde; image source: Wikimedia Commons

Global warming projections

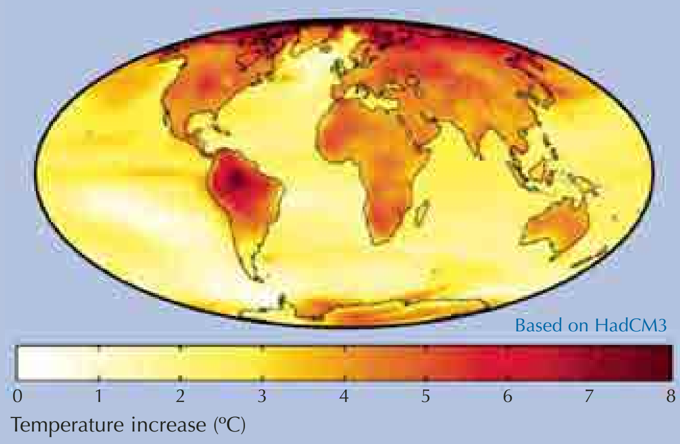
Climate model predictions for global warming relative to average global temperature in 2000. The model data used was taken from the Intergovernmental Panel on Climate Change Data Distribution Centre



Global warming predictions

2070-2100 prediction vs. 1960-1990 average

A map of predicted global warming at the end of the 21st century. This model has an average warming of 3.0°C and uses the Hadley Centre HadCM3 climate model



Certain gases in the atmosphere absorb the infra-red energy (greenhouse gases). Similar to τ_{VIS}, τ_{IR} is the proportion of infra-red energy not absorbed by these gases in the atmosphere, and so the outgoing energy is $F_g \times \tau_{IR}$.

Assuming that the energy from the atmosphere is denoted as F_a and that energy in and out at the surface of Earth and the top of the atmosphere are both balanced, then:

at the surface of Earth:

$$F_S(1-A) \times \tau_{VIS} + F_a = F_g \qquad \textit{Equation 2}$$

and at the top of the atmosphere:

$$F_g \times \tau_{IR} + F_a = F_S(1-A) \qquad \textit{Equation 3}$$

Combining Equations 2 and 3 gives:

$$F_g = \frac{F_S(1-A)(1+\tau_{VIS})}{(1+\tau_{IR})}$$

Finally,

$$F_g = \sigma T_E^4 = \frac{F_S(1-A)(1+\tau_{VIS})}{(1+\tau_{IR})}$$

$$T_E = \left[\frac{F_S(1-A)(1+\tau_{VIS})}{\sigma(1+\tau_{IR})}\right]^{0.25} \qquad \textit{Equation 4}$$

If we take the following values:

$F_S = 1370/4 = 342.5\ Wm^{-2}$ (solar constant divided by 4)

$A = 0.3$

$\tau_{VIS} = 0.8$

$\tau_{IR} = 0.1$

Equation 4 gives us:

$T_E = 288.5$ K (15.5 °C),

which is a close approximation to the current average surface temperature of Earth.

It is Equation 4 that can be put into a programme such as Microsoft Excel so that students can see the changes in global temperature when the equation parameters are changed. This has been done and an interactive version can be used online or downloaded from the Bristol University website[w1].

Table 1 shows examples of the output if the variables A, τ_{VIS} and τ_{IR} are altered. In Example 1 we assume that the atmosphere does not absorb any of the incoming or outgoing energy fluxes (i.e. both τ_{VIS} and τ_{IR} are equal to 1.0) and the albedo is 0.3, giving a temperature of 255 K. In Example 2, we assume that there are no clouds or ice (i.e. A = 0.0), which raises the temperature of Earth to 279 K, showing the importance of the albedo. In Example 3, there are also no clouds or ice (A = 0.0) but the atmosphere now absorbs all the outgoing infra-red radiation (i.e. $\tau_{IR} = 0.0$) and Earth warms to 331 K. If we now reintroduce clouds and ice in Example 4 (A = 0.3), the temperature drops to 303 K.

Table 1: Example experiments

Example no.	1	2	3	4
S (Wm^{-2})	1370	1370	1370	1370
A	0.3	0.0	0.0	0.3
τ_{VIS}	1.0	1.0	1.0	1.0
τ_{IR}	1.0	1.0	0.0	0.0
T_E (K)	255	279	331	303
T_E (°C)	-19	5	57	29

Possible questions

Typical questions that could be asked, and which would require students to use this model, are:

1. Which of the variables has the greatest effect on average global temperature?
2. If the average distance from Earth to the Sun was increased by 1% of the current value, the solar constant would be reduced by a factor of 1.0201, i.e. it would become 1343 Wm^{-2}. What would the temperature be? Assume an albedo of 0.3, τ_{IR} of 0.3 and τ_{VIS} of 0.6.

   (The solar constant will scale with distance squared, so moving Earth 10% closer to the Sun will mean S = $1370/(0.9)^2$ = 1691 Wm^{-2} and moving Earth 1% further away will mean S = $1370/(1.01)^2$ = 1343 Wm^{-2})

Of course, far more challenging questions could be asked.

3. If the sand in the Sahara desert could be made into a glass mirror (sand can be melted into glass),
   (a) How big would the mirror have to be in order to cool the planet by 1 °C?
   (b) What fraction of the Sahara desert would that be?

A more sophisticated model

How does the simple model compare with more sophisticated models such as the Hadley Centre climate model used by the UK's Meteorological Office (see images on page 31)? In fact, the two models are very similar, except that the Hadley Centre model does not consider the atmosphere as one layer, but splits it into a number of boxes based on altitude, latitude and longitude. For each box, the model directly calculates the amount of incoming UV/visible radiation transmitted and scattered within that box, and the amount of outgoing infra-red radiation transmitted by that box, based on the concentrations of key greenhouse gases and the surface area of cloud and ice. The most sophisticated versions of the Hadley Centre model also consider the heat flux into and out of the ocean and the uptake of CO_2 by vegetation. But if you understand the principles of the simple model, you are well on your way to understanding the more complicated real climate models.

Taking part in a real climate simulation

Climateprediction.net[w2] is the largest experiment to try and produce a forecast of the climate for the 21st century. It does this by recruiting help from people around the world who can offer time on their computers – such as when the computers are switched on, but are not being used to their full capacity. The full climate model has many parameters that can be adjusted; to explore all of these parameters, a phenomenal number of simulations must be performed. Even with the computer resources available to the climateprediction.net team, such an ensemble of simulations would take a very long time. The idea behind climateprediction.net is that anyone can download a version of the model that will explore one of these particular parameters (preset). The model will take about three months to run in the background while you work, without compromising the speed of the computer.

Calculations are performed in three parts. The first part runs calculations using data from the years 1850 to 1900, checking the resulting predictions against temperature records: this is known as the calibration run. The second part runs a simulation from 1901 to the present day. The third stage then runs a simulation of the future climate (2000-2100) with one parameter changed, for example the sensitivity of climate to uncertainties in the sulphur cycle. Once the calculations are complete, the data is automatically uploaded to the UK's Meteorology Office the next time that the computer is online. The interface software provided (free of charge) with the simulation gives the computer user a graph of the changes to the climate, as they are calculated. Temperature variations by season with latitude, longitude and altitude are just some of the variables that can be visualised. Such features would enable a cross-curricular school project linking geography and the physical sciences.

In the next issue of *Science in School*, the authors suggest some chemistry experiments relevant to climate change.

Web references

w1 – An interactive version of the simple climate model can be used online or downloaded here: www.chm.bris.ac.uk/acrg/model/simple_climate_model/prediction_model.html

Use the sliders to change the variables.

w2 – For more details about the experiment and how to get involved, see http://climateprediction.net

The climateprediction.net website also offers information and resources specifically for schools, available both in English and Spanish: http://climateprediction.net/schools/resources.php

Resources

Harrison T, Shallcross D, Henshaw S (2006) Detecting CO_2 – the hunt for greenhouse-gas emissions. *Chemistry Review* **15:** 27-30

Pacala S, Socolow R (2004) Stabilisation wedges: solving the climate problem for the next 50 years with current technologies. *Science* **305**: 968-972. doi: 10.1126/science.1100103

Shallcross D (2006) Dirty Air. *Education in Chemistry*, **43** (5): 131-135

Numerous notes for schoolteachers on air pollution, climate change and ozone depletion by the authors can be found here: www.chemlabs.bristol.ac.uk/outreach/resources/Atmos.html

For an excellent source of graphics and data relating to climate change, see: www.grida.no/climate/vital/index.htm

Data from the Earth System Research Laboratory Global Monitoring Station can be found here: www.cmdl.noaa.gov

The website of the Intergovernmental Panel on Climate Change, from which the Climate Change 2007 report and other data may be located, is: www.ipcc.ch

Haubold B (2008) An Inconvenient Truth. *Science in School* **9**: 72. wwwscienceinschool.org/2008/inconvenient

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Dudley Shallcross is the Professor in Atmospheric Chemistry and Tim Harrison is the School Teacher Fellow at the School of Chemistry at the University of Bristol, UK. The latter is a position for a secondary-school teacher that was created to bridge the gap between secondary schools and universities, and to use the resources of the School of Chemistry to promote chemistry regionally, nationally and internationally.

For more information about modelling climate change or about the post of school teacher fellow please contact Dudley Shallcross (d.e.shallcross@bristol.ac.uk) or Tim Harrison (t.g.harrison@bristol.ac.uk).

Much of this article was originally published in: Shallcross DE, Harrison TG (2007) Climate change made simple. Physics Education ***42****: 592-597*

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REVIEW

Climate change should certainly be one of *the* topics of today's science teaching at all school levels throughout Europe. In particular after Al Gore's enormous *Inconvenient Truth* campaign, the topic has gained world-wide recognition. However, useful materials with usable background information for science teachers are not always readily available. This two-part article, however, offers a suitable and easy-to-adapt approach to the rather complicated process of modelling atmospheric developments.

Whereas the mathematical model is best suited for use in advanced science courses for students aged 16 and over, the basic phenomena could easily be presented to students at the age of 15 or even younger – even if they are not intending to specialise in science in later school years. The web resources mentioned offer a wide range of approaches and ready-to-use images, applets and graphs, thus providing a very useful resource for any science teacher.

Tobias Kirschbaum, Germany

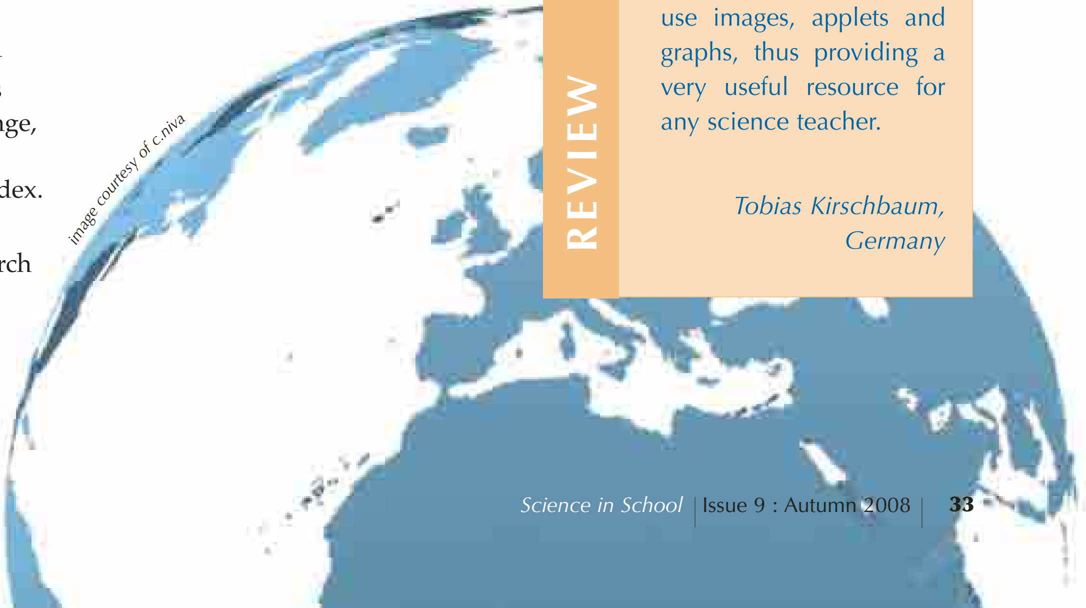


image courtesy of c.niva

Meet the Gene Machine: stimulating bioethical discussions at school

Host: … What do you call that thing?
Chris: Oh, the Microarray and Microassay Hyper Channel Optimising Genetic Analysis with Real Time Interpretive Functionality Unit.
Host: OK… the Gene Machine. And what does it do?
Chris: I take a sample of DNA, insert it in here and the Microarray and…
Host: Gene Machine.
Chris: …and the Gene Machine analyses it and prints out a complete genetic profile.

Laura Strieth, Karen Bultitude, Frank Burnet and **Clare Wilkinson** use drama and debate to encourage young people to discuss genetics and what it means for us all. Why not join in?

Image courtesy of the Science Communication Uni

Image courtesy of the Science Communication Unit

Genetics: a difficult subject

Genetic technologies have advanced dramatically since Watson and Crick first announced the structure of DNA 55 years ago. But these advances – including an increase in the number of genetic tests to diagnose or predict disease, the growth of gene banks[w1] and advances in reproductive technologies – have raised complex personal, social and ethical questions. Who should have access to a person's genetic profile and how should it be used? How does personal genetic information affect our perception of ourselves and others? Who owns and controls genetic data? How are minority communities affected by genetic information? These are just some of the questions that audiences (aged 13-18) are encouraged to think about and discuss during a 'Meet the Gene Machine'[w2] event, and which you can employ in your own classroom.

The activity concentrates on discussion and debate – encouraging the students to think critically about the impact that science has on their lives and on society. These skills are central to the science courses recently introduced in England and Wales[w3] (Burden, 2007; Millar, 2006), and school students themselves have been shown to value them[w4].

Meet the Gene Machine was devised by the Science Communication Unit[w5] at the University of the West of England[w6], Bristol, and is funded by the Wellcome Trust[w7]. The project and the training materials were developed with the advice of a genetic counsellor, scientists, a teacher and a playwright. The activity has been tested across the UK and internationally.

The format is transferable and easy to perform: it has been used successfully by university students, science centre and museum staff, actors and secondary-school students. It is particularly appropriate for students aged 13-18 but could also be used with other age groups.

Chris: Ah, now that's a really interesting gene.
Host: Uh huh.
Chris: Well, it's pretty technical. You might want to talk to a few people about that…
Host: Yes?
Chris: (DEEP BREATH) That gene suggests you have a predisposition towards breast cancer.

Try it in your own classroom

Meet the Gene Machine opens with a short play to inform and amuse young people: a scientist explains his newly developed gene machine during a television chat show. The play stimulates an informed and lively debate by introducing pupils to basic genetics and raising vital ethical and social questions about modern and future genetic technologies.

The script for the play can be freely downloaded[w2] for use in the classroom and may be performed either by two teachers or by two pupils. The only essential props are a cotton bud and a fictional gene machine, which can be designed in accordance with the teacher's or students' imagination.

Following the play, there is a structured discussion, during which students can express their own opinions and consider the opinions of their peers on matters of genetic testing. To enable teachers running the activity to involve as many students as possible in the discussion, the Meet the Gene Machine team have developed some ideas and games suitable for a range of settings. Below are two of the most successful techniques.

The ranking game

Ask the audience to grade an array of characteristics (such as hair colour or criminality) on a spectrum between 'very genetic' and 'not genetic at all'. Not only do students react enthusiastically to this game, but it enables the teacher to clarify the basic science and draw attention to uncertainties in the field of genetics.

Resources required

1) Print a selection of genetic and non-genetic characteristics (see examples below) on laminated A4 or preferably A3 paper. The students should discuss to what extent each characteristic is genetically determined.

Ranking game characteristics:

Musical ability
Cystic fibrosis
Alcoholism
Hair colour
Athleticism
Intelligence
Bowel cancer
Huntington's disease
Sickle cell anaemia
Schizophrenia
Criminality
Homosexuality
Bad breath
Eye colour
Short hair

2) A sign reading 'very genetic' and another reading 'not genetic at all' should be positioned at opposite ends of the classroom. During the discussion, the students should pin the laminated paper for each characteristic on the wall at the appropriate point on the spectrum between these two signs.

Tips

To keep the class interested, we recommend that you run the ranking game for no more than four or five characteristics. You could either select characteristics that have been considered in previous lessons or introduce a fresh topic to students.

For the first characteristic, you could ask your pupils to each stand on the spectrum according to how genetic (or not) they believe the feature to be. This way you can get them moving and talking to each other right from the start.

For many characteristics, there is no known right or wrong answer; it is

Image courtesy of the Science Communication Unit

BACKGROUND

International transferability

Meet the Gene Machine was originally delivered by the UK team as part of Czech Science Week in 2003, and has since been performed successfully in many other countries, including Italy, Portugal, Latvia, Costa Rica and Hong Kong. The format is easily transferable, requires few specialist props or theatre effects, and is easy to stage for various audience sizes and venue types. The materials and event format are currently designed for students aged 13-18, and the science is accessible to mixed-ability groups.

important to emphasise this, as it will encourage the students to share their opinions. This uncertainty in the field of genetics is what makes it possible to have an open discussion and for the activity to be updated with new developments as they occur.

For information on current genetic news and technologies, visit the Science Communication Unit website[w4]. Here, you can find an archive of our monthly newsletter, produced during the UK rollout of the Meet the Gene Machine project, which contains information on genetics. The newsletter is freely downloadable.

Disclosure

In this activity, the audience explores issues of confidentiality, ownership of information, consent to the information being shared and the wider implications of genetic testing.

Split the audience into groups and ask them to discuss whom they 'would really tell' details of their genetic information to and whom they 'would really not tell'.

Resources required

Print A4 or preferable A3 laminated cards with any of the options below. In a classroom of 30 pupils, we suggest you use a total of 24 cards, but this depends on whether you decide to run the activity in small groups or with the whole class.

Family
Doctor
Insurance company
Employer
School
Police
Friends

Tips

Try splitting your class into groups of five and giving each group four cards to talk about. You can decide which combination of four cards each group receives. Within their groups, the students should discuss whom they would be happy to divulge their genetic information to, whom they would prefer not to tell, and why. At the end of the activity, a spokesperson from each group should share with the class the points that were raised during their discussion. Groups do not need to reach a consensus but they should explain their reasons for divulging the information to some groups and not to others.

More activities for the classroom

The Meet the Gene Machine team has designed further teachers' resources to facilitate discussions of bioethics in the classroom. The material is easy to use with lesson plans and suggested resources, for example handouts to produce, to run the activity in the classroom. It is freely available online in Word format[w2].

For advice on using the resource materials, contact the Science Communication Unit (science.communication@uwe.ac.uk).

References

Burden J (2007) Twenty First Century Science: developing a new science curriculum. *Science in School* **5**: 74-77.

BACKGROUND

Feedback from the audience

'The drama is humorous and informative, and you get to hear lots of different opinions during the discussion' (14-year-old student)

'The group discussion worked very well and makes you think about everyday issues' (17-year-old student)

'With an emphasis on developing scientific thinking, the Meet the Gene Machine materials provide a valuable opportunity for students to discuss different aspects of genetics. The resources support teachers to engage students through structured debate of contemporary issues. A number of useful strategies for group work are included, which can be successfully applied across several subject areas' (head of science)

REVIEW

This article gives a brief description of a set of fairly simple, yet innovative activities that can be easily used in any science (especially biology) classroom to promote student interest, thinking and debate on important ethical issues about the application of genetic knowledge.

The article provides a sample of a large selection of teaching activities complete with instructions and lists of required materials; more activities are available on the Internet. The material is ready to use; the teacher has only to download it and – if necessary – translate it from English. Furthermore, motivated teachers can be inspired by the material to develop their own similar activities for use in other science subjects (protection of the environment versus economic development, and a comparison of the pros and cons of different energy sources could make interesting cases).

The article could be used as the basis of a debate or discussion about:

1. What is included in a person's genetic profile?
2. Who should have access to a person's genetic profile and how should it be used?
3. How does personal genetic information affect our perception of ourselves and others?
4. Who owns and controls genetic data?
5. How are minority communities affected by genetic information?
6. What is the impact of genetic knowledge on people's lives and on society?

Additionally, the didactic material presented in the article (and on the related website) could be used as a model for developing similar material to investigate other 'hot' issues.

Michalis Hadjimarcou, Cyprus

www.scienceinschool.org/2007/issue5/c21science

Millar R (2006) Twenty First Century Science: insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education*. **28**: 1499-1521

Web references

w1 – UK Biobank aims to study how the health of 500 000 people is affected by their lifestyle, environment and genes. The purpose of this major project is to improve the prevention, diagnosis and treatment of a wide range of illnesses and to promote health: www.ukbiobank.ac.uk

w2 – To find out more about the Meet the Gene Machine project, read the script and download resources, see: www.scu.uwe.ac.uk/projects/events/meetthegenemachine.htm

w3 – To find out more about the Twenty First Century Science curriculum introduced in England and Wales, see: www.21stcenturyscience.org

w4 – *Student Review of the Science Curriculum: Major Findings*, a project conducted as part of Science Year and published in 2003, is available at: www.planet-science.com/sciteach/review/Findings.pdf

w5 – To learn more about the Science Communication Unit, see: www.science.uwe.ac.uk/sciencecommunication

w6 – To find out more about the University of the West of England, see: www.uwe.ac.uk

w7 – The Wellcome Trust is the world's largest medical research charity funding research into human and animal health. To find out more, see: www.wellcome.ac.uk

Laura Strieth, Karen Bultitude, Frank Burnet and Clare Wilkinson all work at the Science Communication Unit at the University of the West of England. Located in the School of Life Sciences, the Science Communication Unit was created in 1997 and is one of the most innovative and original science communication teams in the UK, specialising in taking science directly to the public. The Science Communication Unit has developed and been involved in a large variety of projects such as 'Walking with Robots', drawing together a network of key roboticists and science communicators to engage a range of audiences, and 'Zero Carbon City', a thought-provoking activity on the implications of climate change.

Well known within the UK and internationally, the core team travel extensively, working in numerous countries – including, most recently, Costa Rica, Hong Kong, Greece and Latvia. The Science Communication Unit has pioneered the use of interdisciplinary approaches to the communication of science to members of the public and comprises an interdisciplinary team with science, social science and science communication backgrounds.

Investigating the action of urease

The soya plant

Anna Lorenc from the Volvox project explains the importance of the enzyme urease and presents a protocol to demonstrate urease activity in the classroom.

Enzymes play an essential role in the metabolism of all organisms. They catalyse and control most biochemical reactions in our body – from the replication of genetic information (DNA polymerase) to digestion. Enzyme activity, however, is not always easy to visualise. This is a simple and cheap practical protocol to help teach the topic of enzyme activity in the classroom. All of the required materials are readily available and safe.

In this investigation, the enzyme urease from soya beans (*Glycine max*) breaks down urea to ammonia and carbon dioxide:

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

Ammonia (NH_3) solution has a high pH which can be detected using a simple pH indicator, such as that obtained from red cabbage. The ammonia produced by the reaction can also be detected by smell.

As urease is produced by a wide range of different organisms, this practical activity can be used in lessons on:

- The nitrogen cycle
- The influence of organisms on their environment
- The adaptation of animals to different diets.

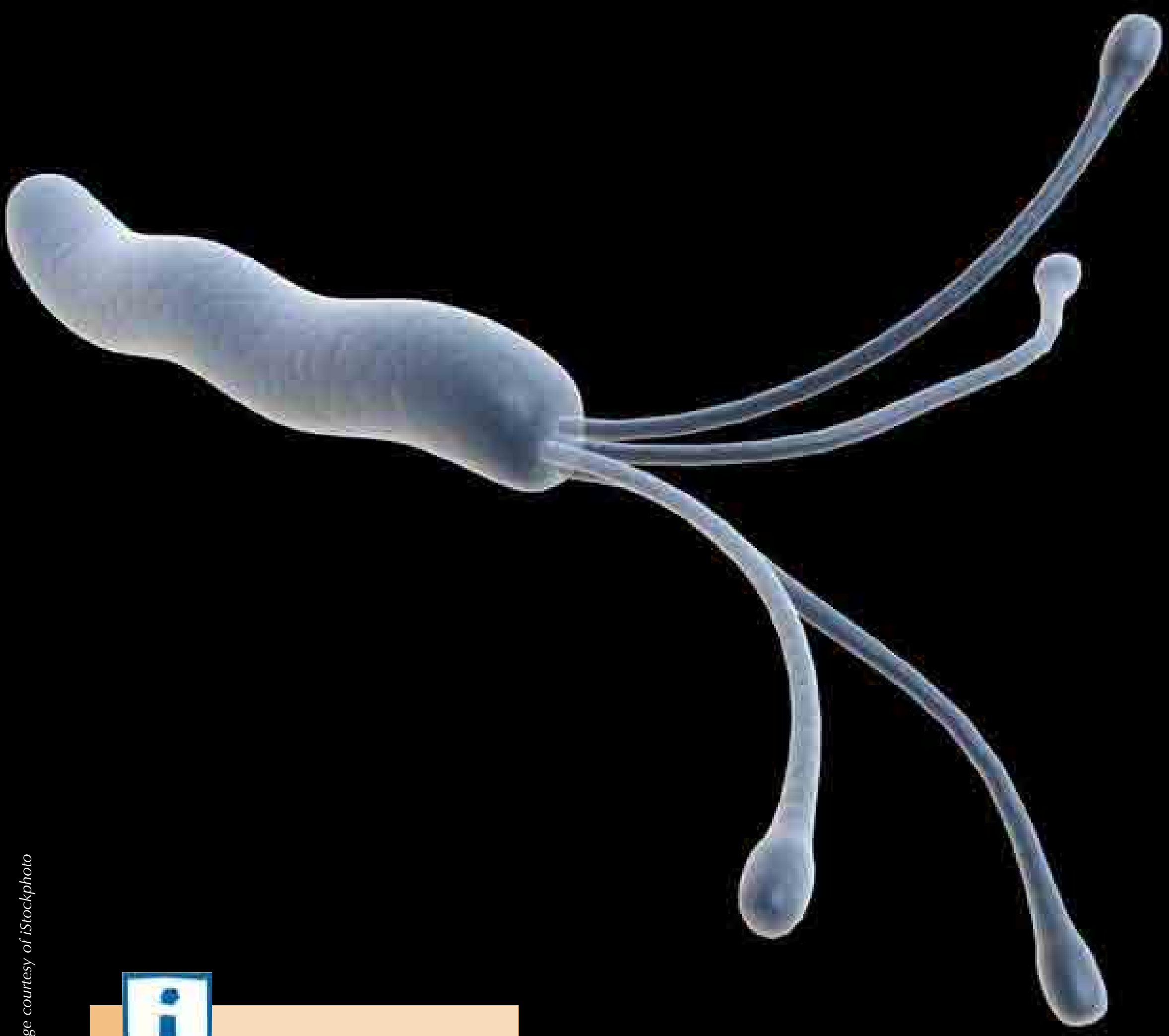


Image courtesy of iStockphoto

Helicobacter pylori

BACKGROUND

The Volvox project

The Volvox project team is a group of biology teachers and specialists from ten countries across the European Union, aiming to provide secondary-school biology teachers and others with proven laboratory protocols, simulations, classroom activities and numerous other educational resources. See www.eurovolvox.org

Background to the protocol

What is urea?

Every organism decomposes nucleic acids and proteins, generating nitrogenous waste because nucleic acids and proteins contain nitrogen. Mammals, amphibians and some invertebrates excrete nitrogenous waste as urea, which is produced in the liver. Urea is an especially good compound for disposing of nitrogen because it is water-soluble and less toxic than ammonia – the excretory produce of fish, for example. Human urine contains 2% urea.

Urea was also the first organic compound ever synthesised. In 1828, Friedrich Wöhler synthesised urea from inorganic compounds (lead cyanate and ammonium hydroxide). This was a landmark achievement: until then only living organisms were believed to be able to produce organic compounds, and these compounds were thought to be special and require a 'vital force' to make them. Wöhler bridged the gap between the living and non-living worlds. He didn't receive a Nobel Prize for his discovery though, because the Nobel Prize did not exist at that time. Today,

Image courtesy of iStockphoto

Soya beans

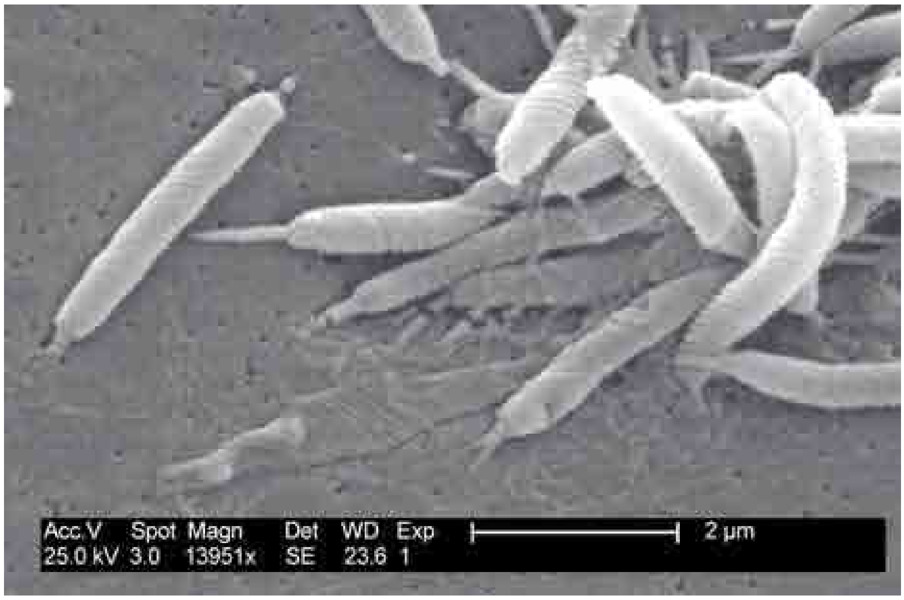


Image courtesy of CDC/Dr. Patricia Fields, Dr. Collette Fitzgerald; image source: Wikimedia Commons

Helicobacter pylori

urea is synthesised in vast quantities: it is used to make plastics and as a cheap nitrogenous fertiliser.

What is urease?

Urease catalyses the hydrolysis of urea to carbon dioxide and ammonia. It is found mainly in seeds, micro-organisms and invertebrates. In plants, urease is a hexamer – it consists of six identical chains – and is located in the cytoplasm. In bacteria, it consists of either two or three different subunits. For activation, urease needs to bind two nickel ions per subunit.

How did urease become famous?

Urease from jack beans (*Canavalia ensiformis*) was the first enzyme ever purified and crystallised, an achievement of James B. Sumner in 1926, at a time when most scientists believed that it was impossible to crystallise enzymes. This earned Sumner the 1946 Nobel Prize in Chemistry. Today, crystallisation of proteins helps scientists to discover their structure and determine how they work. This knowledge permits the design of substances that interfere with enzyme action, such as the anti-AIDS drugs which inhibit the action of HIV's enzymes or recent developments towards a possible rabies treatment (Ainsworth, 2008).

Why is there urease in soya beans?

The role of urease in soya beans is not entirely clear, although it is possible to speculate. Soya leaves also contain urease, but here, the enzyme is a thousand times less active than in the beans. It is known that the leaf enzyme helps to recycle nitrogen from proteins (the proteins are broken down to urea). In the beans, urease does the same when the beans germinate. The resulting ammonia from the reaction may also protect the plant cells from pathogens – it seems that the plant enzyme itself is an insecticide.

Where else can urease be found?

Many species of bacteria produce urease, including *Helicobacter pylori*, the bacterium responsible for stomach ulcers. By doing this, *H. pylori* raises the pH of the gastric juice from about pH 3 to pH 7, the optimal pH for its growth. A commercially available test for *H. pylori* checks for the presence of urease in breath, and is used as a tool for diagnosing stomach ulcers.

Ruminants (such as cows and sheep) have cellulose-digesting bacteria in their rumen – the first compartment of their stomachs – to help them digest their plant diet. Ruminants excrete urea into this part of the stomach, the urea making an excellent source of nitrogen for bacterial growth. To take up the nitrogen, the bacteria secrete urease to break down the urea. Eventually, the animals digest the bacterial mass.

Is urease in soya beans harmful to humans?

Urease is not harmful. However, raw soya beans contain other compounds which are unhealthy. For example, there is a protein inhibitor in raw soya beans which prevents the digestive enzyme trypsin from working and makes raw soya beans inedible. The presence of the inhibitor is not easy to detect, but fortunately, it has a similar level of heat intolerance to urease – both are inactivated by heating. Therefore, to ensure that the inhibitor is inactivated, commercial preparations of soya beans (soya flour or foods that contain soya, such as

Images courtesy of Dean Madden

tempe and tofu) are tested for urease activity – in a very similar way to the test described here. If no urease activity can be detected, the inhibitor has presumably also been inactivated.

Urease in the nitrogen cycle

Nitrogen is a crucial element for plant growth, but most plants can only use it in the form of ammonium or nitrate. Only legumes (thanks to the bacteria they live in symbiosis with) and cyanobacteria can use elemental nitrogen from the air.

Many animals excrete urea in their urine. Soil micro-organisms feed on animal urine, producing urease to transform the urea to ammonia, which is then readily accessible to plants. This is part of the nitrogen cycle, the process by which the nitrogen from proteins and other compounds is constantly recycled.

The protocol

This protocol allows students to detect the activity of a plant enzyme in seeds. When the substrate (urea) is present, urease breaks it down into carbon dioxide and ammonia. Dissolved in water, ammonia raises pH, an effect seen with the red cabbage pH indicator. In the experiment, students observe that to obtain the product (ammonia), both a substrate (urea) and an enzyme (urease) are needed. They observe that the enzyme activity raises the pH.

Red cabbage extract – a great pH indicator

In this protocol, we use red cabbage extract as a pH indicator. It contains anthocyanins. The structure and colour (when in solution) of these compounds are pH-sensitive. At pH 7, the solution is violet/blue; in the acidic range it turns red. When the pH rises above 7 and the solution is more alkaline, the extract turns green. These colour changes are reversible – just check what happens when you add citric acid and baking soda (sodium bicarbonate) one after another.

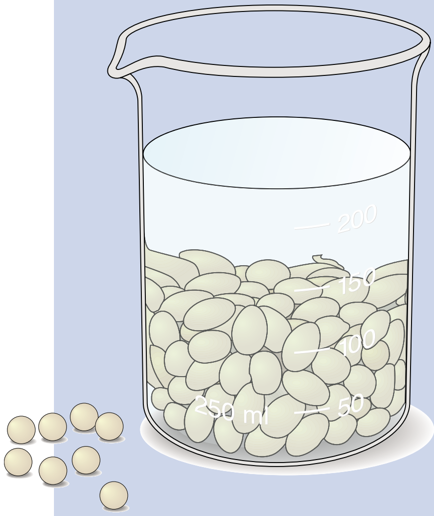
Materials and equipment

For each student or group of students:

- 20 ml 10% solution of fertiliser urea (a solid fertiliser made of pure urea)
- 5 ml 10% solution of citric acid (or other low-pH solution)
- 5 ml 10% solution of sodium bicarbonate ($NaHCO_3$) (or other high-pH solution)
- 40 ml red cabbage indicator, prepared as described below
- 10 ml soya bean extract, prepared as described below (from 1 g of dried soya beans)

- 10 ml distilled water
- Pasteur pipettes or a plastic drinking straw, for transferring the solutions
- 6 test tubes and a test tube rack.

For preparing soya extract and red cabbage indicator, a blender and boiling water are needed, as well as coffee filter paper and a funnel.



Timing

The experiment can be completed in 30 minutes.

The soya bean suspension and red cabbage extract can be made in advance, or their preparation can be demonstrated during the lesson. This takes only ten minutes, but note that the soya beans must be soaked in water for *at least* one hour before the lesson.

The reaction between soya urease and urea also takes about ten minutes.

Preparation

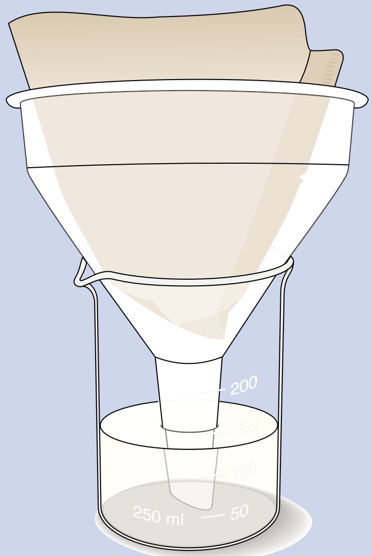
Red cabbage indicator

Cut two large red cabbage leaves into strips and place them in a heat-resistant container such as a beaker. Pour on 200 ml of freshly boiled water, soaking the leaves completely.

1. After 5 min, decant the liquid and leave it to cool.
2. Throw the leaves away.

Soya bean extract containing urease

1. Soak the soya beans in water for at least 1 h (preferably overnight).
2. Blend the soaked soya beans in a food blender with about 10 ml of water per gram of dry soya (the water from soaking the beans can be used) until the mixture is smooth (for about 5 min).
3. Filter the soya purée through filter paper in a funnel.
4. Collect and keep the filtrate, which contains urease.



Images courtesy of Dean Madden

Investigation

The volumes given below are for standard (~10 ml) glass test tubes.

First, ask the students to check how pH influences the colour of the red cabbage extract.

- Pour 3 ml of red cabbage indicator into each of three tubes.
- Add 2 drops of citric acid solution to the first test tube. Mix and observe the colour change. Rinse the pipette with water after the addition of each component.
- Add 2 drops of sodium bicarbonate solution to the

second test tube. Mix and observe the colour change.

- Add 2 drops of distilled water to the third test tube. Mix and observe the colour change.
- Compare and note the colours of the solutions in all three test tubes. Put the tubes aside to act as a reference.

Next, investigate the effect of urease from soya beans on urea.

- Add 2 ml of red cabbage indicator to each of three fresh tubes.
- Mix 2 ml of urea solution each into two of these tubes. Note the colour.
- Add 2 ml of the soya suspension each to the remaining tube and to one of the tubes with urea solution.
- Compare the colours and odours of the mixtures in all tubes. Repeat this observation after 3 min.

REVIEW

Enzyme activity is frequently investigated using the action of amylase on starch, which links to food and nutrition. The simple method presented here makes a good change that links to the nitrogen cycle, which can be a difficult concept for students to grasp. The idea of using a natural indicator that students can isolate themselves makes the lesson more fun. Also, students can smell the product of the reaction due to the release of ammonia! Factors affecting enzyme activity could be investigated as group work and this could be discussed in a plenary session.

The article could be used to test comprehension by asking questions such as:

- Why are the cabbage leaves placed in boiling water?
- What colour will the indicator turn if ammonia is present in the solution?
- Describe what you would see if you used boiled soya bean extract and explain why this happens.
- State which of the reaction tubes is the 'control' experiment. Explain what this means and what you would expect to observe in this tube.

Shelley Goodman, UK

Image courtesy of Alamy

Interpretation

Red cabbage indicator turns green with increasing pH. This colour change, along with an ammonia odour, can be detected in a tube containing both the enzyme and its substrate. In tubes containing either enzyme only or substrate only, the pH stays stable, so the red cabbage indicator stays violet.

Safety

Approximately 1% of children may be allergic to soya bean extract (see McGee, 2004). Teachers are advised to check that none of their students is affected before attempting this protocol.

Further investigations

A follow-up experiment could be conducted to investigate factors influencing enzyme activity (such as temperature, pH and the concentrations of enzyme, substrate and product).

Acknowledgements

This practical protocol was developed by Anna Lorenc for the Volvox project, which is funded by the Sixth Framework Programme of the European Commission.

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McGee H (2004) On food and cooking. London, UK: Hodder & Stoughton. ISBN: 0340831499

Resources

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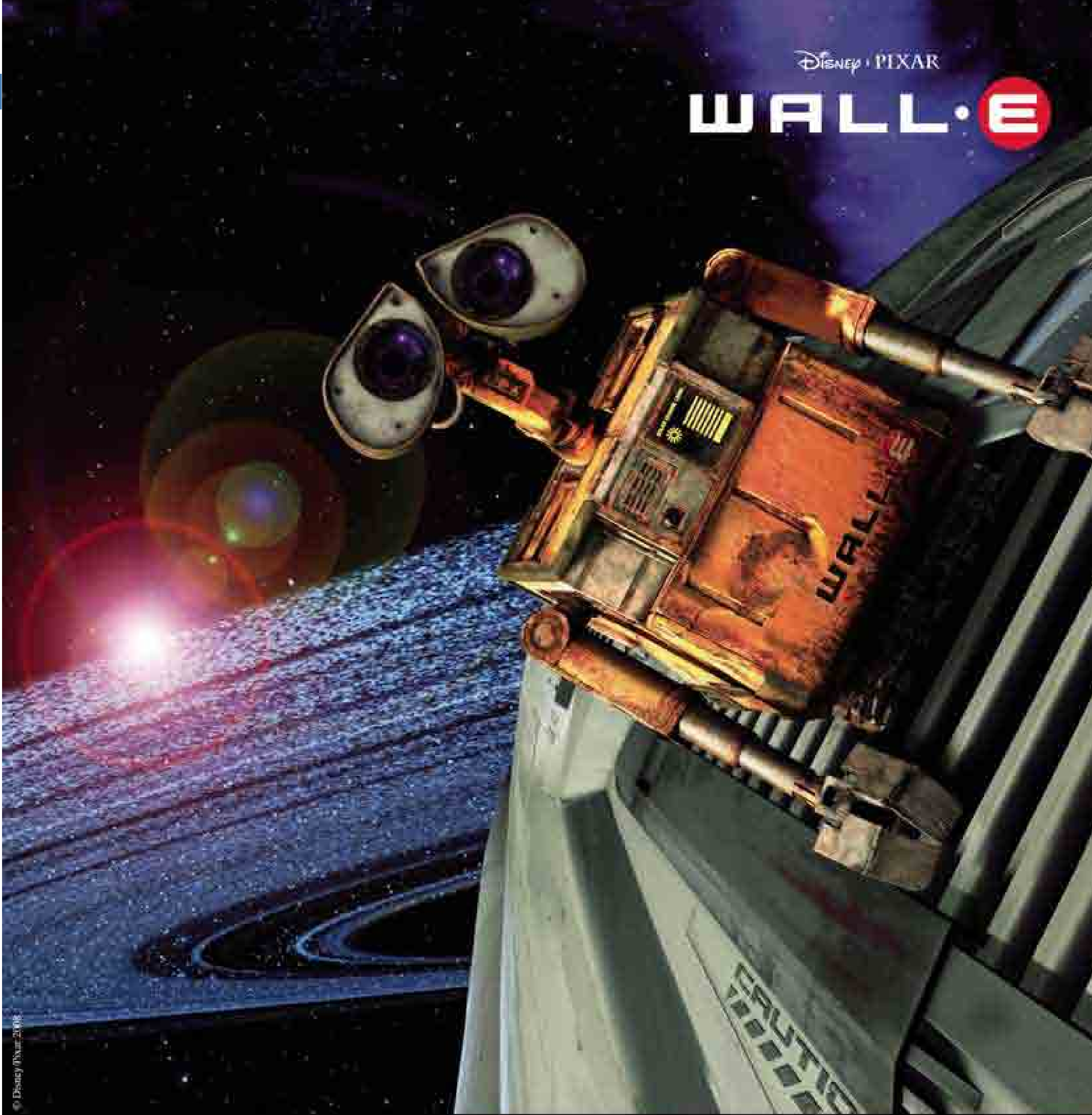

Disney · PIXAR
WALL·E
WALL·E
CAUTION
© Disney Pixar 2008

Kristina (left) and Julia demonstrate that a dill pickle will emit visible light when a standard alternating current is passed through it

Fun physics in school: students perform for students

Herbi Dreiner and **Tobias Strehlau** describe how a university physics show inspired a secondary-school teacher and his students to perform their own school physics show. Why not try it in your school?

The inspiration – at university

The auditorium of the Amos Comenius Gymnasium in Bonn, Germany, is packed with 400 teenagers. It is completely dark; Lena creates methane-filled soap bubbles, and her partner Stefanie ignites the rising bubbles with a gas flame. The result is a spectacular burning gas cloud, which lights up the whole stage and the beaming faces of the audience. It is the last of 18 exciting experiments that 16 high-school students (aged 15-18) have presented to their fellow students in a 75-minute physics show.

★★★

This project was initiated by Werner Urff, physics teacher at the high school, and Herbi Dreiner, a physics professor at the University of Bonn. Every year for the past six years, Dreiner and his second-year university physics students have presented a new 'Physikshow' at the university[w1]. In these two-hour shows, university students demonstrate and explain funny, fascinating physics experiments to an audience consisting largely of children and teenagers aged 10 and older.

Like most German university physics departments, the Bonn department has a collection of experiments suitable for lecture demonstration: typically large and impressive, they reveal particular physical phenomena. Some of the Physikshow experiments are taken from this collection; others are invented and built by the physics students themselves. Some are large and very spectacular, but special small effects can also be entertaining – for example when combined with music. They all help to convey one message: physics is fun. Fun is also what the university students are there for, since there is no grading or other curricular advantage for them. They enjoy physics and demonstrate their enthusiasm to their audiences with each performance.

The implementation – at school

After one show, Urff and his high-school students thought: "Wouldn't it be great if we presented a show at our own school?" Dreiner and eight university students, all Physikshow veterans, supported them in the preparation. Two months before the school show, the high-school students – all volunteers – assembled into pairs, each with a university student to help, and chose experiments from the demonstration pool at the university. Of special interest were experiments for which the school does not have the equipment, because it is too expensive or too large to store: this was a great chance to borrow it from

Lena and Stefanie demonstrate an aluminium ship which floats on invisible sulphur hexafluoride

the university. These were the experiments they were going to present and explain in their own school show.

Before the rehearsals began at school, the teenagers visited the university to try out their experiments with the help of their Physikshow mentors. On each of the following four afternoons, the school students and mentors met in the school auditorium to build and arrange the equipment, rehearse the experiments, devise comprehensible explanations of the phenomena and find the best camera angles for the big-screen projection. The camera work was done by the school's student stage crew, which takes care of lighting and sound for school plays.

Although this was not really enough rehearsal time, the final result was amazing. The school students showed tremendous confidence and – most importantly – had loads of fun. Lena and Stefanie probably embody this the best. At the beginning, they did not seem very motivated or interested. However, during the rehearsals, they emerged as leaders of the group and displayed a great will for perfection in performing their experiments. After the show their opinions had completely changed: "We are so glad that we took part. It is so much fun. Let's do it again!"

Half of the group were girls, none of whom had been especially interested in school physics before. Our impression from this group of high-school students was that the show was their first opportunity to be creative in physics and thus they were very happy to get more involved in the subject.

Do it yourself

If you want to initiate a project like this, your primary motivation should be getting the message across that physics is extremely enjoyable and entertaining, both for the performing students and for the audience. Though the show demanded a lot of time and work from both the high-school and university students, it was definitely worth it: the high-school students not only learned some physics, but also learned to organise themselves as a team and to perform confidently in front of hundreds of people. Through all of their effort and dedication, this had become their show: they were very enthusiastic and this enthusiasm carried over to their fellow high-school students in the audience.

Perhaps not all schools have the chance to work with a nearby university on such a project. But half the fun is actually finding and building experiments yourself. This requires a lot of preparation time, but is also

Image courtesy of Herbi Dreiner

Philipp makes sound waves visible with a long pipe filled with gas, which is perforated with a series of holes on top

Image courtesy of Herbi Dreiner

The kids in the audience try to 'catch' the smoke vortices emanating from the smoke box

very rewarding. There are endless ideas for experiments on the Internet[w2] and in books – or just play around, for example placing things in a microwave (under supervision) to see what is fun.

Three of our most successful experiments were very cheap:

1. The methane soap bubbles described above. We took methane from a gas bottle and hooked it up to a large cone-shaped 'soap bubble former' from a toy shop. We dunked this in a standard soap bubble solution and thus made large bubbles. The soap bubbles rise because methane is lighter than air, and this also makes it easier to ignite them. They burn because methane is flammable.
2. A 25 kg steel ball pendulum hung from the ceiling. We put a teacher on stage and released the pendulum just in front of her nose. The camera was focused on her frightened face as the ball swung back towards her at high speed. Of course it did not reach her face because of the conservation of energy, but it approached so fast that even the most hardened physicist might lose faith in the fundamental laws of physics.
3. Smoke rings. We had a large plywood box, 1.4 m wide and deep, with a circular opening of 40 cm diameter on one side. The opposite side was open and covered with plastic foil. We filled the box with stage smoke and banged the foil back. This released a large stable smoke ring, which floated right across the auditorium. With a spotlight in a dark hall this was a spectacular effect. It also demonstrates that vortices are surprisingly stable.

Safety note: Ensure that the proposed procedures are in line with commonly adopted risk assessments.

Good experiments are often more a question of presentation than money. Music is also a helpful tool. If money is a problem, though, perhaps the parents and school board could be asked to provide modest financial assistance for materials. After all, such events not only motivate the students but can also attract external visitors and media to a school.

Our success in getting high-school students involved is mirrored in a project at the Gesamtschule Hennef, near Bonn. Six years ago, Ingo Wentz, a physics teacher, started the 'Physikusse'[w3] with a group of his students. They meet weekly and work on different physics projects, such as building demonstration experiments themselves. Once a year they participate in the 'Freestyle Physics' competition[w4] at the University of Duisburg, Germany, where high-school students must meet challenges such as building their own hovercraft.

The Physikusse have also planned and performed several physics shows using simple materials, starting with 20-minute performances for parents and fellow students on the school's open days and also at an open day at the German Physical Society. Wentz himself talks of 'low-cost physics'. He has also had some success in acquiring more expensive materials: for example, he persuaded a local company to donate liquid nitrogen whenever the group needs it. The Physikusse receive modest financial support from the school board and Wentz gets a slight reduction in his teaching load to allow him to organise the activities.

In summary, a physics performance by students for fellow students is a great way to get children of all ages motivated and attracted to physics. It is rewarding for the audience, the teacher and most of all for the participating students. We would be happy to advise or discuss with people who are thinking of setting up something similar.

Web references

w1 – More on the Bonn University Physikshow can be found at: http://de.arxiv.org/abs/physics/0701344 and http://cerncourier.com/cws/article/cern/31198

w2 – For inspiration for experiments, see: http://physikshow.uni-bonn.de/index.php?job=Versuche

w3 – For more information about the 'Physikusse' project in Hennef, see: www.physikusse.de

w4 – For more information about Freestyle Physics, see: www.freestyle-physics.de

Resources

A very good book with inspirational experiments to be performed is

Sprott JC (2006) *Physics Demonstrations: A Sourcebook for Teachers of Physics.* Madison, WI, USA: University of Wisconsin Press

Part of it can even be read online: http://sprott.physics.wisc.edu/demobook/intro.htm

Another good book is:

Walker J (1975) *The Flying Circus of Physics*. New York, NY, USA: Wiley

The US journal 'The Physics Teacher' regularly has good experiments. See: http://scitation.aip.org/tpt/

REVIEW

In schools and colleges, the fun, showy side of practical work in physics can get buried deeper and deeper under dry theory as students progress up the years. The authors give us encouragement to dust down that apparatus languishing in the physics preparation room or to cajole neighbouring college or university physics departments to come in and 'show their stuff'. The primary motivation for such a show is the excitement of the demonstrations and conveying enthusiasm for the subject (with any improved appreciation of the concepts involved being a welcome bonus, not to mention a successful event being great public relations for the school physics department!).

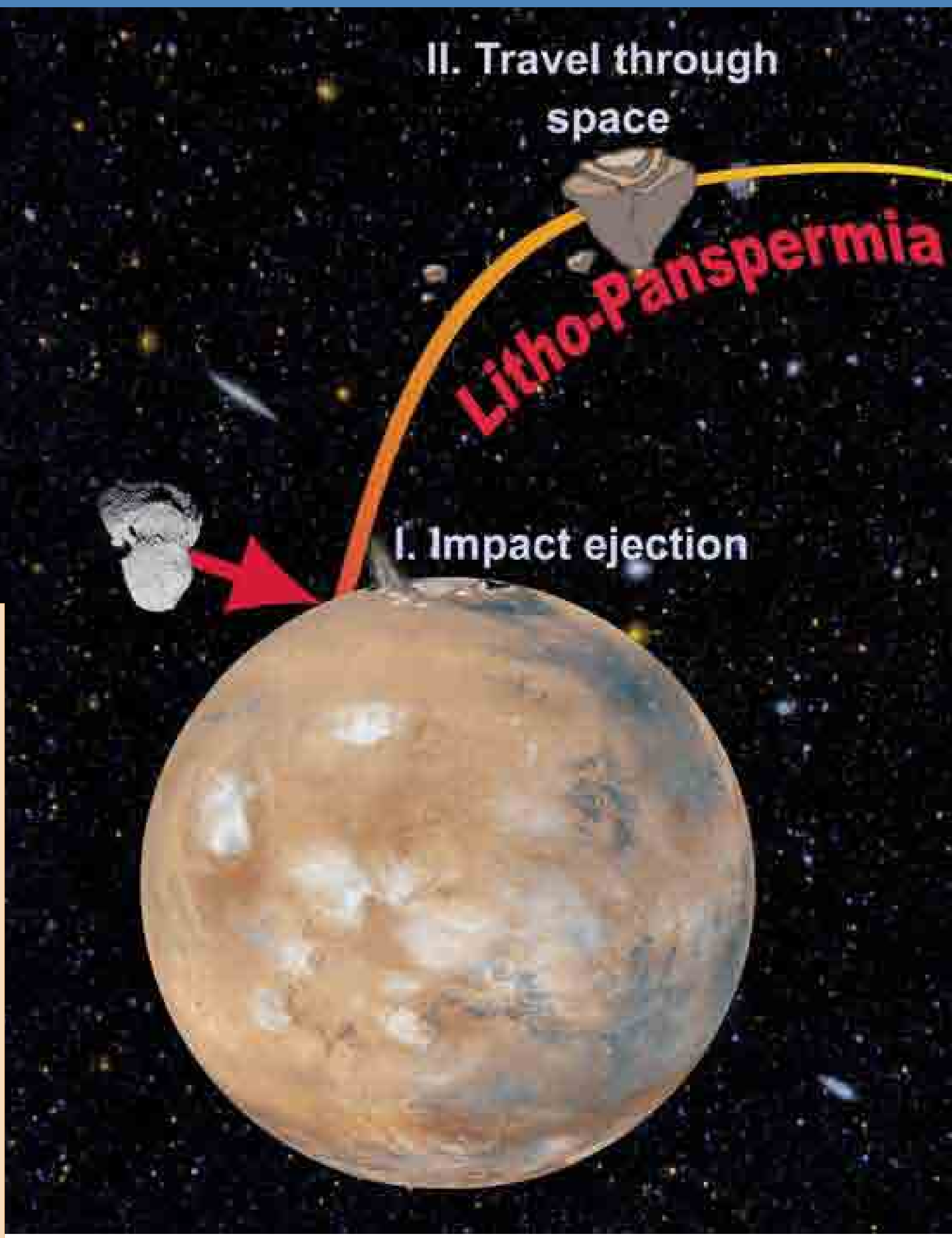
In most UK schools, the closest we tend to get to this kind of showmanship is on open evenings, when parents of prospective pupils tour the school. Running a science show, with genuine pupil involvement as demonstrator-explainers, takes this to the next level, with the benefit of a captive audience. The slightly theatrical nature can encourage the participation of girls, too, and anyone too shy to present or explain a demonstration can still be a useful team player by helping with lighting or sound. It could be just the thing to enable your physics students to practise their communication skills in a meaningful way.

Ian Francis, UK

Herbi Dreiner (dreiner@th.physik.uni-bonn.de) is a particle theorist at the University of Bonn, Germany. Tobias Strehlau is a physics student, also at the University of Bonn.

The entire group of high-school students on stage at the end of the performance. On the right are two university students and Herbi Dreiner

Image courtesy of Herbi Dreiner



BACKGROUND

Glossary

Asteroid: One of the numerous small rocky bodies in orbit around the Sun. Most asteroids reside in the 'main belt' between Mars and Jupiter, but some have orbits that cross Earth's orbit and could strike its surface.

Comet: One of the primitive icy bodies originating in the outer reaches of the Solar System that are in elliptical orbits around the Sun. Near the Sun, icy material vaporises and streams off the comet, forming a glowing tail.

Meteorite: An extraterrestrial rock that has fallen to Earth. Most meteorites are pieces of asteroids and are made of stone, stone and iron, or iron.

Meteoroid: A small solid body moving through interplanetary space. After falling to Earth it is called a meteorite.

On 7 August 1996, scientists at NASA announced they had identified structures that looked like microscopic fossil bacteria in the Martian meteorite ALH84001, found in Allan Hills, Antarctica. Although scientists disagree about the significance of the Allan Hills meteorite, the question remains: was there life on Mars?

When comets and asteroids strike planets, they can dislodge rock fragments that are catapulted into space and – like the Allan Hills meteorite – sometimes land on other planets as meteorites (see glossary). This has caused much speculation. Could the first life forms have arisen not on Earth but on Mars, or perhaps another distant planet? If so, could meteorites then have transported life to Earth?

In 2007, three other postgraduate students – Ralf Moeller, Thomas Berger and Jean-Pierre de Vera – and I decided to investigate this idea, known as the lithopanspermia theory (see image above), in three steps:

Mars image courtesy of NASA; Earth image courtesy of the Deutsches Zentrum für Luft- und Raumfahrt

Is there anybody out there? An ark of life

An enormous meteorite impact and then a rocky flight from Mars. Is that how life appeared on Earth? **Cornelia Meyer** takes us on a space trip through the litho-panspermia theory and describes how she is putting it to the test with the help of student colleagues.

1. The ejection of living organisms into space, on board a meteorite.
2. The effect of space travel on living organisms.
3. Their survival as they enter Earth's atmosphere and land.

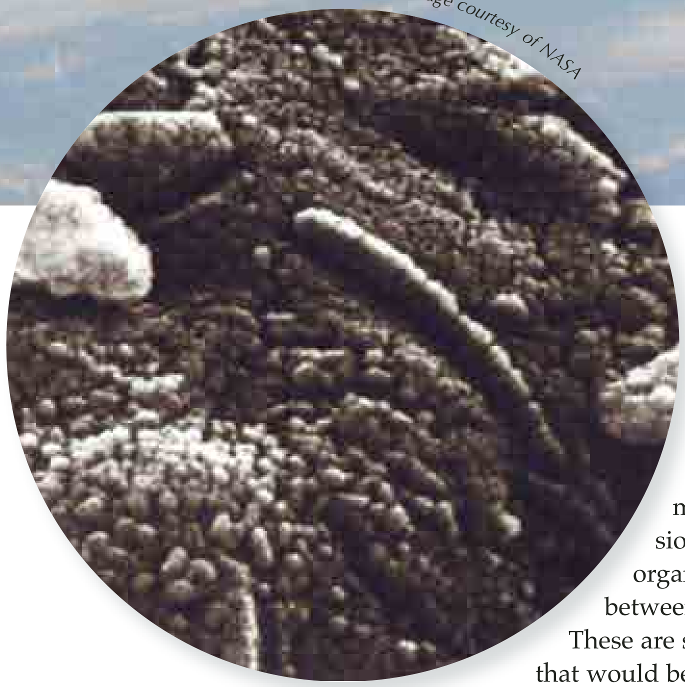
1. The journey begins

As part of our Masters and PhD theses, we investigated the feasibility of the first step: the ejection phase, in which living material is launched into space by a meteorite impact (Horneck et al, 2008; Stöffler et al, 2007). To simulate the event, we took two slices of rock thought to be similar to the rocks on Mars, put a layer of micro-organisms between them, placed this 'sandwich' in an iron cylinder and blasted it with TNT.

We had good reasons for using micro-organisms in this experiment. On Earth, only microbes are known to survive in extremely hostile environments, so they were more likely to endure the experiment. Also, as simple organisms, they may be similar to the putative first life forms on Mars. The particular micro-organisms chosen for the experiment were bacterial spores, cyanobacteria and lichens that live inside or on rocks, and are known to survive simulated space conditions.

We also chose the rocks carefully. To discover whether a meteorite originates from Mars, its composition is compared with that of rocks studied on the surface of Mars. The most frequent Martian meteorites found on Earth are known as basaltic Shergottites, and are formed by volcanic activity. For our experiment,

Image courtesy of NASA

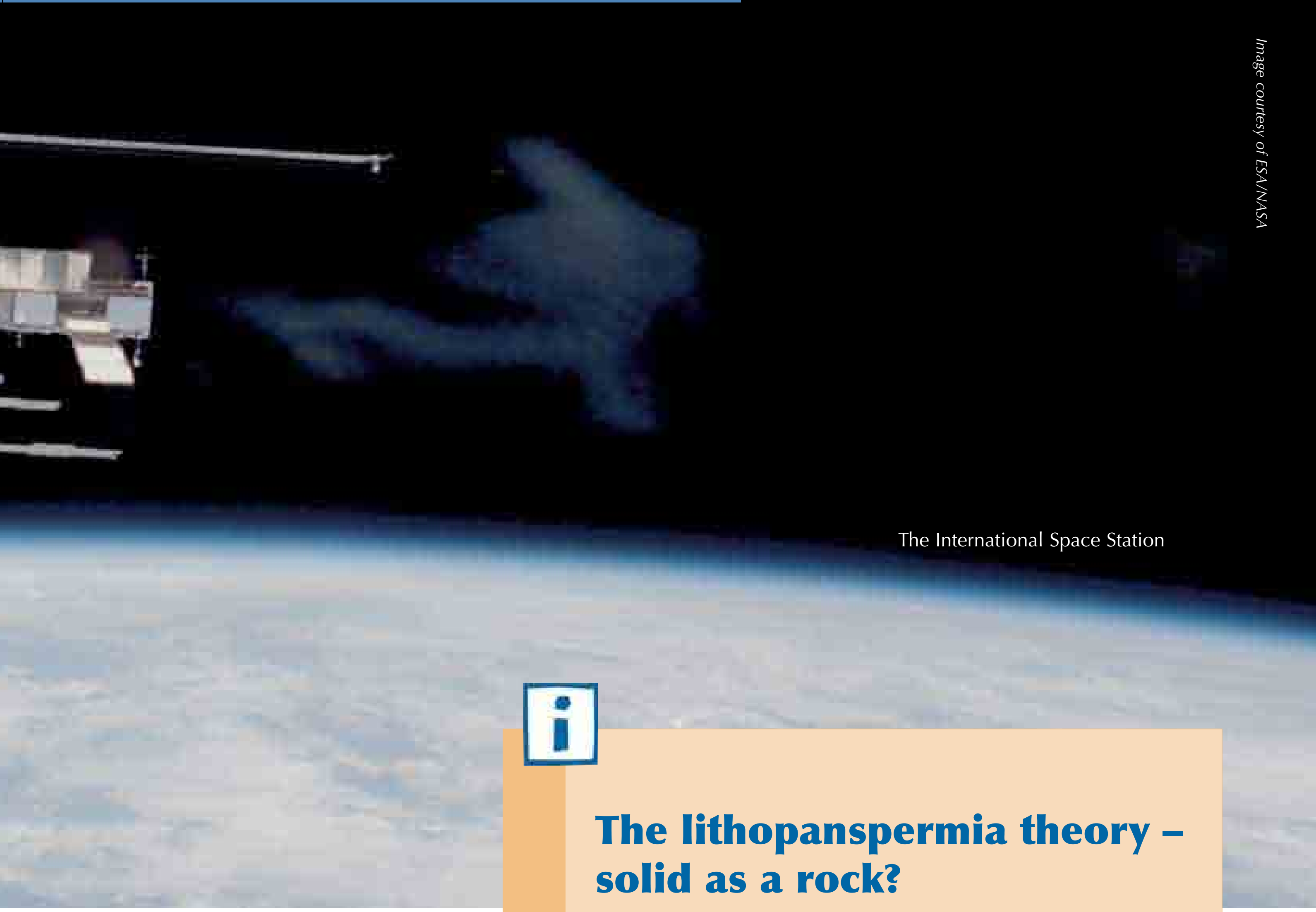


High-resolution scanning electron microscope image showing an unusual tube-like structural form that is less than 1/100th the width of a human hair in size, possibly representing the remains of extraterrestrial bacteria, found in meteorite ALH84001, a meteorite believed to be of Martian origin

therefore, we used basalt: readily available on Earth and similar to Martian rock.

In repeated experiments, the TNT explosions exposed the micro-organisms to pressures of between 50 000 and 500 000 bar. These are similar to the pressures that would be generated by meteorite impacts on Mars, causing craters of more than 75 km in diameter and launching Martian rocks into space. The compression of the blast also exposed the micro-organisms to temperatures of up to 1000 °C. Although such conditions might be expected to destroy all life, at 400 000 bar (400 000 times normal air pressure), 0.02% of the micro-organisms survived.

Today, temperatures on Mars range from -143 °C at the poles to +27 °C at the equator. Although early Mars would have been warmer than it is today, it would have cooled down faster than Earth because it lost its atmosphere. This means that by the time of the proposed transfer of life from Mars to Earth (up to 20 million years ago), Mars would already have reached the low temperatures that exist there today. Therefore, in a second experiment to better reflect conditions on Mars, we used dry ice (solid carbon dioxide) to cool the apparatus to -80°C before blasting it, and found that some of the micro-organisms survived even at 500 000 bar. In the previous, uncooled, experiment, none had survived at that pressure.



The International Space Station

Image courtesy of ESA/NASA

During the experiments, the micro-organisms were exposed to the high temperatures and pressures only for a few microseconds, as would happen with a real meteorite impact on Mars. This may have been the key to their survival. So, the first part of the lithopanspermia theory appears to be plausible: organisms on rocks could survive the launch into space.

2. Space travel: the ESA SUCCESS student contest

Next, we decided to compete for the opportunity to investigate step two of the lithopanspermia theory: could living organisms survive the extreme cold, cosmic radiation and vacuum during a long space journey? In the SUCCESS student contest[w1], organised by the European Space

BACKGROUND

The lithopanspermia theory – solid as a rock?

The lithopanspermia theory (from the Greek: lithos = rock, pan = all, sperma = seed) was proposed in 1903 by the Swedish scientist Svante Arrhenius. Although the idea is not widely accepted, there is some evidence to support it:

- The existence of lunar and Martian meteorites on Earth
- The presence of organic material and (possibly) microbial fossils on the Allan Hills meteorite (see image on page 52)
- The fact that large comets or asteroids hitting a planet launch pieces of rock with enough velocity to overcome gravity and leave the planet (as meteoroids)
- The ability of bacterial spores to survive the shock waves caused by such an impact
- The UV-resistance of micro-organisms at the low temperatures found in space
- The survival for millions of years, in amber or salt, of bacterial spores
- The survival of bacterial spores in space for up to six years
- The palaeogeochemical evidence for ancient microbial ecosystems on Earth, leaving only about 400 million years for the evolution from simple precursor molecules to cellular life.

BACKGROUND

The ESA SUCCESS contest

SUCCESS, the Space station Utilisation Contest Calls for European Student initiativeS, organised by ESA[w1], aims to make today's students into tomorrow's users of the International Space Station (ISS). European university students up to Master's level or equivalent, from any discipline, are invited to propose an experiment to fly on board the ISS.

The first prize is a one-year internship at ESA's space research and technology centre ESTEC in the Netherlands. The winner will be able to work on their experiment, to enable it to fly to the ISS.

The contest is currently closed for new contestants. A new SUCCESS Student Contest is foreseen for 2010.

Image courtesy of Cornelia Meyer

Cornelia Meyer, Ralf Moeller and Jean-Pierre de Vera

Agency (ESA), we were offered the opportunity to fly an experiment on board the International Space Station (ISS) in November 2009.

Since the 1980s, several experiments have shown that micro-organisms are capable of surviving in space (e.g. Mileikowsky et al, 2000). However the micro-organisms in those tests either were shielded from radiation by aluminium, or only spent a few days in space. So how long could they survive in space? We want to use the ISS for a more realistic investigation into the effect of space conditions on living organisms.

We suggested building an artificial meteorite packed with micro-organisms as well as sensors to measure cosmic rays and temperature. A piece of basaltic rock will be cut into eight slices, with holes for the micro-organisms and sensors. The holes will be sealed with rock, and the slices fitted back together into an airtight structure. The artificial meteorite will then be transported to the ISS, mounted onto an aluminium platform outside the Station and exposed to space conditions for six months. As a control, a second artificial meteorite will remain on Earth.

Once the meteorite returns to Earth, the biologists Ralf and Jean-Pierre will determine the survival rate of the micro-organisms and look for physiological changes induced by the conditions in space. As the mineralogist on the team, I will investigate the effects of space weathering on the artificial meteorite. Space weathering is a blanket term for processes, including cosmic radiation, solar winds and meteorite bombardment, that act on bodies in the harsh space environment. We will also compare the physical properties of the artificial meteorite with those of the rock that remained on Earth.

Besides providing evidence that may support the lithopanspermia theory, these results could supply information about the effect of space weathering on the optical properties of rock. These properties are important for the observation of asteroids, as optical spectroscopy is used to determine their elemental composition. Knowing more about the effects of space weathering, therefore, could help scientists to determine whether meteorites found on Earth and asteroids observed in space come from the same parent bodies.

3. A new experiment? The soft landing

Even if first two parts of the lithopanspermia theory are plausible – micro-organisms could survive take-off from their home planet and a lengthy journey through space – could they survive on another planet? Astrobiologists at the Deutsches Zentrum für Luft- und Raumfahrt have suggested that Earth micro-organisms could survive for some time on Mars[w2]. This suggests that Martian life forms might also be able to survive on Earth, assuming they could withstand the impact. So far, however, we know very little about what would happen if a meteorite carrying living organisms landed on Earth. We do, however, have information that enables us to speculate.

When objects enter Earth's atmosphere at high speed, their surfaces are exposed to very high temperatures

Image courtesy of Cornelia Meyer

Panels representing experiments on top of the ISS, similar to the artificial meteorite planned

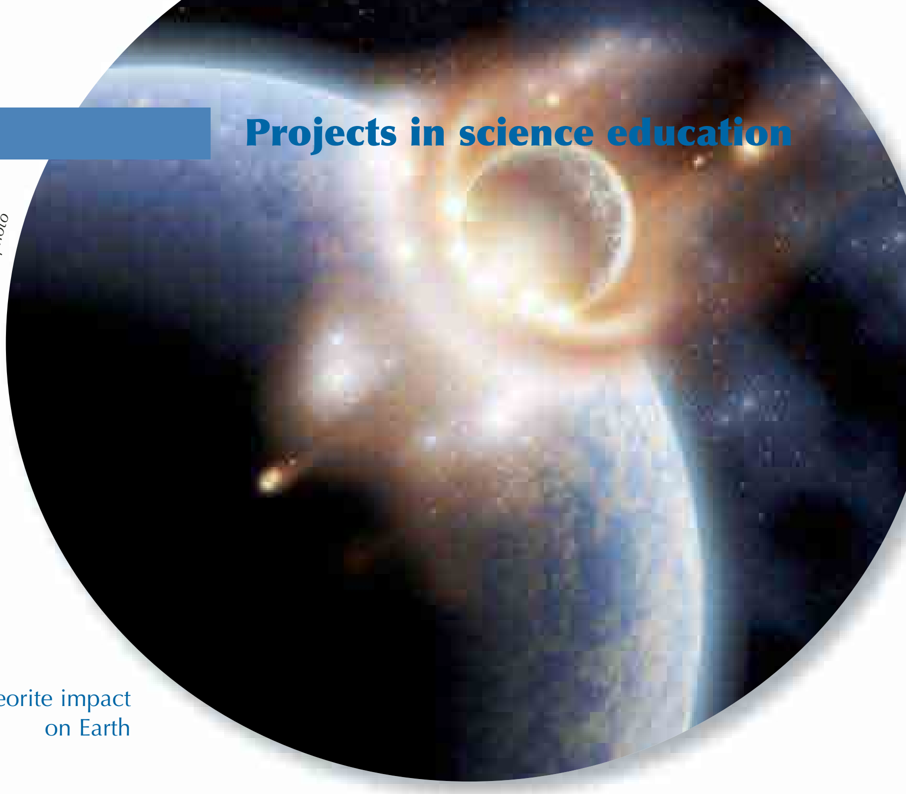


Image courtesy of iStockphoto

A meteorite impact on Earth

due to friction. However, although temperatures in the outer layers of the meteorite are high enough to melt – or even vaporise – the rock, the inside of the meteorite remains closer to the -273 °C (0 K) found in space.

Very often, meteorites break up when they hit the ground. If any organisms survived inside the meteorite – protected from the very high temperatures at the surface – they would thus be released and could begin to colonise Earth. They would experience a temperature shock, coming from -273 °C in the meteorite core to the ambient Earth temperature, but micro-organisms are known to be able to survive rapid changes in temperature.

The evidence for lithopanspermia?

Although micro-organisms *could* have survived all three steps described in the lithopanspermia theory, this is not evidence that life on Earth has an extraterrestrial origin. Above all, we don't actually know whether life exists beyond our planet – but the search for extraterrestrial life continues. And speculation about our origins continues too.

References

Horneck G et al (2008) Microbial rock inhabitants survive impact and ejection from host planet: first phase of lithopanspermia experimentally tested. *Astrobiology* **8**: 17-44

Mileikowsky C et al (2000) Natural transfer of viable microbes in space; Part 1: From Mars to Earth and Earth to Mars. *Icarus* **145**: 391-427

Stöffler D et al (2007) Experimental evidence for the potential impact ejection of viable micro-organisms from Mars and Mars-like planets. *Icarus* **186**: 585-588

Web references

w1 – Details on the ESA SUCCESS student competition can be found here: www.esa.int/esaHS/SEMU9TGHZTD_education_0.html

w2 – For more information about the Deutsches Zentrum für Luft- und Raumfahrt, see: www.dlr.de/en

For details of their work on whether micro-organisms can survive on Mars, see: www.dlr.de/me/en/desktopdefault.aspx/tabid-2016

w3 – For more information about the Museum of Natural History in Berlin, Germany, see: www.naturkundemuseum-berlin.de/index_english.html

Resources

Astrobiology Lecture Course Network: http://streamiss.spaceflight.esa.int/?pg=production&PID=alcn

For more information about panspermia, see:

www.karlsims.com/panspermia.html and www.archive.org/details/sims_panspermia_1990

Hartevelt S, Walker C (2008) The International Space Station: a foothold in space. *Science in School* **9**: 62-65. www.scienceinschool.org/2008/issue9/iss

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Warmbein B (2007) Down to Earth: interview with Thomas Reiter. *Science in School* **5**: 19-23. www.scienceinschool.org/2007/issue5/thomasreiter

Warmbein B (2006) Launching a dream: the first European student satellite in orbit. *Science in School* **1**: 49-51. www.scienceinschool.org/2006/issue1/sseti

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When the group began the experiments, Cornelia Meyer was studying for a Master's degree in mineralogy at the Museum of Natural History[w3] in Berlin, Germany. Ralf Moeller (Deutsches Zentrum für Luft- und Raumfahrt, DLR – the German Aerospace Centre) and Jean-Pierre de Vera (University of Düsseldorf, Germany) were working towards PhDs in biology. Thomas Berger was studying for a PhD in physics at the DLR. Cornelia is now a PhD student while the others are doing postdoctoral research.

Materials science to the rescue: easily removable chewing gum

Halina Stanley investigates the history of chewing gum, how the chemistry of the gum affects its properties, and how scientists are using this knowledge to make chewing gum less of a pollutant.

Image courtesy of iStockphoto

Love it or hate it, chewing gum is a ubiquitous and usually benign activity. Benign, that is, until some idiot decides to put some in your hair. Wouldn't it be nice if gum didn't stick to carpets, shoes and the underside of school desks? Terry Cosgrove, professor of chemistry at Bristol University, UK, has decided to take action; his easily removable chewing gum may save millions in cleaning bills[w1].

The stickiness of chewing gum may be an unwanted side-effect[w2], but chewiness is a very desirable property. Manufacturers of chewing gum – and old wives' tales – suggest that chewing gum can be helpful for improving focus, concentration and alertness, reducing stress, and enhancing weight loss; we now even have versions that help us stop smoking and prevent seasickness. There are even marketing claims that chewing gum can significantly reduce tooth decay and bad breath. However, a 'scientific' survey of two high-school students, carried out by the author, suggests that children actually chew gum as a displacement activity for pen and pencil chewing: chewing appears to be a universal human need.

So what is chewing gum? Historically it was simply resin bled from trees. For example, in the Yucatan Peninsula in Central America, Amerindians (native Americans) extracted gum from a tropical evergreen tree called the Manilkara chicle. More than a thousand years ago, they made gashes in the trunk, collected the drips of gum and then heated it until it reached a useful consistency for chewing. The word 'chicle' even means 'sticky stuff' in the ancient Nahuatl Aztec language. But chewing gum is not – even originally – a purely American habit: European Stone-Age people also used to chew gum. In 2007, Sarah Pickin from the University of Derby, UK, found a 5000-year-old piece of gum, complete with fossilised tooth marks, while on an archaeological dig in Finland[w3]. This gum was extracted from birch trees by Stone-Age people and heated to form a kind of tar which would have been solid when cold, but softer if warmed. It seems that it was used as glue for repairing cooking pots or for sticking arrowheads onto their shafts, but clearly it was also chewed. Professor Trevor Brown, Sarah's tutor at the University of Derby, says that this gum contains natural antiseptic compounds, so Neolithic people would have had their own medicated chewing gum to treat mouth infections.

Chicle, and other tree saps – including latex, from which natural rubber can be produced – are natural polymers. These polymers – polyterpenes – are composed of thousands of C_5H_8 isoprene subunits[w4]. Depending on the species of tree or plant, the natural polymers may be more or less highly branched, have differing sizes (molecular weight) and may be mixed with volatile essential oils, all of which lead to differing softnesses and elasticities. (The effects of the chemical structure on the physical properties of polymers can be readily investigated in the classroom[w5].) These viscous liquids can be solidified by introducing cross-links into the polymers; this process can be investigated by adding sodium tetraborate solution to

Public domain image; image source: Wikimedia Commons

Manilkara chicle tree

BACKGROUND

Adhesion

There are many ways in which things stick. These include:

- **Mechanical interlocking**, such as occurs with Velcro or glues that flow into cracks and crevices of the substrate and then harden, physically locking on to the substrate.
- **Intermolecular attractions** (e.g. hydrogen bonds and Van der Waals forces). Geckos are renowned for scampering up smooth vertical walls (even glass). Each of their feet is covered in nearly 500 000 hairs, which adhere to surfaces via weak Van der Waals forces (Autumn et al, 2000). The adhesion of a gecko's foot to the wall needs to be reversible (imagine the poor gecko if it were not), so this is a good strategy: the forces are weak but the cumulative effect of 500 000 hairs is not; by peeling its foot off the surface, the gecko can break the forces bit by bit.
- The formation of **chemical bonds** (covalent or ionic bond formation). Mussels, which unlike geckos are not very mobile creatures, stick firmly to rocks in stormy weather using rather stronger covalent bonds. And some glues form covalent or ionic bonds with surfaces, although the exact details tend to be commercial secrets.
- **Interdiffusion at the interface**. This generally leads to very strong adhesion, since the two materials are mixed at a molecular level. Many materials interdiffuse to some extent – two similar polymers at a moderate temperature will interdiffuse, and the process is important in metal-metal contacts and metal-metal oxides.
- **Electrostatic attractions**. Researchers at the US National Institute of Standards and Technology (NIST) are currently examining the possibility of using electrostatic charges to bond semiconductors.

polyvinylalcohol 'white' glue. Worksheets for this classic experiment can be found on a number of websites[w6] and it is interesting to observe the effect of varying cross-link density (by changing the ratio of sodium tetraborate to glue).

Although the first chewing-gum factory, which opened in the USA in 1870, used sap from the Manilkara chicle tree as its gum base, modern chewing gums use synthetic polymers. With consumption of gum at a staggering 50 billion sticks a year in the USA alone (around 170 sticks per capita per year), relying solely on tropical forests to supply the raw material is not a viable option. Some formulations may still include natural ingredients but data are hard to come by – these are closely guarded commercial secrets. Instead, the synthetic polymer gum bases used in commercial chewing gum mimic and optimise the properties of the natural polymers: they are inert, insoluble and entirely non-nutritive. These polymers are synthesised from petroleum products to which sugar (or a sweetener such as aspartame) and other flavourings are added. Colouring (traditionally bright pink for bubblegum) is the only additional ingredient, unless the gum is to be used in a medical application, for example to help quit smoking, since these gums obviously also contain a drug (e.g. nicotine) in a water-soluble form.

The formulation of gum base, so that it gives the right chewiness (elasticity) and flavour release, is complex and varies depending on the desired elastic properties (bubblegum is more elastic than ordinary chewing gum, for example). It contains various elastomers (to provide the elasticity), resins (that act as binders), fillers (that contribute to overall texture and may help create low-calorie gums by bulking the gum up without adding nutritive ingredients) and plasticisers (to soften the mixture)[w7]. The main component is typically a mixture of synthetic elastomers such as polyisobutylene, isobutylene-isoprene co-polymers (butyl rubber), styrene-butadiene co-polymers and polyvinylacetate – you may have heard of some of these in connection with car tyres. These polymers are all insoluble in water, hydrophobic (water-hating) and non-biodegradable. This explains why scrubbing your carpet with water doesn't shift chewing gum. Soaking in water won't help either. And if the gum is stuck to a concrete wall or paving stone, rain won't wash it away.

When a stick of gum is chewed, the water-soluble part (sugar and flavourings) is gradually released, while the polymer base (the plastic) remains. After a while, the gum becomes tasteless because all the flavourings have been released; the gum base never dissolves away. The warmth of the mouth softens the gum base and makes it more pliable, but it isn't really changed and will harden again on cooling (although it may become somewhat tougher if any plasticisers are released). To blow the best bubbles, chew until all the sugar has been released and only the stretchy polymer base is left: sugar is not a polymer, doesn't stretch, and can cause bubbles to collapse prematurely.

So to return to the original question: why does chewing gum stick so well to most surfaces? The science of adhesion is complicated (see box) and in the case of chewing gum, probably involves both mechanical effects and chemical bonds. However, whatever the sticking mechanism, the two surfaces must be in very close contact, to 'wet' each other ('wetting' describes the contact between a liquid and a solid surface, resulting from intermolecular interactions) before they will adhere. Soft chewing gum fits the bill perfectly. And once it is stuck, the energy that you put into pulling it doesn't go into breaking the bonds holding the gum to the surface (as you would like); instead, you just stretch and slide the polymer molecules in the gum. This is a general property of polymers (above a certain temperature): the long tangled molecules tend to have lots of bends that can be straightened a little by pulling on them. (You can demonstrate the stretching of polymers in the classroom using polythene bags[w8]). So how does this knowledge help us make chewing gum that is less sticky?

Reducing the stretchiness of chewing gum is not a sensible strategy: who would want to chew a bouncy ball? Instead, Professor Cosgrove has incorporated a hydrophilic (water-loving) polymer into the gum base. When the gum is chewed, the hydrophilic polymer absorbs saliva and softens the gum. It also migrates to the surface. This means that there is always a thin film of water on the surface of the wad of chewing gum after chewing. This persistent film of water ends up between the gum and any surface, preventing close contact and preventing the gum sticking. Simple? Not really. If a hydrophilic polymer were simply added, it wouldn't mix with the gum base (just as you can't mix oil and water). Instead, a co-polymer (a polymer made of two types of monomers, or building blocks) that has both hydrophilic and hydrophobic parts must be used; even this needs to be carefully added to avoid phase separation[w9]. Paint manufacturers use a similar trick: they mix the elastomeric polymer(s), which will dry to become a water-resistant coating, with water using this kind of co-polymer[w10].

The addition of the water-loving polymer has another benefit. Ordinary chewing gum is pretty resistant in the environment: it doesn't dissolve in rain and weathering

Image courtesy of Luis Fernández García, image source: Wikimedia Commons

Manilkara chicle tree with gashes to collect the sap tends to harden it, which makes it a very persistent pollutant (think of those grey blobs on the pavement!). In contrast, the gum containing a hydrophilic polymer (the non-stick variety of chewing gum) slowly disintegrates in the presence of water.

Although the co-polymer used in non-stick chewing gum has been patented[w11], the team is still perfecting the exact composition of its gum base. So far they have tested more than 200 different formulations – I understand Violet Beauregarde was one of their first employees (read *Charlie and the Chocolate Factory* by Roald Dahl). In addition to the usual polymer parameters of molecular weight, degree of branching and cross-link density, the team has to optimise their water-loving/-hating schizophrenic co-polymer. Too much water-loving polymer and the gum may be too soft. The wrong composition and the gum may fall apart in the mouth or still stick to surfaces. The team seems confident that a product will be ready for marketing in the near future. I'm keeping my fingers crossed that it proves popular – otherwise we'll just have to put non-stick coatings on the underside of all the school desks!

Acknowledgements

I would like to thank Professor Cosgrove for useful discussions and for critically reading this manuscript.

References

Autumn K et al (2000) Adhesive force of a single gecko foot-hair. *Nature* **405**: 681-685. doi: 10.1038/35015073. Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2008/issue9/chewinggum) or subscribe to *Nature* today: www.nature.com/subscribe

In Roald Dahl's well-loved children's book, *Charlie and the Chocolate Factory*, Violet Beauregarde is a loathsome child addicted to chewing gum:

Dahl, R (2007 and earlier) *Charlie and the Chocolate Factory*. Puffin Books, London, UK. ISBN 978-0141322711

Web references

w1 – More information about Professor Cosgrove's research is available on the University of Bristol website: www.chm.bris.ac.uk/pt/polymer/introduction.shtml

w2 – An entertaining video of Professor Cosgrove attempting to remove chewing gum from shoes can be found at www.revolymer.com

w3 – The story of Sarah's discovery can be read here: www.derby.ac.uk/press-office/news-archive/heres-a-story-to-get-your-teeth-into

w4 – To learn about rubber- and chicle-producing plants and their polymers, see:
http://waynesword.palomar.edu/ecoph13.htm
http://en.wikipedia.org/wiki/Chicle
http://en.wikipedia.org/wiki/Terpene

Image courtesy of iStockphoto

w5 – A great teaching activity about changing the properties of polymers and plastics (activity number 3.1.5) can be downloaded from the Royal Society of Chemistry (UK) website: www.chemsoc.org/networks/learnnet/inspirational/

w6 – Informative websites on the polyvinylalcohol and sodium tetraborate (borax) experiment include:
www.chemsoc.org/networks/learnnet/inspirational/ (specifically experiment 3.1.8, 'Investigating cross-linking, making slime')

www.iop.org/activity/education/Events/Events%20for%20Teachers/Schools%20Physics%20Group/file_5747.doc

http://pslc.ws/macrog/activity/ball/lev3/level3p.htm

w7 – Learn more about the basis of chewing gum on the Gumbase website: www.gumbase.com

w8 – An interesting teaching activity (experiment 3.1.6, 'Polythene bags') for understanding the stretching of polymers can be found on the Royal Society of Chemistry website: www.chemsoc.org/networks/learnnet/inspirational/

w9 – A video about how gum bases are made ('Making clean gum') can be viewed here: www.revolymer.com

w10 – Co-polymers of polyvinylacetate (a water-insoluble polymer) with polyvinylalcohol (a water-loving polymer) as used in paint are very well described here: http://pslc.ws/macrog/pva.htm

w11 – The patent (WO/2006/016179, 'Polymeric materials having reduced tack, methods of making the materials and chewing gum compositions containing such materials') can be viewed on the World Intellectual Property Organization website:
www.wipo.int/pctdb/en/wo.jsp?wo=2006016179&IA=WO2006016179&DISPLAY=STATUS

Resources

For a classroom activity to measure the citric acid concentration in chewing gum, see:

Gadd K, Szalay L (2008). Chewing flavours. *Science in School* **8**: 34-37. www.scienceinschool.org/2008/issue8/chewinggum/

If you want to follow the reviewer's suggestion for a chewing-gum testing activity, why not have a look at the chocolate-tasting activity from *Science in School*?

Scholar J (2006). The chocolate challenge. *Science in School* **2**: 29-33. www.scienceinschool.org/2006/issue2/chocchallenge

For some exciting background reading on the chewing-gum industry, see:

Redclift M (2004) *Chewing Gum: The Fortunes of Taste*. New York, NY, USA: Routledge. ISBN: 9780415944182.

and 'All About Chewing Gum': www.wrigley.com/wrigley/kids/kids_report.asp

REVIEW

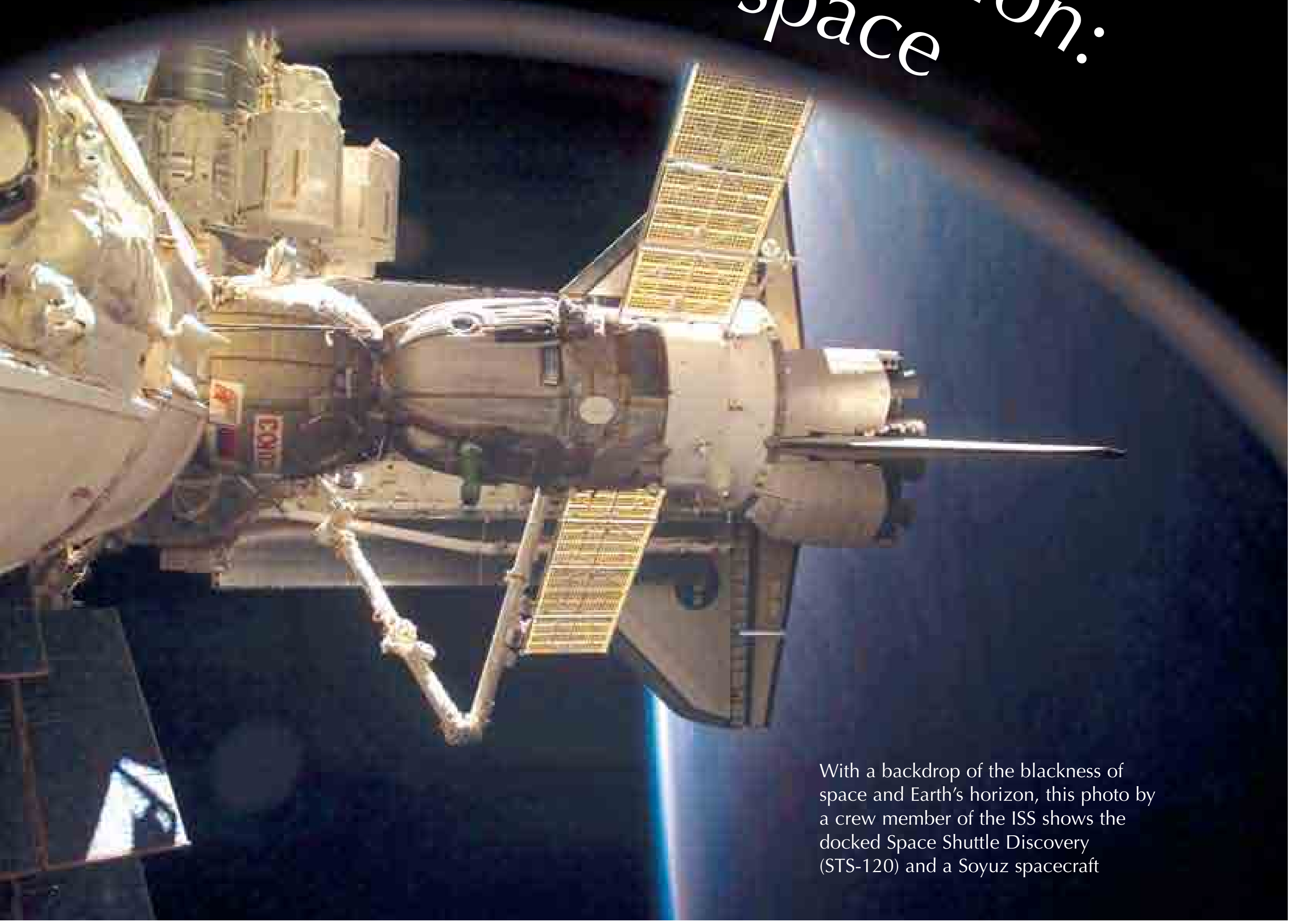
This is a new way for teachers to become popular among students: buy lots of different chewing gums! Let the students be the experts by assessing different brands – perhaps by giving marks for different properties such as chewiness, duration of flavour release, and consistency. Read the article and discuss the chemical expressions that are used. Finally – try to make your own easily removable chewing gum.

Sølve Tegner Stenmark, Norway

Halina Stanley is a physicist by training, who has worked for Exxon in New Jersey, USA, and ICI in the UK. While working for ICI, she spent a lot of time watching paint dry (they make the Dulux® range) and helping to develop polymer blends for controlled drug release (this part of the company is now AstraZeneca). ICI is now part of AkzoNobel. Halina was ICI's representative at the Rutherford Appleton Laboratory in Oxfordshire, UK, where she participated in materials research using neutron scattering, including an experiment with Professor Cosgrove.

Halina has taught physics, chemistry and mathematics to secondary-school students at the American School of Grenoble, France, for the past seven years.

The International Space Station: a foothold in space



With a backdrop of the blackness of space and Earth's horizon, this photo by a crew member of the ISS shows the docked Space Shuttle Discovery (STS-120) and a Soyuz spacecraft

In the first of two articles, **Shamim Hartevelt-Velani** and **Carl Walker** from the European Space Agency take us on a trip to the International Space Station.

What is the ISS?

Imagine an array of bright solar panels fanning out from a central support about 100 metres in length. At various locations along the support, cylindrical pressurised modules are attached. Astronauts live and work inside these modules. Some modules are laboratories; others provide a living space for the crew, including a kitchen and an exercise area. Additional modules provide storage facilities for water, food, equipment and experiments, and house systems for recycling air and water, as well as a lavatory. Nodes connect the different modules and provide a docking port for vehicles arriving from Earth.

Science fiction? No, this amazing structure has been fact since 20 November 1998, when the first building block called 'Zarya' ('Sunrise' in Russian) was launched into orbit by a Russian Proton rocket from Baikonur in Kazakhstan. The International Space Station (ISS) is the biggest man-made structure ever to fly in space. It is a collaboration between the European Space Agency (ESA)[w1], the US National Aeronautical and Space Administration (NASA)[w2], the Russian Federal Space Agency (Roscosmos)[w3], the Canadian Space Agency (CSA)[w4] and the Japan Aerospace Exploration Agency (JAXA)[w5]. The continuing assembly of the station uses the robotic arms of the Space Shuttle and the ISS, as well as the astronauts who help complete the work by performing extravehicular activities (EVAs, or spacewalks) in the vacuum of space.

The ISS provides a unique opportunity to conduct pioneering investigations in numerous scientific fields. Compared with earlier space stations, the ISS provides substantially more opportunities for carrying out dozens of experiments, either on racks inside the Station or at special external attachment points. This is because the ISS has a larger internal volume, more available computing power, more electrical power and an extended lifetime that allows scientists to conduct experiments over longer periods with a continual flow of data.

Gravity affects almost everything we do on Earth. In orbit, the effects of this force virtually disappear and are replaced by microgravity conditions, or 'weightlessness'. Astronauts float around, able to carry huge pieces of equipment with ease. In these conditions, scientists can test and modify existing theories, which could lead to new discoveries and advances.

Image courtesy of ESA/NASA

Dutch ESA astronaut Andre Kuipers views the Earth from the ISS window

Travelling to the ISS

From May 2009, the ISS will be permanently manned by a crew of six astronauts from the USA, Canada, Japan, Russia and ESA. The crews are exchanged throughout the year, but the average stay is six months. Crews are made up of a mixture of nationalities, the combination of which depends on agreements between the governments. All crews must have a good understanding of spoken and written English and Russian.

The crew reach the ISS either in a Russian Soyuz capsule, launched from Baikonur, or in an American Space Shuttle, launched from Cape Canaveral in Florida, USA. From Earth, it takes about ten minutes for the astronauts to reach orbit.

During the launch of a Space Shuttle, there are loud noises and huge vibrations as the main engines burn liquid hydrogen and oxygen. After lift-off, the speed quickly increases, and the rapid acceleration squashes the astronauts into their seats as acceleration forces increase from 1 g to as much as 4 g – similar to some of the fastest roller coasters.

The Shuttle soon reaches 10 km above sea level, the cruising altitude of airliners. The temperature drops to below zero and it is also at this point that the greatest air resistance with the atmosphere is encountered. As the Shuttle soars still higher, the horizon curves and the astronauts first experience the darkness of space. After two minutes, the Shuttle reaches an altitude of 45 km and is travelling at around 4.5 times the speed of sound.

Four minutes later, the Shuttle reaches an altitude of 130 km and is travelling at 15 times the speed of sound. The central propellant tank is now empty and separates, eventually burning up in the atmosphere. The main engines are switched off, but the Shuttle continues to move through space because now there is no air resistance. Objects inside appear to become weightless and anything not firmly strapped down begins to float.

The vibrations end and silence surrounds the spacecraft. The Shuttle reaches a speed of 22 times the speed of sound (28 000 km per hour) and an altitude of nearly 400 km; it is now in the same orbital plane as the ISS. The Shuttle begins to chase the Station – it is 10 000 km behind and lower in altitude and two more days are required for the rendezvous and docking, to make sure all the system checks are finalised. Docking takes place very slowly to avoid any accidents.

Research on board

Our current understanding of the life sciences, physics and chemistry is almost entirely based on observations and theories influenced by the ever-present force of gravity. On the ISS, research carried out in an environment of weightlessness allows scientists to test and modify existing theories.

For example, the properties of materials are determined by their fine structure and influenced by the imperfections that are formed mainly during the transition from liquid to solid. This process is influenced in very complex ways by gravity. By studying solidification in microgravity, it is possible to better understand how gravity affects the process back on Earth. As a result of this space-based research, engineers can improve the manufacturing processes used on Earth to produce cheaper, stronger and more reliable castings.

Astronauts also carry out experiments in biology, medicine and human physiology. ESA's activities in this research are currently focused on the effect of gravity on development and maintenance of bone tissue, as well as the influence of medication. Early long-term spaceflights revealed not only that living in space conditions led to loss of bone mass, but also that this loss varied from very little to as much as 20% of bone minerals after 6-8 months in space.

It is common knowledge that loss of bone quality is the main characteristic in osteoporosis sufferers on Earth. The same loss of bone mass and quality can also be observed in healthy space crews. By doing research into these similar problems, we have a better chance of solving both. Research over the past decade has made significant progress, and so much more is known today than ten years ago. Experiments in space are helping us to understand the maintenance of bones, and may help space crews to maintain their bone quality while spending more time in a weightless environment.

In the next issue of *Science in School*, read about how astronauts live in space and how their bodies adapt to conditions of microgravity.

Image courtesy of ESA/NASA

Astronauts Pam Melroy, STS-120 commander (left); Peggy Whitson, Expedition 16 commander; and Stephanie Wilson, STS-120 mission specialist, pose for a photo in the Zvezda Service Module of the ISS while Space Shuttle Discovery is docked with the Station

Web references

w1 – For more information about the European Space Agency, see: www.esa.int. See below for information about ESA's education resources.

w2 – For more information about NASA, see: www.nasa.gov

w3 – For more information about Roscosmos, see: www.roscosmos.ru

w4 – For more information about the Canadian Space Agency, see: www.space.gc.ca

w5 – For more information about the Japan Aerospace Exploration Agency, see: www.jaxa.jp/index_e.html

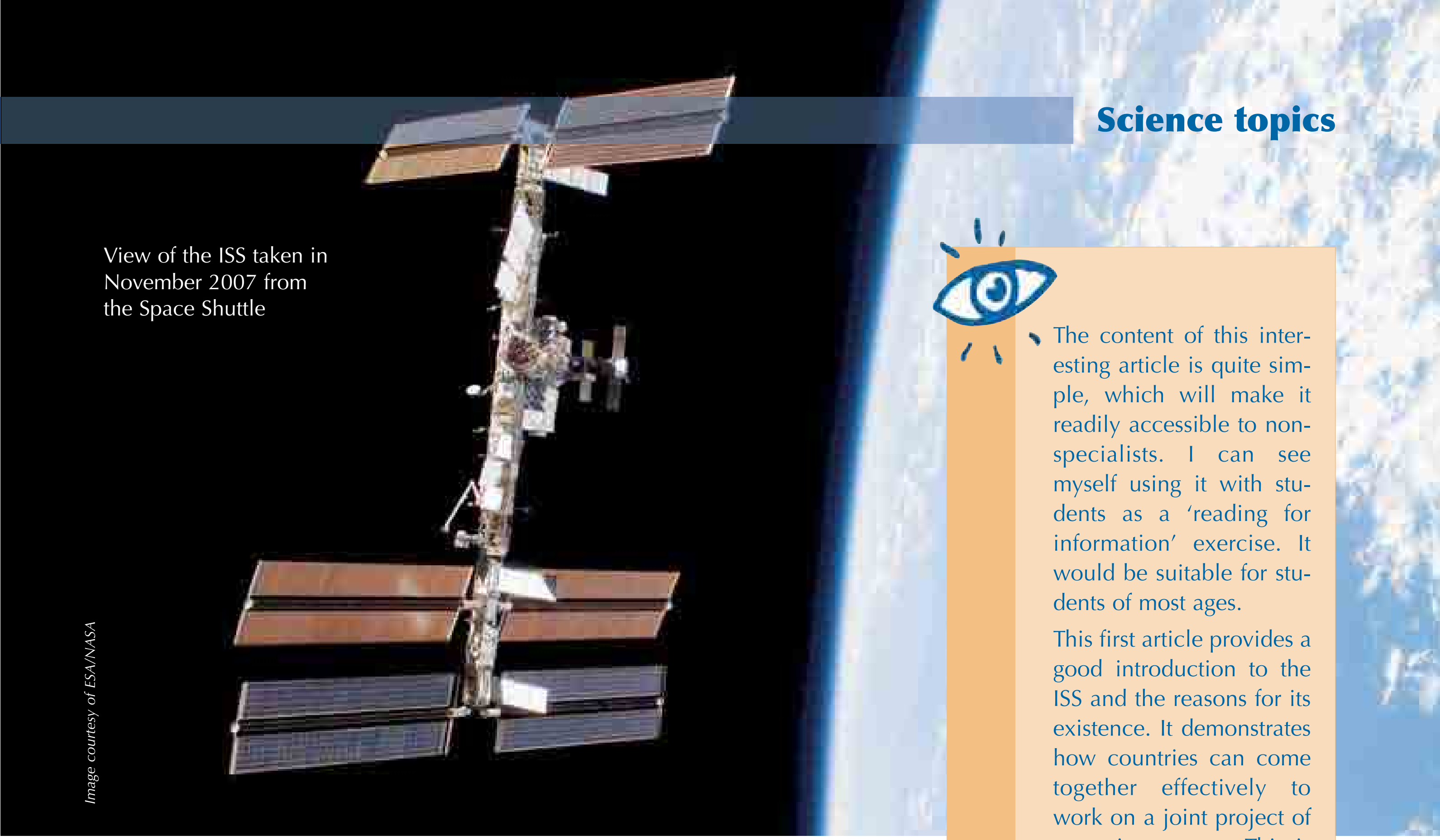
Resources

For a complete interview with Thomas Reiter, see:

Warmbein B (2007) Down to Earth: interview with Thomas Reiter. *Science in School* **5**: 19-23. www.scienceinschool.org/2007/issue5/thomasreiter/

For other related articles, see:

Wegener A-L (2008) Laboratory in space: interview with Bernardo Patti. *Science in School* **8**: 8-12. www.scienceinschool.org/2008/issue8/bernardopatti/



View of the ISS taken in November 2007 from the Space Shuttle

Image courtesy of ESA/NASA

Williams A (2008) The Automated Transfer Vehicle – supporting Europe in space. *Science in School* **8**: 14-20. www.scienceinschool.org/2008/issue8/atv/

Many hundreds of images, videos and animations about human space flight are available on the ESA website and can be used for education purposes: www.esa.int/esa-mmg/mmg.pl?collection=Human+Spaceflight

ESA have produced many educational materials relating to the ISS:

A printed ISS Education Kit for both primary- and secondary-school teachers is available in all 12 ESA languages. The kits are based on all the fascinating activities involved in building, working and living on board the ISS, and provide background information and exercises for classroom teaching. They are available to all school teachers in ESA member states and can be ordered free online: www.esa.int/spaceflight/education

An interactive version of the ISS Education Kit is available at: www.esa.int/spaceflight/education

'Space Robotics', the latest in a series of four ISS DVD lessons covering topics relating to European school curricula and based on Project Zero Gravity, is now available.

A new DVD on the physics involved in the Automated Transfer Vehicle (ATV) is due to be released later this year. DVDs can be ordered free by teachers: www.esa.int/spaceflight/education

ESA is also developing a series of online lessons for primary- and secondary-school students and their teachers. See: www.esa.int/SPECIALS/Lessons_online

A new Space Exploration Kit 1 for primary schools will be released in 2008.

Further details and education materials:

European Space Agency Education website: www.esa.int/education

European Space Agency Human Spaceflight Education website: www.esa.int/esaHS/education.html

REVIEW

The content of this interesting article is quite simple, which will make it readily accessible to non-specialists. I can see myself using it with students as a 'reading for information' exercise. It would be suitable for students of most ages.

This first article provides a good introduction to the ISS and the reasons for its existence. It demonstrates how countries can come together effectively to work on a joint project of some importance. This is useful with the emphasis given to citizenship in many schools and can give rise to a lot of cross-curricular work, especially with social-science subjects.

The resources listed in this article are very impressive and show ESA's commitment to education. They are well worth ordering or taking the time to download.

Mark Robertson, UK

Shamim Hartevelt-Velani is a secondary-school teacher currently working under contract at ESA's European Space Research and Technology Centre (ESTEC), in the Directorate of Human Spaceflight. She is the didactics specialist in the education team.

Carl Walker is ESA's corporate writer and editor, based at ESTEC. He writes and edits a wide range of books and other communications materials about space flight and the European space programme.

Cornelius Gross: from the classroom to the laboratory

The majority of young scientists working in research have only ever been that – scientists. But **Vienna Leigh** reports how one group leader at the European Molecular Biology Laboratory started his career at the front of a classroom – and feels that his science benefits as a result.

Image courtesy of EMBL Photolab

Cornelius Gross

These days, Cornelius Gross works with mice to determine the causes of human personality traits and psychiatric disease, but at the start of his career, his day-to-day job involved dealing with much bigger animals – high-school students, to be exact.

Unlike most scientists who work in or lead basic research groups, as he does at the European Molecular Biology Laboratory (EMBL) Mouse Biology Unit in Monterotondo, Italy, Cornelius started his working life as a teacher, moving into laboratory work much later. "Though I still loved research when I finished my PhD, which was in *Drosophila* [fruit fly] genetics and protein biochemistry at Yale University [USA], I wasn't keen to stay in the laboratory," explains American-born Cornelius. "I think that was mainly because I felt I hadn't had many personal life experiences or seen much of the 'real' world.

"So I started looking around for a job which would challenge me as a person, and one which would allow me to get immediate feedback on my performance, unlike research."

Before long, Cornelius found himself in front of a science class of 15 to 17-year-olds at Landmark High School, a small experimental public school in Manhattan, for two years. "Our school was unusual, since all the students were poor. There were only four white children in the school, which had 450 students in total, and 90 percent of them were first-generation immigrants, mainly from Caribbean countries," he says. "Since it was an experimental school, the principal had lots of leeway to design the curriculum as she wanted. Nearly all decisions were put to the vote of the teaching staff."

Being an inexperienced teacher in such an environment, Cornelius seemed to have his work cut out for him – but he feels that being a teacher of science, rather than any other subject, made it easier. “Science is a fantastic subject, because nearly all students can relate to it and become engaged in it,” he says. “The experimental parts, in particular, really appeal to students who perform badly or are unmotivated. Several students who had done nothing all year in their other classes performed outstandingly when faced with an experimental task.”

However, it was by no means easy. “I had to develop and produce all my curriculum materials myself – I rarely used textbooks,” he explains. “Parents were frequently absent from the children’s lives, and if they were around, they often failed to appear at teacher-student-parent meetings – although the students would turn up, nonetheless!”

Despite the hardships, though, Cornelius was able to draw much personal satisfaction from the experience. “All my success stories derived from personal tutoring of difficult students. One in particular, who clearly had learning disabilities, took up a lot of my time, but helping him was very rewarding,” he recalls. “He was a Haitian student whose mother had remained in Haiti. His father was very strict, so I found myself mediating between the student and his father. In the end, I think I managed to help each of them to appreciate the other.

“After leaving the school, I was able to travel to Haiti to see the student’s mother and take an autobiographical video that he made for her. He hadn’t seen her for seven years, but a few years later he was able to return to see her himself, in part because of my instigation.

“Another student was a precocious loner who hardly showed up at school, and when she did she usually came just to talk to me – she saw me as a confidant, someone she could talk to about her difficult life, which included experiences as a prostitute. She was half African-American with a German mother, and she idolised

Image courtesy of EMBL Photolab

Nazi paraphernalia and ideas; she made everyone hate her by shouting racist slogans, and no one wanted her in their class. I remember giving her a cartoon book about Freud, which she loved, and she wrote a great report about Freud with ideas derived from the book.

“Those are the experiences that remain most clearly in my mind, although there were many less vivid, but equally satisfying encounters.”

Cornelius never lacked ideas for experiments and assignments. “I taught with a mixture of lectures, group activity and individual research. At the time there were no such activities available for groups of my students’ age and skill level, so I created lots of experimental projects. They helped the students discover things, rather than teaching them what has already been discovered,” he says.

Image courtesy of iStockphoto

A Haitian beach

"One involved a 'prisoner's dilemma'[w1] module where the students had to develop their own algorithm and play against classmates. In another activity, we looked at the chemistry of commonly used drugs including cocaine and heroin, using gumdrops as the drugs and drawings of the synapse to explain their target sites."

It was one such project that led to him eventually leaving the classroom and returning to research. "One day I read Peter Kramer's landmark book about antidepressants, *Listening to Prozac*, which inspired me to devise a module about neurobiology. We had many visiting speakers and made a model of the areas of the brain using coloured clay. We also read Oliver Sacks' [neurologist and author of *The Man who Mistook his Wife for a Hat*, among others] stories about brain injuries. The students thought I was a total nerd, but they loved it.

"All this re-awoke my interest in research, and in neurobiology in particular, which wasn't really something I'd done before – I'd studied biophysics before my PhD. So, soon afterwards I left the school and joined a neurobiology lab to determine the serotonin receptor that mediates the antidepressant effects of Prozac. We actually succeeded, and published this in *Science* in 2003 [Santarelli et al, 2003]."

Now Cornelius runs a lab of ten people and is sure, despite his positive teaching experiences, that research is the right job for him. "I love the creativity and freedom in science," he says. "I feel very fortunate to be a scientist and to be able to run my own lab and be independent. It has just the right mixture of solitary thinking and people management on a small scale."

His two years as a teacher, though, equipped him with special skills he's very grateful for to this day. "Teaching requires excellent people-management skills. I learned to be light-hearted, eccentric and playful as a way to deflect conflict and engage students," he says. "Being a group leader in science is much the same. Several scientific results have been surprising and made me extremely proud of the people in my lab, just as I was proud when those underachieving kids really got engaged in science and came through with projects.

"Recently, for example, a young researcher in my lab had the idea to look at the body temperature of a group of mice that had been dying for no apparent reason. She found extremely dramatic and unexpected drops in temperature that are now the basis of an article that was published in *Science* [Audero et al, 2008]. The thing I remember the most was the smile on her face when she presented the data to me. Seeing such satisfaction is enough to keep me going for many months!"

References

Kramer PD (1994) *Listening to Prozac: Psychiatrist Explores Antidepressant Drugs and the Remaking of the Self*. London, UK: Fourth Estate. ISBN: 9781857022841

Sacks O (1986) *The Man who Mistook his Wife for a Hat*. London, UK: Picador. ISBN: 9780330294911

Santarelli L et al (2003) Requirement of hippocampal neurogenesis for the behavioral effects of antidepressants. *Science* **301:** 805-809. doi: 10.1126/science.1083328

Audero E et al (2008) Sporadic autonomic dysregulation and death associated with excessive serotonin auto-inhibition. *Science* **321:** 130-133. doi: 10.1126/science.1157871

Web references

w1 – For more information about the prisoner's dilemma, see:

The Wikipedia page on the prisoner's dilemma: http://en.wikipedia.org/wiki/Prisoner's_dilemma

An interactive game about the prisoner's dilemma: http://serendip.brynmawr.edu/playground/pd.html

Resources

For an example of a move in the opposite direction, see the story of Paul Matthews, who moved from the lab into the classroom:

Leigh V (2008) Paul goes back to the classroom. *Science in School* **8**: 63-65. www.scienceinschool.org/2008/issue8/paulmatthews

For more information about the work of Cornelius Gross's research group, see: www-db.embl.de/jss/EmblGroupsOrg/g_177?sP=1

Image courtesy of Rama; image source: Wikimedia Commons

Curiosity killed the cat – or did it?

Frode Skjold tells **Sai Pathmanathan** about some of his favourite activities to teach science in primary school.

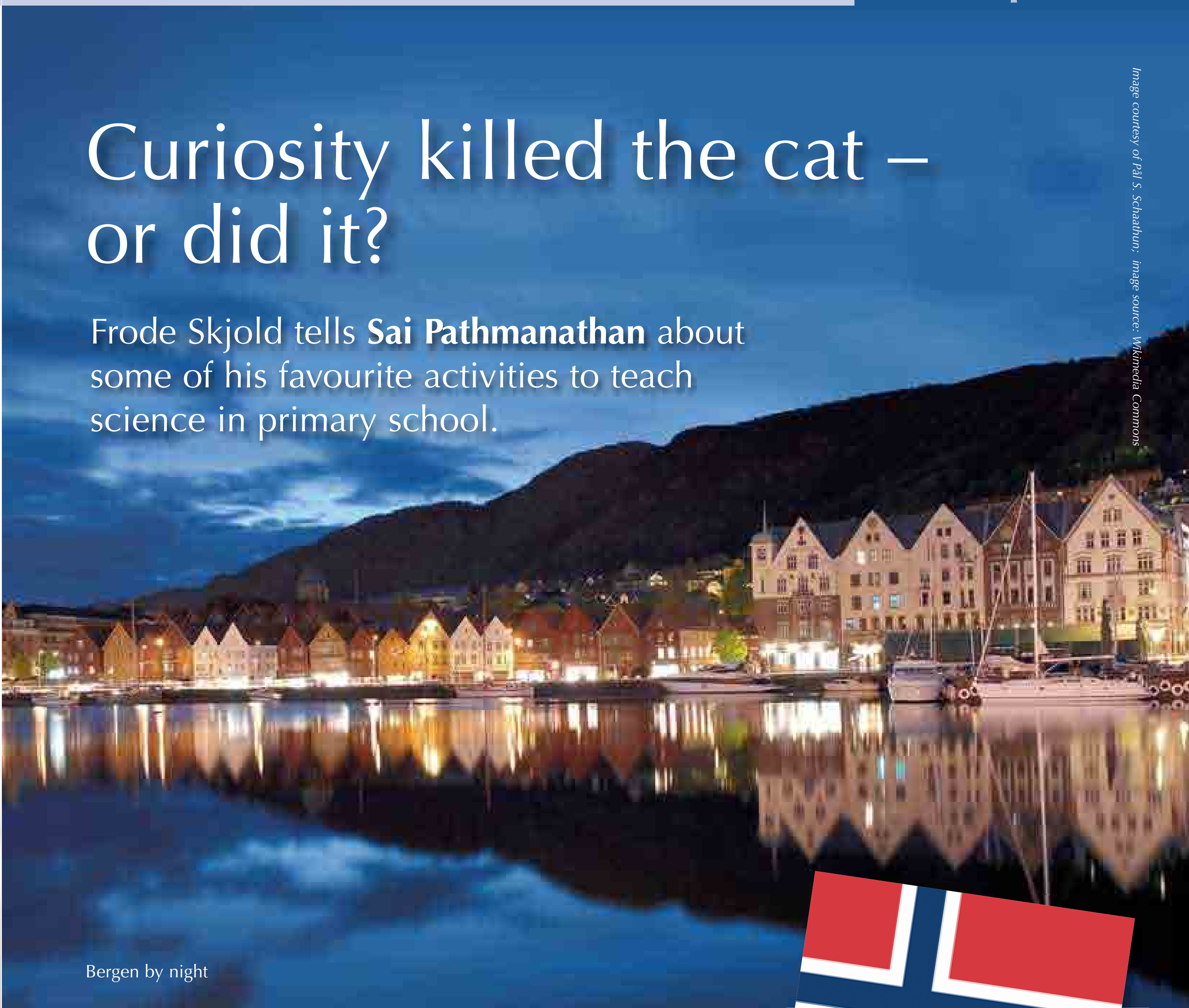


Image courtesy of Pål S. Schaathun; image source: Wikimedia Commons

Bergen by night

Frode Skjold has been teaching in Norway since 1994, and is currently working at Ulsmåg primary school in Bergen. The country's second largest city, this seaport in the west of Norway is renowned for its pouring rain, colourful wooden houses and good fish. Frode describes himself as a jack of all trades – teaching all core subjects in primary school (focusing on basic skills such as mathematics, reading and writing) – but his passion is for science and he has never yet met a child who isn't interested in it too.

Frode grew up on a little farm near the sea with four brothers. His parents, who were both teachers, were very enthusiastic and often spoke to their boys about nature and science. It didn't take long for Frode and his brothers to start exploring the local flora and fauna. As children, they went on long hikes, recording the kinds of birds they saw, as well as fishing, playing in the woods and tending the farm animals. The foundation for a lifelong interest was laid without them even realising. Three of his brothers are now working in scientific fields – one is a landscape architect, while the others work in environmental management and fisheries science – and Frode is proud to be a science teacher.

His educational background is eclectic, made up of a little of everything, as he has to teach all subjects – from Norwegian to science. He specialised in biology and physics, but he doesn't count formal education as his

Image courtesy of Frode Skjold

Frode Skjold

sanded and rounded down the points in order to reduce the air resistance. A physicist from one of the universities told us that the piece of wood should have an initial speed of 90 km/h. But the pupils knew that we could never gain such a speed using only our hands and arms; we needed some sort of device to fling the piece of wood into the air. After discussing this, we settled on using a long stick as an extension of our arms, and attaching a rope to this stick. If we only could find a way to transmit the power from the rope to the piece of wood, it would now gain a tremendous speed – or at least, so we hoped. Working on this problem, we tried to follow the experts' instructions about transmission and design down to the last detail."

One of Frode's pupils, a quiet girl, did not approve of the proposed design. She carved her own piece of

only education. "What I learn through teaching and from the daily contact with pupils is such an educational experience for me," says Frode. "Most kids are natural researchers with their own curiosity and the need to experiment, classify and verify. The pupils' thirst for knowledge constantly challenges us teachers to find new approaches to our teaching."

He's a naturally curious person and thinks that being curious in the company of children is as good an education as anything else. He believes that if pupils are presented with the right scientific context and the tools, that is enough. Pupils can work out the experiments all by themselves; instead of showing them the way, the teachers can inspire the pupils to discover the path themselves.

Frode works with the Research Council in Norway on their project for primary school children, Nysgjerrigper[w1] (in English, 'curious Peter' – the Norwegian name for someone who wants to know about and questions everything). He is one of their 'resource teachers', sharing his experience, knowledge and teaching activities with other science teachers across Norway, and giving short lectures on using scientific working methods in the primary-school science classroom, the 'Nysgjerrigper method'[w2].

For the Nysgjerrigper research competition each year, Frode starts with a research project for his class, challenging the pupils to explain 'inexplicable' phenomena; they have competed very successfully for the past six years. As we all know, teaching is full of highs and lows, but Frode is fascinated by the success stories he has witnessed. One particular experience comes to mind.

"My class had decided to embark upon a new research project: how to make a piece of wood fly up in the air, at least 30 metres high," Frode recalls. "The pupils had so many suggestions as to how this could be done. They carved their pieces of wood,

BACKGROUND

Nysgjerrigper

The Nysgjerrigper Science Knowledge Project[w1] is a special initiative of the Norwegian Research Council targeted at pupils and teachers in primary schools. The main objective is to encourage children and teenagers to maintain and cultivate their own curiosity, fantasy and desire to learn. Children deserve exciting, engaging forms of research dissemination. Nysgjerrigper seeks to heighten interest in research and science among young people – and hopes that more of them will choose a career in research.

Image courtesy of Ritchyblack; image source: Wikimedia Commons

Bryggen – the famous commercial buildings of the Hanseatic League in Bergen

wood to look more like a big pencil or arrow, about 20 to 30 centimetres long, and then attached two feathers to the arrow's rear end. Towards the front end she cut a notch where the rope's end could fit in and be secured with a knot. "When we tried it out, the girl's arrow sped out from the rope and continued to fly further and further up, pointing beautifully upwards all the way," remembers Frode. "When it finally lost power, it fell down gracefully, pointing downwards, thanks to the feathers. The girl who came up with the arrow design was a quiet and careful one, but obtained what everyone had dreamed of!"

The arrow had flown over 30 metres high, and the goal was thus accomplished. This was a challenge – a scientific challenge that all children excitedly took part in. Frode has yet to meet a child who is not interested in science. He has faith that all children have an inborn curiosity, and an urge to experiment and challenge established facts.

Teachers often feel that their science teaching suffers as a result of poor equipment and facilities. Whilst Frode agrees, he feels that a great number of scientific studies can be carried out using free or very cheap materials, such as cans, old bottles, ropes, water and air. "One teacher at every school could specialise in researching ways to run easy experiments, co-ordinating purchases, inspiring other teachers, demonstrating experiments during lunch hours, developing equipment and so forth," says Frode. But

The winning arrow

Image courtesy of Frode Skjold

he realises that he may just be one of the lucky ones. “Our local authority in Bergen gives high priority to school science.” The only thing Frode would wish for is a designated classroom for science so that all the equipment can be set up in one place. He thinks the lack of such a room is the reason why some primary-school teachers are reluctant to include practical activities in their teaching.

Between the 1970s and 1990s, science in the primary-school curriculum was taught as part of a multidisciplinary subject that also included social studies. The balance between social studies and science often depended on the individual teacher. More recently, science has been resurrected as an independent subject in the primary-school curriculum – something that makes Frode very happy.

The latest Norwegian curriculum gives detailed descriptions of what pupils are supposed to know at the end of each year. For the first time in his career, Frode and his colleagues at school have agreed on what their pupils should know by the end of the fifth, sixth and seventh grades. Every teacher is committed to this agreement, and Frode feels that this educational reform will help pupils as well as the teaching professionals, as everyone is now aware of the targets to reach.

So there is a need to have common guidelines for each subject. But Frode believes that although there should be some standardisation, there should also be enough space within the curriculum to allow teachers to follow their own interests and scientific curiosity: “A certain amount of impulsivity and expressiveness is needed in teaching. For this reason, you can’t direct a teacher’s job in each and every detail.” And he feels strongly about the need for hands-on experiments. “An experiment should be carried out so that pupils can see first-hand what is happening and easily express what they are learning. The experiment always comes first. If eight experiments aren’t enough for pupils to get the point, you should perform a ninth!”

At present, Frode is touring Norway with his lecture on the Nysgjerrigper method, explaining how to use scientific methods in the primary-school classroom. “The teachers needs to tune in to the researchers’ frequency,” as Frode calls it. They have to open up their minds and think of themselves as scientists.

BACKGROUND

The resource teachers network

The resource teachers are a network of teachers[w4] with special expertise in the Nysgjerrigper method. They can provide other teachers in their areas with tips and advice on how to implement science projects in primary schools. All of the resource teachers have experience with research-related activities in the classroom and have previously participated in the Nysgjerrigper annual science contest for children and their teachers. The resource teachers mainly offer courses in the Nysgjerrigper method, but they also give lectures and other types of presentations at conferences and teachers’ seminars.

Bryggen, Bergen

Image courtesy of Perplex; image source: Wikimedia Commons


Image courtesy of Thomas Halszka; image source: Wikimedia Commons

Bryggen, Bergen

Ask a question, formulate a hypothesis, think of an experiment to test it, perform the experiment and evaluate the results – all this with the main input coming from the pupils. Frode and the other Nysgjerrigper resource teachers have seen the benefits of this method: the increase in creative thinking, curiosity and active participation among the pupils indicates that this is an excellent supplement to conventional teaching.

Frode also stresses the need for researchers to excite pupils about the wonders of science. He has asked researchers interested in science education to contact schools, arrange events and invite classes to their departments. "For several years now, the Department of Chemistry at the University of Bergen has invited sixth graders (aged 11-12) to visit, introducing the kids to different topics in chemistry," says Frode. "For pupils in primary school this is an excellent experience, especially because schools are deprived of expensive equipment, such as liquid nitrogen or fume cupboards. However, there is always a long waiting list for visitors to the Department of Chemistry. So maybe this is something that other departments at local universities could consider as well."

One of Frode's other projects is 'The Research Frequencies'. This is a set of worksheets he developed on topics from the ideal design of paper planes to experiments with Cartesian divers. Their purpose is to get pupils, teachers and trainee teachers to tune into their 'research frequencies' and open their minds to their innate curiosity and investigation skills. These positive experiences can be life-changing for pupils: they may make up their minds to pursue a career in science, instead of the more popular social sciences.

Interdisciplinary teaching isn't always easy, but this doesn't faze Frode. His work combining science with creative writing and painting is nothing short of fascinating. He loves to include Norwegian when teaching science, and a while back his pupils carried out a research project to find out about how dust forms dust bunnies (balls of dust that typically hide under the bed, behind the cupboard, etc.). The pupils cleaned their bedrooms thoroughly at the start of the project and then didn't clean them for six weeks. During those six weeks, the pupils observed dust bunnies appearing and marked them with tiny, coloured feathers to keep track of the dust bunnies' movements around their bedrooms. This research led to some rich Norwegian creative writing, including stories written from the point of view of the dust bunnies[w3]. All of a sudden, pupils were able to think like dust bunnies, dive into the dust bunnies' world and try out new forms of literary language to describe their thoughts.

"I generally like to vary the genres and styles in my research projects," says Frode. "Of course you can't be very creative with numbers and tables, but you can do exciting things like chemical painting. Start off with a sheet of paper soaked in the pigment from red cabbage, and then get the pupils to paint using acids and bases. The pigment goes green when exposed to bases, and pink when using acids. The results are great pieces of art for display."

His one piece of advice to science teachers: be curious yourselves and help to foster the same curiosity and inherent need for knowledge in your pupils.

Web references

w1 – To find out more about the Research Council of Norway's project for primary school children, Nysgjerrigper, see: www.nysgjerrigper.no/Artikler_Engelske/in-english0

and www.nysgjerrigper.no/Artikler_Engelske/AboutNysgjerrigper

For more extensive information in Norwegian, see: www.nysgjerrigper.no

A free tool for participation in the annual science contest is available here: www.nysgjerrigpermetoden.no

w2 – The teachers manual on the Nysgjerrigper scientific working method in primary schools can be downloaded here: www.nysgjerrigper.no/filer/nys_method-eng-web.pdf

w3 – For more information about the dust-bunny project, see: www.nysgjerrigper.no/Artikler/why-does-dust-form-dust-balls

w4 – More information about the resource teachers network is available (in Norwegian) here: www.nysgjerrigper.no/Artikler/2004/juli/nysgjerrigpers-ressurslaererere-inspirerer-og-veileder

University of Reading

Nature's dice

Simulation of genetic screening

Genetics is often difficult for students to understand. This innovative practical kit uses modern DNA technology to help students learn about classical Mendelian inheritance.

Nature's dice provides a practical simulation of genetic screening, centred on a fictitious extended family with 24 members. The DNA samples are distributed by the teacher so that students can investigate the inheritance of an autosomal recessive condition.

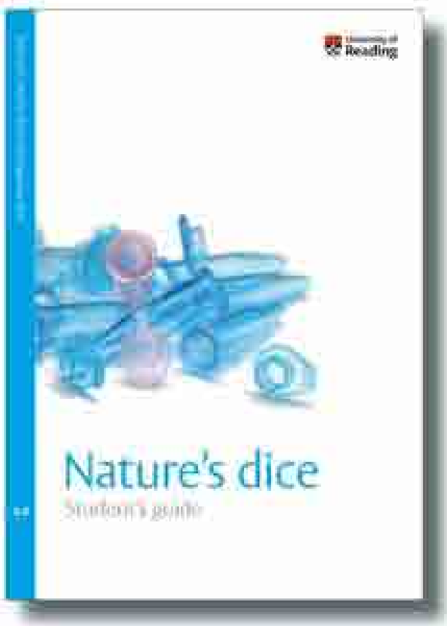
Students treat the DNA samples provided with a restriction enzyme and run them on electrophoresis gels. The results from the class are combined so that the pattern of inheritance may be determined.

This activity is a novel practical way of reinforcing learning about Mendelian inheritance, the use of restriction enzymes and gel electrophoresis. It presents an ideal opportunity to stimulate discussion about genetic counselling, confidentiality of genetic information and other ethical concerns.

Kit contents

The module contains materials for 2 complete 'runs' of the *Nature's dice* protocol, each with 24 students or working groups. The kit includes:

- 1 fixed-volume 25 µL minipipette
- 25 µg 1 kb DNA 'ruler'
- DNA samples
- 48 tubes of *Bam*HI restriction enzyme (blue)
- 48 1.5 mL microcentrifuge tubes
- Floating tube holder
- 2 g DNA electrophoresis-grade agarose
- 100 microsyringe tips
- 8 sheets of carbon fibre electrode material
- 50 mL TBE buffer (10x concentrate)
- 8 1.5 mL bromophenol blue loading dye
- 50 mL Azure A stain for DNA (2x concentrate)
- 8 copies of the student's guide (full colour)
- Teacher's guide



You will also need equipment for DNA gel electrophoresis. A 'Base unit' containing eight sets of inexpensive electrophoresis equipment can be purchased from the NCBE, as can a suitable 36 volt mains transformer (which will power four gel tanks). Individual replacement items are also available.

National Centre for Biotechnology Education
University of Reading, Earley Gate, Reading, RG6 6AU, United Kingdom.

www.ncbe.reading.ac.uk

An Inconvenient Truth

By Al Gore

Reviewed by Bernhard Haubold, Max Planck Institute for Evolutionary Biology, Ploen, Germany

Horror movies are a popular, albeit rather despised, film genre. It is all the more surprising that the most horrific of the current crop of scary movies has recently won an Oscar, not to mention the Nobel Peace Prize awarded to its main protagonist. Like all effective horror movies, *An Inconvenient Truth* has a slow build-up; in fact, the setting is about as banal as it gets: a public lecture given by a well-known member of the political establishment, former US Vice President Al Gore. The hair-raising message he relates is also beginning to become as clichéd as last year's favourite psychopath: inhabitants of industrialised nations are collectively destabilising Earth's climate. But as the discerning movie buff knows, it all comes down to delivery. And Gore is a master of the unsettling plotline.

It all started, he tells his audience, when one of his professors at Harvard University, Roger Revelle, presented in class the now iconic serrated curve describing the concentration of atmospheric CO_2 over time. This curve is also known as the Keeling Curve in honour of Charles Keeling, who took the CO_2 measurements from 1958 onwards. He established that in the summer, when the plants in the northern hemisphere are busy fixing CO_2, its atmospheric levels decrease; during the northern winter, they increase. So far, this is reassuringly in agreement with high-school biology.

However, the unease starts creeping in as we realise that, in the summer, the curve almost never returns to its previous minimum but levels off at a slightly higher point. The rate of this overall increase looks tiny, but a plot of atmospheric CO_2 and temperature over the past 650 000 years reveals that the two quantities are tightly correlated. And then comes the crunch: on the scale of the past 650 000 years, the increase in CO_2 since World War II is extremely rapid. More disquieting still, the current level of atmospheric CO_2 is unprecedented over the past 650 millenia.

So what? If it gets a bit hotter, crank up the air conditioner, get a beer from the fridge and rent another gory movie. The trouble is, Gore points out, that as the ice at the poles melts due to global warming, less sunlight is reflected by the polar glaciers, which creates a positive feedback cycle of warming at the poles. The effects of this are visible all around us: of the 21 hottest years since 1860, 20 occurred over the past quarter of a century. The heat wave of summer 2003 caused thousands of deaths in Europe. Hotter summers are correlated with stronger cyclones. Gore punctuates his slide show with footage taken in 2005 when Hurricane Katrina devastated New Orleans.

The ex-Vice President is not a scientist (he trained as a lawyer) and his presentation is a work of advocacy aimed at a lay audience. Having said that, unless you are an earth scientist, you will probably find something new and stimulating in what he is saying.

This is particularly true if you read the book of the same name. I found the film moving, but the book – with its carefully presented charts and statistics – more rewarding. Being rich today means rich in fossil fuels. It is no coincidence that the leaders of the USA and Russia, and the previous Chancellor of Germany, are closely allied with oil and gas companies. The carbon consumers in the G8 countries are causing environmental change that has its gravest effects on the poorest countries. This thought alone should rouse us enough to act upon Gore's inconvenient truth.

Details

Book

Publisher: Bloomsbury Publishing

Publication year: 2007

ISBN: 9780747590965

DVD

Publisher: Paramount Home Entertainment

Release year: 2006

Just a Theory: Exploring the Nature of Science

By Moti Ben-Ari

Reviewed by Andreas Quale, Department of Teacher Education and School Development, University of Oslo, Norway

It is a regrettable fact that there is a marked decline of interest in learning about science among school students today (in many developed countries, at least). In fact, there appears to be a widespread lack of understanding and appreciation of scientific issues among the general public. One observes a trend of distrust (and even rejection) of science, along with an upsurge of interest in various kinds of pseudo-science: astrology, creationism, faith healing and occultism, for example. This presents us with predicaments on many levels: diminishing recruitment of skilled personnel into scientific and technological professions, and less opportunity for an informed public participation in the societal discourse on issues involving science and technology. This poses a problem for the science education community: how do we (and how should we) present science to students and to the general public?

In this situation, *Just a Theory: Exploring the Nature of Science* from Moti Ben-Ari is a timely and welcome addition to the literature. It presents an extensive general overview of the basic nature of science: how it works, what it claims, what it is (and, equally important, what it is not), and what it does (in contrast to several popular misconceptions of science). The topics covered include some fundamental scientific concepts (such as induction and deduction, observation and experiment, prediction and retrodiction, explanation and mechanism, and evidence and falsification), science versus pseudo-science, science versus religion, the role of logic and mathematics, the sociology of science, and the postmodernist critique.

For a book of this modest size (some 230 pages), the presentation of the various topics is quite thorough and comprehensive. Some of the points discussed are rather controversial (for instance, the continual confrontation with creationism) and the style of argumentation then becomes a bit polemical. Nevertheless, *Just a Theory* manages to give a reasonably fair exposition of the subject matter, as viewed from the standpoint of science and assessed by scientific criteria.

There is one issue, concerning the philosophy of science, that I would have liked to see receive a more extensive and equitable treatment: namely, the dichotomy of realism versus idealism. Without explicitly stating it, the author comes out strongly on the side of realism but he gives the other side rather short shrift, more or less dismissing it out of hand as 'relativism' and as being 'unscientific'. Now, this topic is central to much of the current debate in the philosophy of science, and I would suggest that it merits a more balanced review than is given here. This is, however, a minor criticism.

Concerning the book itself: the style of writing is light without loss of precision, often humorous, at times polemical – in short, an enjoyable read. An extra plus is the short biographical sketches of important scientists which appear at the end of each chapter – they add perspective and depth to the discussion. The text should be quite easy to follow for students at university level, and even for students in upper secondary school (with some help from the teacher in parts). I believe that this book would be a very good choice for a course on the nature of science – a topic that, in my view, should be mandatory in the education of science teachers at all levels. In addition, I believe that the teaching of science in secondary school would also be considerably enriched by including a judicious selection of material presented in *Just a Theory*, to help the students acquire some deeper understanding of the basic features of science.

Details

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Can You Feel the Force? Putting the Fizz Back into Physics

By Richard Hammond

Reviewed by Jennie Hargreaves, Lockerbie Academy, UK

Any book that has in its introduction "Physics is the action department of science... only physics can explain what happens if you throw [an apple] at a brick wall at 200 mph" has my attention.

In addition to such punchy text, *Can You Feel The Force?* by Richard Hammond includes beautiful colour photographs and is creatively presented in a format that is typical of the publisher, Dorling Kindersley. For example, some of the pages are printed upside down to indicate opposites: the spread on light wave/particle duality has the particle information the right way up but the wave material upside-down. This approach is also used for the 'slip and grip' pages.

The book begins with a timeline for some of the major fathers of science, starting with the ancient Greeks, such as Aristotle, continuing with Archimedes, Copernicus and Galileo, and finally ending with Newton. You won't find any women here, although Marie Curie is included in the modern timeline at the back of the book – together with Einstein, Heisenberg and Dirac.

The book suggests that scientists are eccentric and that science and religion cannot function together because they are diametrically opposed. For example, it states, "Like many great thinkers and scientists, Aristotle was a little eccentric." I am not sure that it will encourage young people to study science if we are all seen as mad. Likewise, although the church has held back some scientific ideas, religion and science can both aid our understanding of the world. These stereotypes deserve to be challenged.

The book has some inconsistencies – for example, the assertion that "There are forces acting on you all the time" contrasts with the statement that "before you set off, your bike is standing still because there's no force acting on it." There are other criticisms that could be made, but this is a book that can be read and enjoyed even by children who would never open a standard physics book.

My two children, who love reading, found the book very enjoyable. My 9-year-old son wants to make a secret squirter. This is built from a plastic bottle filled with water with the words 'DO NOT OPEN' written on it. Holes are made in the bottle with a pin, and the water will only leak out when the lid is taken off. My 12-year-old daughter initially felt that the book was for 7 to 9-year-olds because of the large print and layout, but eventually got lost in string theory as it does cover some heavy science.

Can You Feel the Force? would be excellent in the school library with a couple of extra copies on the classroom shelf. Teachers could try the short experiments, use the book to generate questions, or give the students tasks to do at home.

Details

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Volcano Island

By David Lea and Professor Steve Sparks

Reviewed by Caroline Neuberg, Guiseley School, UK

Image courtesy of Marco Fulle

The Soufrière Hills volcano in Montserrat

If you ask Italian school students to name an active volcano in their country, they will have a wealth of names – such as Vesuvius, Etna, Stromboli and all the other Aeolian Islands – to choose from. Ask students in France to name an active French volcano, and they may be able to name volcanoes from the country's overseas territories, such as Piton de la Fournaise on Réunion island, La Grande Soufrière on Guadeloupe and the infamous Montagne Pelée on Martinique. A similar question posed to a school pupil in the UK would probably produce a blank stare, however – disbelief that such a thing as an active British volcano even exists.

In 1995, the inhabitants of the beautiful island of Montserrat, a rich and flourishing British overseas territory in the West Indies, realised with surprise that Soufrière Hills, a dormant volcano on the island, had awakened. The capital of the island, Plymouth, was evacuated and later destroyed by volcanic activity in 1997. Of the initial 12 000 inhabitants, 8000 were forced to leave the island, relocating to neighbouring islands, such as Antigua, or distant and cold Britain. The remaining population moved to the undeveloped and more austere northern side of the island. With their economy and infrastructure destroyed, Montserratians learned to live alongside their ash-spewing, earth-shaking and growing volcanic neighbour. Twelve years on, this volcano is still active and still disrupting their lives.

When taught about the rock cycle in Year 8, English students aged 12-13 are sometimes shown extracts from *Dante's Peak*, a 1997 Hollywood movie starring Pierce Brosnan. Though Brosnan is a charming and convincing volcanologist in the film, he does study a highly unusual volcano that can produce very low and very high viscosity lava in the same cycle of eruptions. In contrast, the educational documentary *Volcano Island* presents an accurate scientific picture of what it is like to live in the shadow of a volcano. Describing the story of a real volcano, the film has been created by a volcanologist and an experienced videographer, and is aimed at students who want to learn the scientific aspects of volcanology.

Sponsored by The Royal Society, David Lea, a Montserratian videographer, and Professor Steve Sparks, a world-renowned volcanologist at Bristol University, UK, produced *Volcano Island* to tell the real story of Montserrat's misfortune. Available on DVD, it is specifically aimed at secondary-school pupils. Using simple language and the bare minimum of scientific jargon, the film cleverly explains the reason for the presence of a volcano on this particular island. It then describes the volcanic products emitted by the volcano and how they affect the lives of the people living on the volcanic flanks.

The activity of Hawaiian volcanoes is then compared with that of Montserrat. Hawaiian basaltic volcanoes eject a low-viscosity lava, forming dramatic fountains and flows. In contrast, the andesitic volcano on Montserrat extrudes a thick, viscous lava that piles up at the vent, forming a grey dome. When the dome reaches a certain volume and the pressure inside the volcano reaches a certain threshold, the volcano blows its top in a spectacular but dangerous way, forming so-called pyroclastic flows or *nuées ardentes*. As explained in *Volcano Island*, pyroclastic flows are very hot and fast-moving currents comprising rocks, ash and gas, which destroy, burn and bury everything in their path. Such flows from Mount Vesuvius in Naples and Mount Pelée in Martinique eradicated Pompeii in 79 AD and Saint Pierre in 1902, respectively. Both events killed thousands of people.

The film explains, in a very concise manner, how scientists monitor the activity of the Soufrière Hills volcano. It shows how the work of the scientists, who try to understand and predict volcanic behaviour, can help politicians decide whether to evacuate certain parts of the island. It also mentions the dreadful eruption of June 1997 in which 19 Montserratians lost their lives. In an emotional interview, a witness of the eruption recalls her experience.

Scientifically, *Volcano Island* presents a wealth of information on the physical processes acting during this ongoing eruption. Moreover, it also depicts the economic and social disaster that struck the island and its inhabitants. The scientific quality of this movie is strongly reinforced by the amazing footage of eruptions.

Details

Publisher: Price of Paradise

More information about this DVD is available on the Price of Paradise website (www.priceofparadise.com). Alternatively, you can contact David Lea (lead@candw.ms).

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