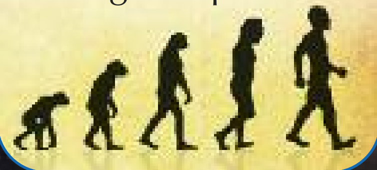
Summer 2010 Issue 15

SCIENCE in SCHOOL

In this issue:

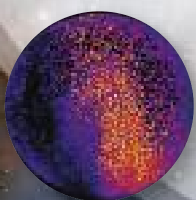
EIROforum: introducing the publisher of *Science in School*

The winners of the *Science in School* writing competition



ESOF special issue

ESOF2010 EUROSCIENCE OPEN FORUM TORINO, JULY 2-7 PaSsion For ScieNCe



EIROforum

Highlighting the best in science teaching and research

Editorial

Welcome to the fifteenth issue of *Science in School*

Have you ever wondered who is behind *Science in School?* We would like to present our publisher, EIROforum: a collaboration between seven European inter-governmental scientific research organisations.

If you attend the Euroscience Open Forum from 2-7 July 2010 in Turin, Italy, you can meet us in person. For five days, the streets of Turin come to life with public science events. In the conference venue itself, members of the public will join scientists, politicians, teachers and journalists to discuss discoveries and developments in science. To learn more about EIROforum and the activities of its member organisations, why not visit the EIROforum stand in the conference exhibition?

For those of you who won't be in Turin, this issue of *Science in School* offers an overview of the seven organisations (page 8). We also highlight some of their projects, such as ALMA, the world's largest radio astronomy facility (page 44), and the digital zebrafish embryo (page 18). Of course there's plenty more to discover in this issue – and don't forget that whereas most of the articles are in the print version, some are online only.

The *Science in School* website offers much more, however, than these online-only articles. For example, all the *Science in School* articles ever published are freely available online – not only in English, but also in many other European languages. You can find them either by browsing the archive or via the links to specific topics, categories or languages at the top of each page. If you're looking for similar articles to the one you're reading, use the linked keywords at the bottom of each article. On our home page, we regularly highlight series of articles on a particular topic, such as climate change, energy or evolution.

To be notified when each new issue is published, subscribe to our email alert. If you're interested in something particular, such as articles in Italian, or about physics, you can also subscribe to an RSS feed – whenever something relevant is added to the website, you'll receive a message.

The *Science in School* website doesn't offer just articles, however – our forum allows teachers and scientists from across the world to exchange ideas and opinions. For example, is it useful to dissect animals at school and is it ethically acceptable? What do you think research scientists can do to help teachers?

Finally, if you live in Europe and don't already receive a print copy of *Science in School*, you can subscribe, free of charge, on our website.

We hope you'll find these and other features of our website useful. To learn more about them, see our help page: www.scienceinschool.org/help.

Marlene Rau
Editor of *Science in School*
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www.scienceinschool.org

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.

The journal addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge scientific research. It covers not only biology, physics and chemistry, but also earth sciences, maths, engineering and medicine, focusing on interdisciplinary work. The contents include teaching materials; cutting-edge science; interviews with young scientists and inspiring teachers; reviews of books and other resources; and European events for teachers and students.*Science in School* is published quarterly, both online and in print. The website is freely available, with articles in many European languages. The English-language print version is distributed free of charge within Europe.

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Subscriptions

Register online to:

- Receive an email alert when each issue is published
- Request a free print subscription (within Europe)
- Swap ideas with teachers and scientists in the *Science in School* online forum
- Post comments on articles in *Science in School*.

Submissions

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

Referee panel

Before publication, *Science in School* articles are reviewed by European science teachers to check that they are suitable for publication. If you would like to join our panel of referees, please read the guidelines on our website.

Book reviewers

If you would like to review books or other resources for *Science in School*, please read the guidelines on our website.

Translators

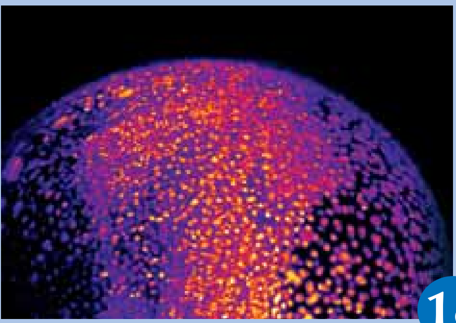
We offer articles online in many European languages. If you would like to volunteer to translate articles into your own language, please read the guidelines for translators on our website.

Contents

Additional online material

See: **www.scienceinschool.org/2010/issue15**

Events calendar: **www.scienceinschool.org/events**


18


39


44


50


60

Our image of the world – a project combining astronomy and art

Schools from all over Austria display their projects

Walking with the planets *(Kinderplanetenweg)*

Science on Stage: gathering momentum

Science on Stage Austria

I was lucky enough to attend the Science on Stage Austria event as a member of the jury. After two days, my head was in a whirl: how to compare a primary school's 7 km scale model of the Solar System – complete with a rucksack full of experiments for the children to perform on each 'planet' – with a project in which secondary-school students developed experiments to explain the physics of music to younger children? And how should we judge those against some impressive original research into the effects of diet on health, performed by students at an agricultural secondary school? Only nine projects could be selected to attend the European teaching festival in Copenhagen, Denmark, in 2011[w1] – and it wasn't an easy choice for the eight scientists, educators, and members of the Austrian education ministry who made up the jury.

All the 41 projects presented were wonderful; all represented inspiration and hard work by teachers and students alike. There were ideas for measuring your mass (not your weight), getting a feel for food webs (with the help of some cuddly toys), investigating the beauty of polarisation, or using Excel to model predator and prey populations; there were also plays, demonstrations and hands-on experiments. From all over Austria, 180 teachers and students came to Linz on 25-26 February 2010 to share their enthusiasm for science, to swap ideas and to gain inspiration for their teaching. Another success for Science on Stage.

For more details, including the winning projects, visit the Science on Stage Austria website[w2].

Science on Stage Belgium

Where could you take a virtual trip to Mars, learn how to build a 'green' battery, or discover the physics of music? Again, at Science on Stage – this time in Belgium, where on 27 February 2010, 140 teachers, inspectors and other participants converged on Ukkel for the Playful Science 4 event.

Walking with the planets (*Kinderplanetenweg*)

Hands-on science and technology, a travelling exhibition

Food webs – a model developed by secondary-school students for kindergarten children, sponsored by the Science Center Netzwerk[w4]

Images courtesy of Science on Stage Austria

Many of the national Science on Stage organisations are already beginning to select which teachers from their countries will attend the European teaching festival in 2011. **Eleanor Hayes** reports on the Austrian and Belgian events.

The day was full with a programme of teachers and university scientists demonstrating the delights of science. For those who preferred something hands-on, there were plenty of activities: you could test for yourself whether film stunts obey the laws of physics, run a gel electrophoresis and calculate the size of a DNA fragment, or try out a solar-powered water pump from Mauritania.

To learn more, visit the Science on Stage Belgium website[w3].

Web references

w1 – The national Science on Stage events culminate in a European teaching festival every two years, the next one being in Copenhagen, Denmark, from 16-19 April 2011. To learn more about Science on Stage and find your national contact, see the Science on Stage Europe website: www.science-on-stage.eu

w2 – More information about Science on Stage Austria is available here: www.scienceonstage.at

w3 – To find out more about Science on Stage Belgium, see: www.scienceonstage.be

w4 – Science Center Netzwerk connects interactive science centre activities throughout Austria. See: www.science-center-net.at

Resources

All previous *Science in School* articles about the Science on Stage activities can be viewed here: www.scienceinschool.org/sons

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Dr Eleanor Hayes is the Editor-in-Chief of *Science in School*. She studied zoology at the University of Oxford, UK, and completed a PhD in insect ecology. Eleanor then spent some time working in university administration before moving to Germany and into science publishing, initially for a bioinformatics company and then for a learned society. In 2005 she moved to the European Molecular Biology Laboratory to launch *Science in School*.

Image courtesy of Henrik Ehrsson

Henrik Ehrsson

Exploring out-of-body experiences: interview with Henrik Ehrsson

We've all sometimes felt 'beside ourselves', but have you ever felt that you were actually outside yourself – looking at yourself from outside your own body? **Marta Paterlini** talked to Henrik Ehrsson, a scientist studying this phenomenon.

Out-of-body experiences (OBEs) have fascinated people for millennia – their existence has raised fundamental questions about the relationship between human consciousness and the body, and has been much discussed in theology, philosophy and psychology. An OBE occurs when a person who is awake sees his or her own body from a location outside the physical body. OBEs have been reported in clinical conditions where brain function is compromised, such as stroke, epilepsy and drug abuse, or in association with traumatic experiences such as car accidents. Around one in ten people claim to have had an OBE at some point in their lives.

However, the neuroscience behind this phenomenon remains obscure. Henrik Ehrsson, a 38-year-old cognitive neuroscientist at the Karolinska Institute[w1] in Stockholm, Sweden, investigates how the brain represents the self, and has induced the phenomenon of OBE in healthy volunteers for the first time. He recreated an illusion in which individuals look at themselves from outside their physical bodies.

Henrik Ehrsson explains:

How do we recognise that our limbs are part of our own body, and why do we feel that our self is located inside the body? In my research, I am trying to identify the neuronal mechanisms that produce the sense of ownership of the body, and the processes responsible for the feeling that the self is located inside the physical body. Previously, there was no way of inducing an OBE in healthy people, apart from unproven reports in occult literature.

Could you describe your experiments?

The volunteers wear goggles with a video screen for each eye. Each screen is fed with images from a separate camera behind the volunteer and, because the two images are combined by the brain into a single image, the individual sees a stereoscopic (3D) image of his or her own back. We

Image courtesy of Henrik Ehrsson

Inducing an out-of-body experience

then move a plastic rod towards a location just below the cameras while the volunteer's chest is simultaneously touched in the corresponding position. The participants reported feeling that they are located back where the cameras are placed, watching a body that belongs to someone else.

To test the illusion further and provide objective evidence, I then performed an additional experiment to measure the volunteers' physiological response – specifically the level of perspiration on the skin – in a scenario in which they feel that their illusory body is threatened. Using a hammer, we 'attacked' a point below the cameras – a point where, according to the illusion, the volunteer's body was located. The volunteer's bodily response strongly indicated that he or she thought the threat was real: at the moment when the hammer 'hit' the illusory body, the volunteer sweated more. This demonstrates that the experience of being localised within the physical body can be determined by the visual perspective in conjunction with correlated multisensory information from the body.

Body swapping with a mannequin

Image courtesy of Staffan Larsson

Then you went further, successfully creating the illusion of body swapping by making volunteers perceive the bodies of mannequins and other people as their own, putting a male in a female body, a young person in an old body, a white person in a black body, and vice versa.

Yes, we presented evidence that the brain, when tricked by optical and sensory illusions, can quickly adopt another human form as its own, no matter how different it is. We designed two experiments. In the first one, the researchers fitted the head of a mannequin with two cameras connected to two small screens placed in front of the volunteer's eyes, so that the volunteer could see what the mannequin 'saw'.

When the mannequin's camera eyes and the volunteer's head, complete with the camera goggles, were direct-

REVIEW

- Biology
- Neurology
- Ages 15–18

This article discusses out-of-body experiences and makes you think about what determines your feeling of self, encouraging you to think about what you really are, how you feel about your body, which concepts are generated purely by our minds, and how easy it is to trick the brain. The article makes you want to be part of the research group and have an out-of-body experience yourself.

In the classroom, the article could be used to discuss neurology and the human brain.

Andrew Galea, Malta

ed downwards, the volunteer saw the dummy's body where he or she would normally have seen his or her own body. By simultaneously touching the stomachs of both the volunteer and the mannequin, we could create the illusion of body swapping. The volunteer could then see that the mannequin's stomach was being touched while feeling (but not seeing) a similar sensation on his or her own stomach. Thus, the volunteer developed a powerful sensation that the mannequin's body was his or her own.

In the second experiment, we mounted the camera onto another person's head. When this person and the volunteer turned towards each other to shake hands, the volunteer perceived the camera-wearer's body as his or her own. The volunteers saw themselves shaking hands, experiencing it as though they were another person. The sensory impression from the handshake was perceived as though coming from the new body, rather than the volunteer's own.

The strength of the illusion was proved when the volunteers exhibited stress reactions after a knife was held to the camera-wearer's arm but not when it was held to their own. However, the volunteers could not fool themselves into identifying with a non-humanoid object, such as a chair or a large block.

Did you detect any gender-based difference in the volunteers' reactions?

We did not find any differences in gender. Everybody was very quick in recognising the new body. During one session, a very fit woman did not like the body of the scientist she swapped with, and was extremely relieved to be back in her own body. And one rather hairy male volunteer adapted well to being the mannequin but was shocked to realise how hairy he was, once he was back in his own body!

What kind of applications might your studies have in medicine or in general?

The knowledge that the sense of self-perception can be manipulated to make people believe that they have a new body can be used in virtual reality applications and robot technology, of course – for example, in the development of a prosthetic limb that feels just like a real limb, or as a method of controlling humanoid robots by the illusion of 'becoming the robot'.

Inducing an OBE could also have industrial applications. This is essentially a means of projecting yourself – a form of cognitive 'teleportation'. If we can project people into a virtual character, so they feel and respond as if they were really in a virtual version of themselves, just imagine the implications. For example, a surgeon could perform remote surgery, by controlling their virtual self from a different location.

Swapping bodies with another human

Image courtesy of Staffan Larsson

When did you become interested in science? Did anyone in particular inspire you?

I started being interested in science very early, when I was 7-8 years old and my father gave me a microscope and a chemistry box. But there was not really a person [who inspired me]. The topic itself inspired me and books played a big role, really. Science was my major topic and I pursued medical studies with the idea that I wanted to become a scientist. As I became fascinated by the brain, instead of attending boring courses on the physiology and anatomy of the body, I craved books on consciousness and realised that so little was known about the brain and the mind.

What would you recommend to teenagers who would like to get into science? Do you have any tips about specific fields or career moves? Which qualities should a good scientist have?

I would recommend them to follow their hearts. Science is hard in the sense that you are supposed to solve problems and when you succeed you want to find and solve more problems. Sometimes it's a struggle and the challenges seem insuperable. Passion is the trigger, but you also need a long-term, defined goal. It is a combination of curiosity, passion, knowledge, hard work and a bit of luck as well. Last but not least, the right environment, where you can grow, and the right financial and intellectual support.

Do you think that science will eventually explain everything?

Absolutely! It might take hundreds of years, but I definitely think that science will explain even such a complex matter as the human mind. Philosophers might not like it and still claim that there are unsolved questions about the mind, but we are deconstructing each component.

Web reference

w1 – To learn more about the Karolinska Institute, one of Europe's largest medical universities, see: www.ki.se

Resources

To learn more about Henrik Ehrsson's research and download (free) the original research articles, see the website of his research group: www.ehrssonlab.se

If you enjoyed this article, you may like to read the other feature articles published in *Science in School*. See: www.scienceinschool.org/features

Marta Paterlini is an Italian freelance science writer based in Stockholm, Sweden. Since 1995, she has contributed regularly to *Le Scienze* (the Italian edition of *Scientific American*) and *La Stampa* (the third major Italian national newspaper).

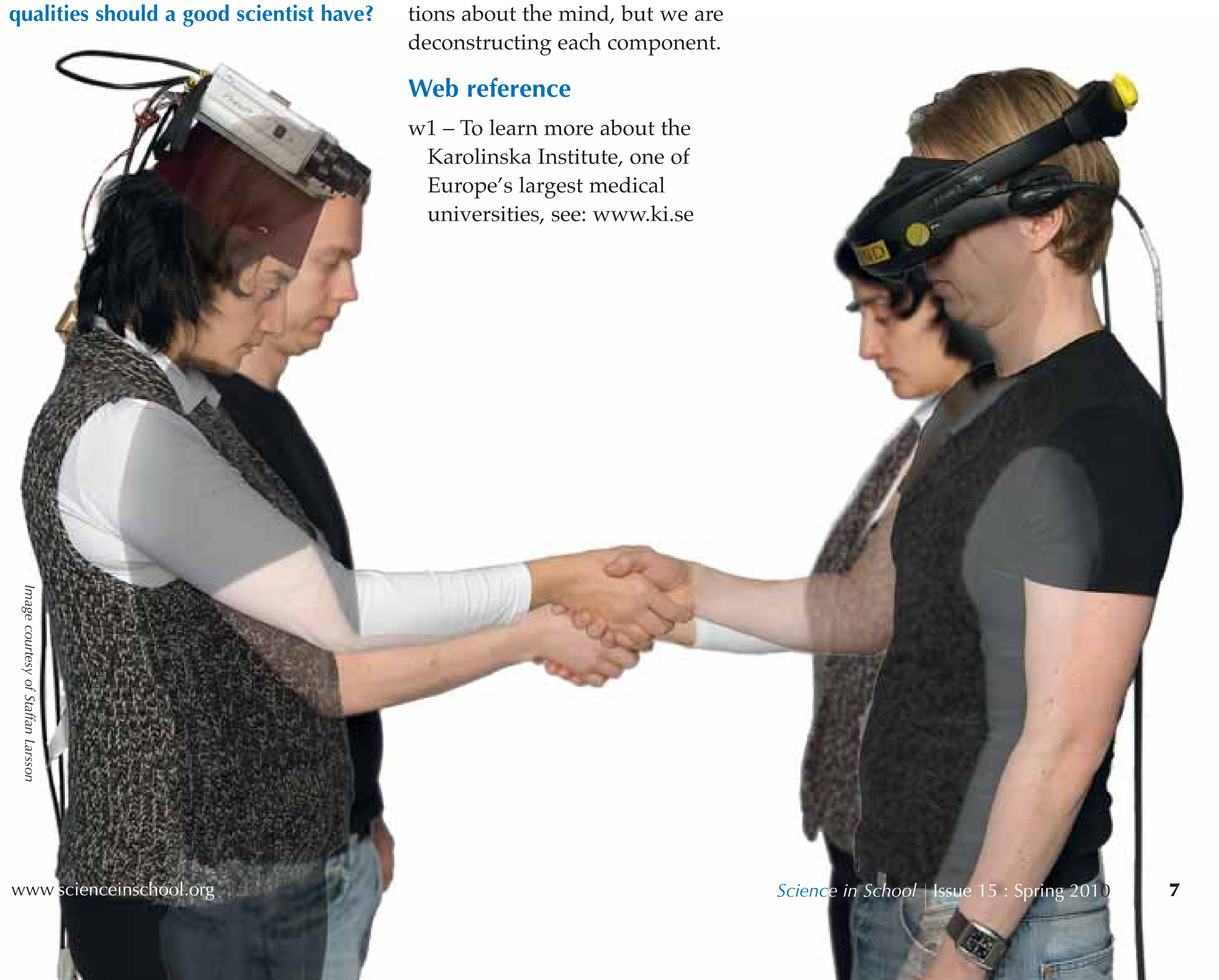


Image courtesy of Staffan Larsson

EIROforum: introducing the publisher of *Science in School*

EIROforum

EIROforum[w1] is a collaboration between seven European inter-governmental scientific research organisations. The organisations focus on very different types of research – from molecular biology to astronomy, from fusion energy to space science. They use very different techniques – including enormous particle accelerators, beams of neutrons or high-energy X-rays, large telescopes or the International Space Station. Nonetheless, the seven organisations share a common structure and – as EIROforum – a common mission.

Each of the organisations (known as EIROs) is funded by member states, which share the costs and can send their scientists to use the facilities. By combining the financial resources of many countries, these organisations provide equipment and facilities far more sophisticated than any one country could afford, enabling world-class scientific and technological research in interdisciplinary fields.

As EIROforum, the EIROs come together to support European science by sharing their experience, resources and facilities. Together, they interact with the European Commission and other organs of the European Union, national governments, industry, science teachers, students and journalists. By co-operating on large-scale outreach activities, EIROforum communicates the importance and fascination of science to a wide audience. Through *Science in School*, for example, EIROforum motivates and encourages young people to explore scientific subjects, and shows them that science is a rewarding career.

EFDA-JET, Abingdon, United Kingdom
ESA headquarters, Paris, France
EMBL headquarters, Heidelberg, Germany
ESO headquarters, Garching, Germany
CERN, Geneva, Switzerland
ESRF, Grenoble, France
ILL, Grenoble, France

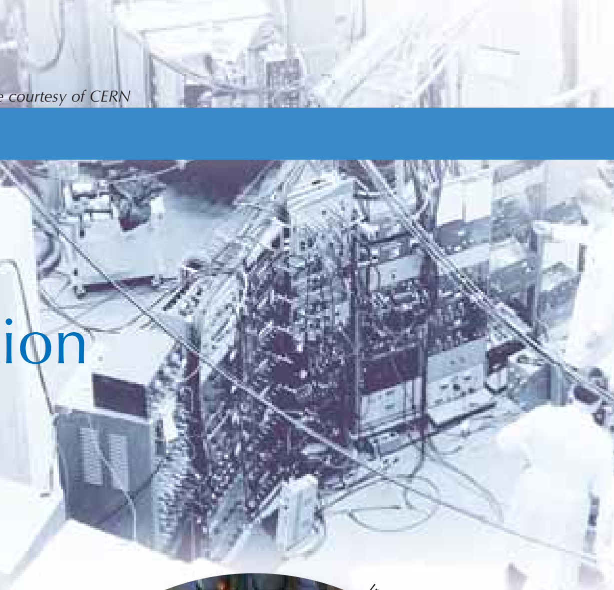


Image courtesy of CERN

CERN, the European Organization for Nuclear Research

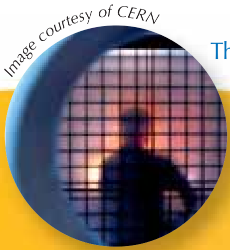


Image courtesy of CERN

The CLOUD experiment

Image courtesy of CERN

Inside the CLOUD experiment

Image courtesy of CERN

The Large Hadron Collider

CERN[w2] is the world's largest particle physics laboratory, and is based in Geneva, Switzerland. Research focuses on fundamental physics: using some of the world's largest and most complex scientific instruments to study the basic constituents of matter – the fundamental particles. By studying what happens when these particles collide, physicists learn about what the Universe is made of and how it works.

The instruments used at CERN are particle accelerators and detectors. Accelerators boost beams of particles to high energies before they are made to collide with each other or with stationary targets. Detectors observe and record the results of these collisions. The newest of CERN's instruments is the Large Hadron Collider (LHC), a 27 km long particle accelerator spanning the French-Swiss border.

Does particle physics have its head in the clouds?

While the LHC is delivering its first beams for experiments, the 50-year-old Proton Synchrotron is being used to investigate Earth's climate.

Although many experiments worldwide are investigating what affects the planet's climate, the CLOUD experiment at CERN is the only one that makes use of a particle accelerator. In the experiment, a beam of protons is used to simulate the difference of particle flux in the atmosphere, which varies by a factor of 100 from ground level to the outermost layers of the stratosphere.

From the Proton Synchrotron, protons enter the experiment's 3 m diameter aerosol / cloud chamber, which accurately recreates various conditions in the atmosphere. The chamber is fitted with an array of sensitive analytical instruments to follow the processes involved: the birth of embryonic aerosols, and their growth to become the seeds for cloud droplets and ice particles. CLOUD will also study the effect of cosmic rays on the cloud droplets and ice particles.

CLOUD is unique in that the parameters that are likely to affect cloud formation can be controlled in the laboratory. CLOUD scientists can vary the chemicals involved and the temperatures of the gas in the chamber. The temperature in the cloud chamber can be varied from -90 °C to +40 °C, which essentially covers the range of atmospheric temperature from the coldest part of the stratosphere to the warmest part of the troposphere.

Ultimately, by modelling how cloud processes affect climate, the CERN scientists and their collaborators hope to be able to investigate possible additional causes of climate change.

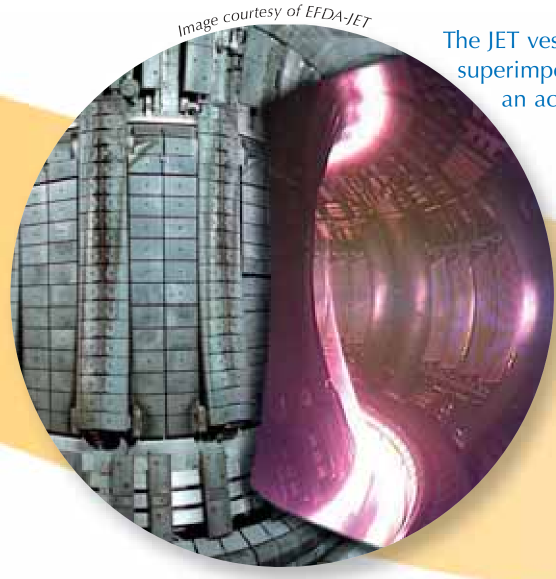
For more information, see Erlykin et al. (2010), CERN (2009), the CLOUD website[w3], and an online lecture about the CLOUD experiment[w4].

The European Fusion Development Agreement – Joint European Torus (EFDA-JET)

EFDA-JET[w5] is Europe's fusion experiment, based at Culham Science Centre in the UK. JET is the world's largest tokamak – a device that uses hugely powerful magnetic fields to confine a very hot gas or plasma so that the hydrogen nuclei in the plasma fuse together to release energy.

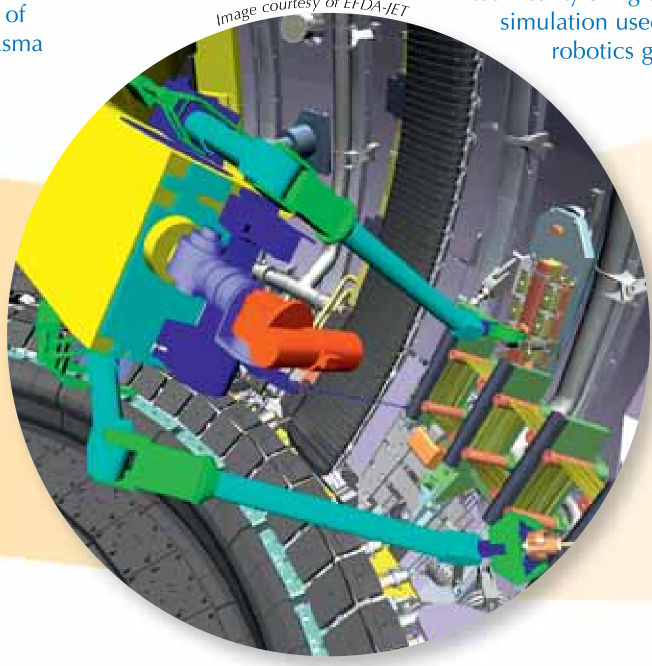
The world's largest fusion experiment, JET is currently the only machine that has created fusion – with temperatures reaching an amazing 150 000 000 °C in the centre of its plasma. At the forefront of research to exploit fusion for commercial electricity generation, JET focuses on key issues for its successor, ITER[w6], an international tokamak experiment being built in France.

Image courtesy of EFDA-JET



The JET vessel with a superimposed image of an actual JET plasma

Image courtesy of EFDA-JET



Virtual reality 3D graphical simulation used by JET robotics group

Another brick in the wall

In fusion devices such as JET, components close to the plasma are constantly bombarded by heavy bursts of heat and neutrons from the turbulent, writhing plasma as it tries to escape from its magnetic cage. Some components have to withstand peak temperatures of more than 1000 °C, despite being actively cooled. As a result, potential damage to plasma-facing walls is a real challenge for fusion research and technology, and identifying new durable materials is crucial in progress towards fusion power plants of the future.

As part of a €60 million enhancement programme, JET is being fitted out with a new internal wall made of the same materials that ITER will eventually use. This is a mammoth undertaking. During all of 2010, more than 4500 carbon fibre composite components that line the inner wall of the machine will be replaced by beryllium- and tungsten-coated components, testing the robotic capability of JET's remote handling systems to its limits.

But when operations restart in 2011, the revamped machine will have the capability of going far beyond current performance levels. The upgraded JET has an ambitious aim: to increase the world-record 16 MW of fusion power produced back in 1997 to 30 MW.

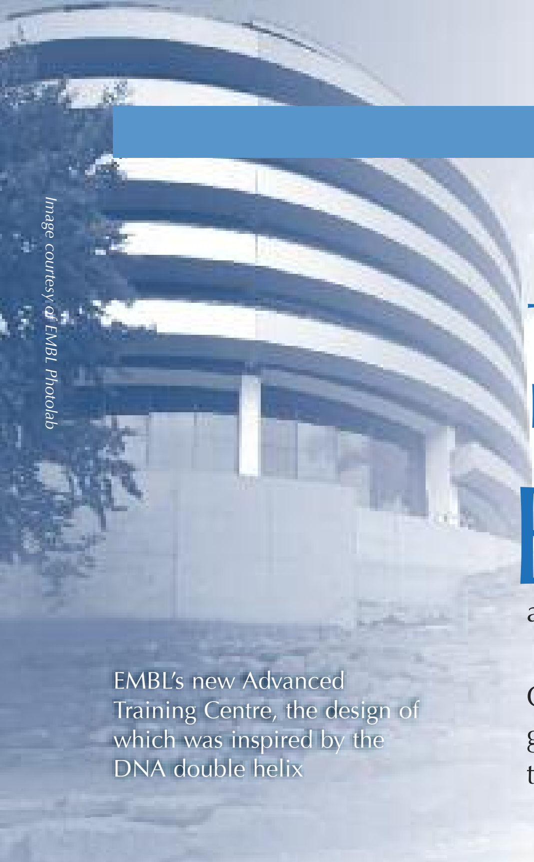


Image courtesy of EMBL Photolab

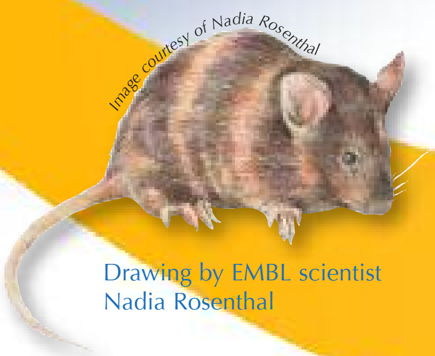
EMBL's new Advanced Training Centre, the design of which was inspired by the DNA double helix

The European Molecular Biology Laboratory (EMBL)

EMBL[w7], with its main laboratory in Heidelberg, Germany, is dedicated to basic research covering the full spectrum of molecular biology at all levels, from the molecule to the organism, as well as computational biology, bioinformatics and systems biology.

Many scientific breakthroughs have been made at EMBL, most notably Christiane Nüsslein-Volhard and Erich Wieschaus's discovery of important genetic mechanisms that control early embryonic development, for which they were awarded the Nobel Prize in Physiology or Medicine in 1995[w8].

Image courtesy of Nadia Rosenthal



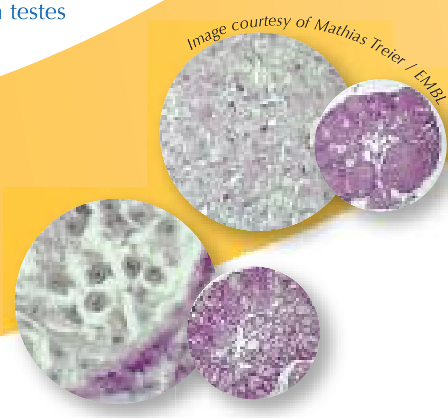
Drawing by EMBL scientist Nadia Rosenthal

An EMBL scientist at work

Image courtesy of EMBL Photolab

Ovary of a normal adult female mouse, with close-up showing the typical female granulosa cells (right), which, when *Foxl2* was silenced (left), took on characteristics of cells normally found in testes

Image courtesy of Mathias Treier / EMBL



EMBL

Gender-bending mice: insights into sex determination

In humans and most other mammals, an individual's sex is determined by its sex chromosomes: females have two X chromosomes, and males have an X and a Y. Scientists had long assumed that the female pathway – the development of ovaries and all other female traits – was the default: if an embryo had a gene called *Sry*, which is located on the Y chromosome, it would develop into a male; if not, then the result would be a female.

A gene called *Foxl2*, which is located on a non-sex chromosome and therefore present in both sexes, was known to play an important role in the female pathway, but its precise function remained elusive. When EMBL scientists and their UK collaborators turned off this gene in the ovaries of adult female mice, they found that cells in the ovaries turned into cells typically found in testes.

"We were surprised," says Mathias Treier, one of the EMBL scientists. "We expected the mice to stop producing oocytes, but what happened was much more dramatic: …cells which support the developing egg took on the characteristics of cells which usually support developing sperm, and female hormone-producing cells switched to the male type." This challenges the long-held assumption that the development of female traits is a default pathway, showing that the male pathway needs to be actively suppressed, and also grants a valuable insight into how sex determination evolved.

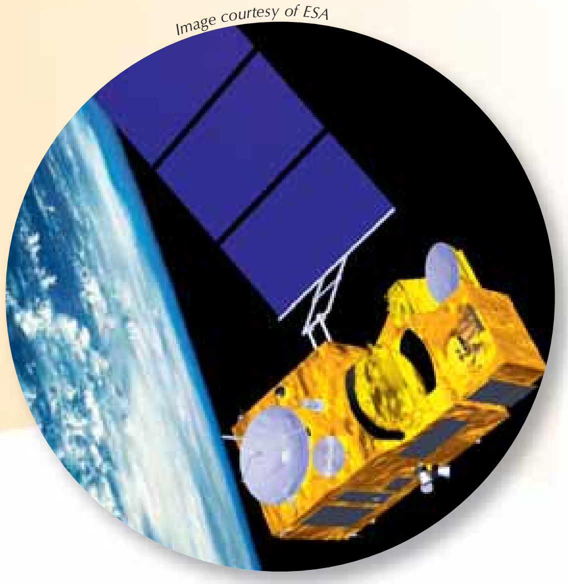
These findings will have wide-ranging implications for reproductive medicine and may help to treat sex differentiation disorders in children or to understand the masculinising effects of menopause on some women.

For more information, see the original publication in *Cell* (Uhlenhaut et al., 2009) and Mathias Treier's online presentation[w9].

Image courtesy of ESA / D Ducros

Artist's impression of the Cupola observation module of the International Space Station

Image courtesy of ESA



MEMS gyros will fly on ESA's Sentinel-3 satellite, scheduled to be launched in 2013, which will provide global ocean, ice and land vegetation observations

Image courtesy of ESA

MEMS rate sensor

The European Space Agency (ESA)

ESA[w10] is Europe's gateway to space. From its headquarters in Paris, France, ESA runs programmes to find out more about Earth, its immediate space environment, our Solar System and the Universe, as well as to develop satellite-based technologies and services, and to promote European industries. Together with the US National Aeronautical and Space Administration (NASA), the Russian Federal Space Agency (Roscosmos), the Canadian Space Agency (CSA) and the Japan Aerospace Exploration Agency (JAXA), ESA operates the International Space Station[w11].

'Sugar-cube' sensors to monitor Earth's orientation

One of ESA's future Earth observation missions will monitor Earth's orientation in space with the help of the smallest gyro ever flown by Europe. Now being tested, the sugar cube-sized device at the heart of the gyro unit is derived from a sensor used in anti-lock braking systems on millions of cars: micro-electro mechanical systems (MEMS).

There is no up or down in space. Satellites track their pointing direction using the same approach that is used onboard submarines and aircraft: fast-spinning gyroscopes that maintain a fixed orientation in the same way as a child's spinning top. But space-quality gyros employing this principle are complex, bulky and insufficiently reliable for long space missions.

For ESA, therefore, MEMS are an especially promising innovation. They are made in a similar way to microprocessors but incorporate moving parts or sensors, enabling complete devices to be fitted onto a single silicon chip.

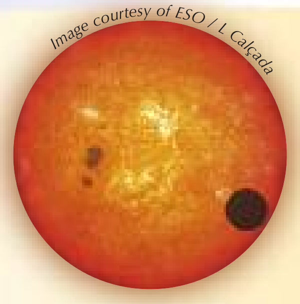
Attractive for space because of their small size, low power consumption and resistance to vibration, these micro-machined devices may sound exotic, but MEMS sensors are already used in their millions on European roads. In the last 15 years, the automobile industry has adopted MEMS in a major way. The devices are embedded throughout modern cars: MEMS accelerometers trigger airbags, MEMS pressure sensors check tyres and MEMS gyros help to prevent brakes locking and maintain traction during skids. And soon there will be MEMS in space, helping to monitor the orientation of Earth. Not bad for something the size of a sugar cube.

To find out more about the use of MEMS in Earth observation, visit the ESA website[w12].

Image courtesy of ESO / J Emerson / VISTA

The European Southern Observatory (ESO)

Image courtesy of ESO / L Calçada



Artist's impression of the newly discovered exoplanet GJ1214b

Image courtesy of ALMA (ESO / NAOJ / NRAO) L Calçada / H Heyer / H Zodet

Artist's vision of the future: ALMA

Image courtesy of ESO / J Emerson / VISTA. Acknowledgement: Cambridge Astronautical Survey Unit

VISTA'S infrared view of the Orion Nebula

ESO[w13] is the foremost inter-governmental astronomy organisation in Europe and the world's most productive astronomical observatory. From its headquarters in Garching, Germany, ESO operates three world-class observing sites in Chile: La Silla, Paranal and Chajnantor. At Paranal, ESO operates the Very Large Telescope, the world's most advanced visible-light astronomical observatory, and VISTA, the world's largest survey telescope. ESO is the European partner of a revolutionary astronomical telescope, ALMA, the largest astronomical project in existence, which is being constructed in Chajnantor. ESO is currently planning the European Extremely Large optical/near-infrared Telescope, the E-ELT, which will become 'the world's biggest eye on the sky'.

Orion in a new light

The Orion Nebula reveals many of its hidden secrets in a dramatic image taken by ESO's new VISTA survey telescope. The telescope's huge field of view can show the full splendour of the whole nebula and VISTA's infrared vision also allows it to peer deeply into dusty regions that are normally hidden and to expose the curious behaviour of the very active young stars buried there.

VISTA – the Visible and Infrared Survey Telescope for Astronomy – is the latest addition to ESO's Paranal Observatory. It is the largest survey telescope in the world, and is dedicated to mapping the sky at infrared wavelengths. The large (4.1 m) mirror, wide field of view and very sensitive detectors make VISTA a unique instrument. This dramatic new image of the Orion Nebula illustrates VISTA's remarkable powers.

The Orion Nebula is a vast stellar nursery lying about 1350 light-years from Earth. Although the nebula is spectacular when seen through an ordinary telescope, what can be seen using visible light is only a small part of a cloud of gas in which stars are forming. Most of the action is deeply embedded in dust clouds, and to see what is really happening, astronomers need to use telescopes with detectors sensitive to the longer-wavelength radiation that can penetrate the dust. VISTA has imaged the Orion Nebula at wavelengths about twice as long as can be detected by the human eye.

For more information, see the VISTA web pages[w14].

The European Synchrotron Radiation Facility (ESRF)

ESRF[w15] operates the largest facility for research with X-rays in Europe. Each year, 7000 researchers travel to Grenoble, France, to conduct some 1000 different experiments, all at the cutting edge of modern science. Physicists work side-by-side with chemists and materials scientists. Biologists, medical doctors, meteorologists, geophysicists and archaeologists have become regular users. Industrial applications are also growing, notably in the fields of pharmaceuticals, cosmetics, petrochemicals and microelectronics.

An aerial view of ESRF

Image courtesy of Denis Morel / ESRF

Putting a sample on a beamline

Image courtesy of G Duvernay / Insign Studio / ESRF

Viewport on an experiment in a beamline

Image courtesy of S Evans / G Carner

More sustainable plastic bags – using X-rays

In early July 2010, the ESOF meeting in Turin, Italy, will coincide with an unusual experiment at ESRF: Dutch and Italian scientists will arrive in Grenoble with a machine for manufacturing thin films such as plastic bags. The objective is to observe, in situ, how the molecular structure of thin plastic film forms, with a view to using smaller quantities of polyolefins, materials synthesised from natural gas and oil, in plastic products of the future.

Plastic films are manufactured by extrusion: plastic granulate is melted and then forced through a die (a specially designed spout that determines the shape of the extruded polymer). The die used for carrier bags differs from a standard extrusion die in that it is cylindrical and has an air ring at the top which distributes an even flow of cool air inside the cylinder. As the plastic is extruded, it forms a tube into which cold air enters through the air ring, causing the tube to expand into a bubble. The air will also cool the plastic as it is moved upwards and rolled up as a double sheet, still sealed at both sides. To produce bags, the plastic films are sealed at one end and perforated at the other end across their width (think of a roll of rubbish bags).

The quality of the bag depends on how the molten plastic solidifies as it expands and cools. At ESRF, the process of solidification will be observed with X-rays while the plastic film is being processed. The scientists will use two experimental methods: wide-angle diffraction delivers information on the structure of the crystalline fraction of the plastic polymer, whereas small-angle scattering is sensitive to the long-range order due to alternating amorphous and crystalline regions. These methods can be used in real time, while the polymer is passing from the liquid to solid state. Both the degree of crystallinity as well as the extent of the long-range order are related to macroscopic properties such as elasticity and strength, which allows the manufacturing process to be optimised, resulting in stronger but thinner plastic films and ultimately saving raw materials.

It is estimated that enough plastic film is produced and used each year to wrap our planet in three layers of polymer film. Polyolefin films will remain part of our daily life for the foreseeable future, so even small savings in their manufacture would lead to a significant reduction in natural gas and oil consumption.

To see for yourself how plastic bags are manufactured, watch a video from Stanford University online[w16].

The Institut Laue-Langevin (ILL)

Image courtesy of ILL / BRIQ

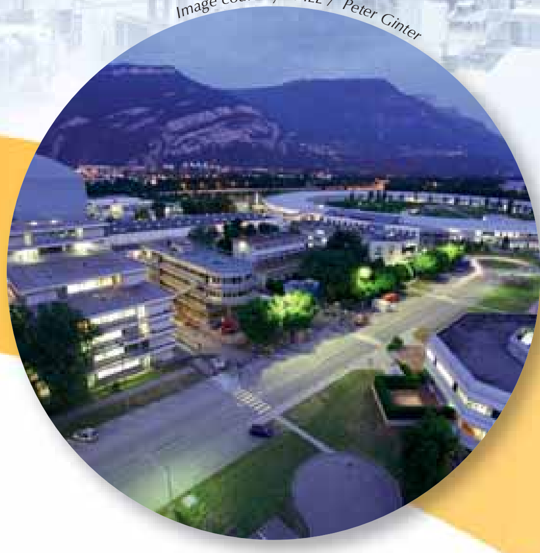
Image courtesy of ILL / Artechnique

The newly upgraded ILL small-angle scattering instrument D11

Image courtesy of ILL / Alexis Chezière

An ILL scientist at work

Image courtesy of ILL / Peter Ginter



ILL (left) and ESRF (the white ring at the back)

Based in Grenoble, France, ILL[w17] operates one of the most intense neutron sources in the world. As a service institute, ILL makes its facilities and expertise available to visiting scientists: every year, some 1200 researchers and 800 experiments from more than 40 countries. Research focuses primarily on fundamental science in a variety of fields, including condensed matter physics, chemistry, biology, nuclear physics and materials science.

Whereas some visiting scientists are working on engine designs, fuels, plastics and household products, others are looking at biological processes at the cellular and molecular level. Still others may be elucidating the physics that could contribute to the electronic devices of the future. ILL can tailor its neutron beams to probe the fundamental processes that help to explain how our Universe came into being, why it looks the way it does today, and how it can sustain life.

NEUTRONS FOR SCIENCE®

Cutting-edge science: neutrons to the aid of European industry

Stone cutting is nothing new – even our prehistoric ancestors knew how to cut stones. Nonetheless, this ancient industry has recently come under scrutiny from scientists using very modern techniques: beams of high-energy neutrons.

Like many other European industries, Europe's stone-cutting industry is under threat from cheaper international competition. To help protect more than 500 000 jobs, therefore, the EU has launched a research project (Pro-Stone) to develop better, longer-lasting stone-cutting tools.

Stone is cut with fast-rotating steel discs. During use, these discs get very hot and are subject to high and uneven stress, which can cause them to suffer metal fatigue and to crack. As part of the Pro-Stone project, the effectiveness of incorporating titanium-nickel (TiNi) alloy inserts into the discs was tested. When the disc reaches a particular temperature, the 'smart' alloy insert is activated, exerting a large, compressive stress close the cutting edge of the disc, which should prevent any cracks from growing and protect the disc from metal fatigue.

Researchers at ILL and their Czech collaborators used high-energy beams of neutrons to map the three-dimensional stresses around the inserts. The stress was investigated both at ambient temperature and at 130 °C, above the activation temperature of the alloy insert. The results show that the insert causes a dramatic change in the stress experienced by the stone-cutting disc.

Through careful placement of smart inserts in cutting discs, therefore, it will be possible to improve the performance and lifetime of stone-cutting tools, giving the EU stone-cutting industry a new, competitive edge.

For further details of this research, see the Pro-Stone website[w18].

To learn more about stress, how it can be applied and how it is studied at ILL, see Hughes (2007).

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Erlykin A et al. (2010) Cosmic rays, climate and the origin of life. *CERN Courier* **50(2)**: 15-17. http://cerncourier.com/cws/article/cern/41723

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Uhlenhaut NH et al. (2009) Somatic sex reprogramming of adult ovaries to testes by *Foxl2* ablation. *Cell* **139(6)**: 1130-1142. doi: 10.1016/j.cell.2009.11.021

Web references

w1 – For more information about EIROforum, see: www.eiroforum.org

w2 – To learn more about CERN, see: www.cern.ch

w3 – Visit the website of the CLOUD experiment at CERN: http://cloud.web.cern.ch/cloud

w4 – For a video of Jasper Kirkby's recent lecture 'Cosmic rays and climate', see: http://indico.cern.ch/conference Display.py?confid=52576

w5 – More information about EFDA-JET is available here: www.jet.efda.org

w6 – To learn more about ITER, the next step towards commercially available fusion energy, see: www.iter.org

w7 – For more details about EMBL, see: www.embl.org

w8 – To learn more about the work for which Christiane Nüsslein-Volhard and Erich Wieschaus were awarded the Nobel Prize in Physiology or Medicine in 1995, see: http://nobelprize.org/nobel_prizes/medicine/laureates/1995

w9 – For an online video of Mathias Treier explaining how ovaries were turned into testes in mice, see: www.youtube.com/watch?v=-oL7RKUNchY

w10 – To learn more about ESA, visit: www.esa.int

w11 – Find out more about the International Space Station here: www.esa.int/esaHS/ESA0I6KE43D_iss_0.html

w12 – For more information about ESA's 'sugar-cube' gyro sensors, see: www.esa.int/esaCP/SEMVXYUHYXF_index_0.html

w13 – For more information about ESO, see: www.eso.org

w14 – To learn more about VISTA, ESO's new telescope, see: www.eso.org/public/teles-instr/surveytelescopes/vista

w15 – To learn more about ESRF, visit: www.esrf.eu

w16 – Stanford University has produced a video showing the manufacture of plastic bags: www.youtube.com/watch?v=fte32FKRG9I

w17 – For more information about ILL, see: www.ill.eu

w18 – To learn more about the Pro-Stone project, see: www.dappolonia-research.com/prostonecm/doceboCms

Resources

To read all the *Science in School* articles about EIROforum, see: www.scienceinschool.org/eiroforum

To read all the *Science in School* articles about CERN, see: www.scienceinschool.org/cern

To find out how to build and use your own cloud chamber, see:

Barradas-Solas F, Alameda-Meléndez P (2010) Bringing particle physics to life: build your own cloud chamber. *Science in School* **14**: 36-41. www.scienceinschool.org/2010/issue14/cloud

To learn more about the LHC, see:

Landua R (2008) The LHC: a look inside. *Science in School* **10**: 34-45. www.scienceinschool.org/2008/issue10/lhchow

Landua R, Rau M (2008) The LHC: a step closer to the Big Bang. *Science in School* **10**: 26-33. www.scienceinschool.org/2008/issue10/lhcwhy

To read all the *Science in School* articles about EFDA-JET, see: www.scienceinschool.org/efdajet

To read all the *Science in School* articles about EMBL, see: www.scienceinschool.org/embl

To read all the *Science in School* articles about ESA, see: www.scienceinschool.org/esa

To learn more about the International Space Station, see:

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

Hartevelt-Velani S, Walker C, Elmann-Larsen B (2008) The International Space Station: life in space. *Science in School* **10**: 76-81. www.scienceinschool.org/2008/issue10/iss

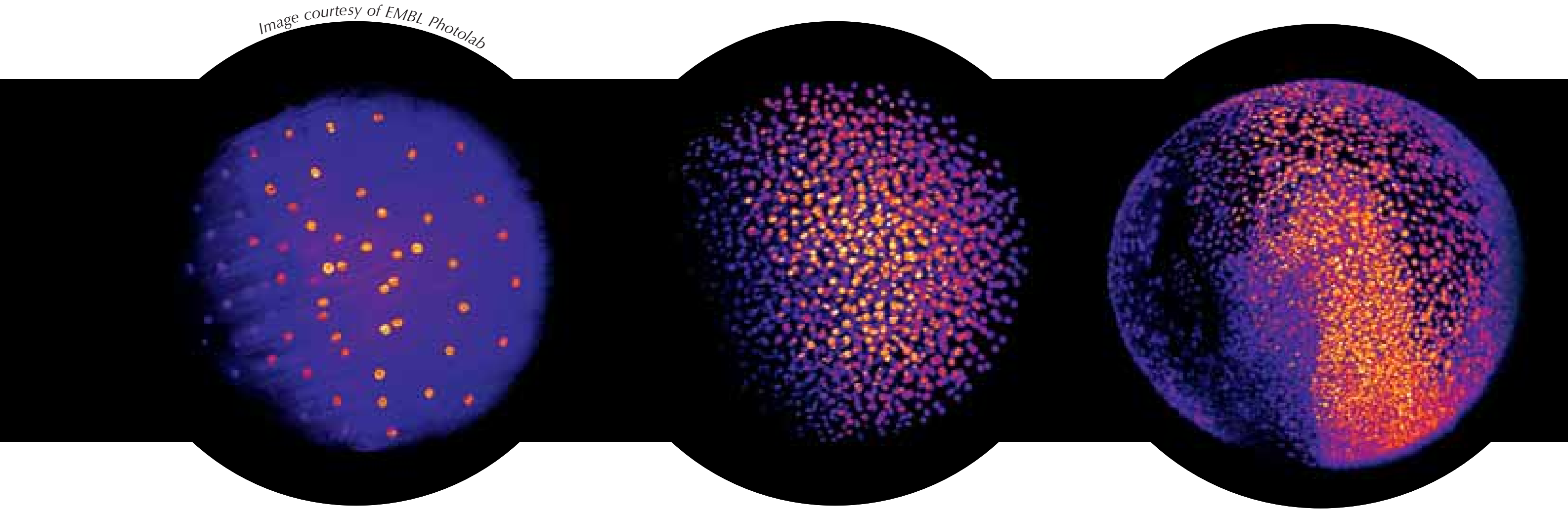
To read all the *Science in School* articles about ESO, see: www.scienceinschool.org/eso

To read all the *Science in School* articles about ESRF, see: www.scienceinschool.org/esrf

To read all the *Science in School* articles about ILL, see: www.scienceinschool.org/ill

Watching it grow: developing a digital embryo

Image courtesy of EMBL Photolab



What if you could witness the development of a new life, taking your time to study every detail, every single cell, from every angle, moment by moment? **Sonia Furtado** talks to the scientists who made this possible by creating a digital zebrafish embryo.

Imagine Google Earth™ took new satellite photos at regular intervals, so that as well as viewing the whole planet and zooming in on different countries or cities, you could play back the sequence of photos and see what had changed over 10 or 20 years. Replace Earth with a developing zebrafish embryo, collect a few hundred thousand snapshots recorded over 24 hours, and you get what scientists at the European Molecular Biology Laboratory (EMBL)[w1] have dubbed 'the digital embryo'.

Biophysicist Philipp Keller, biologists Annette Schmidt and Jochen Wittbrodt, and physicist Ernst Stelzer teamed up to develop a technique for

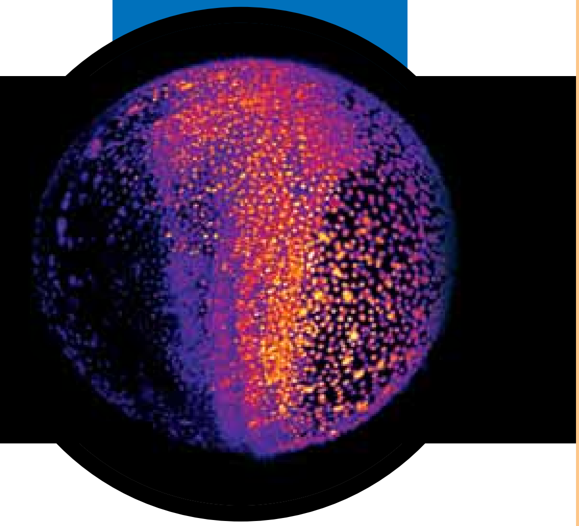
Image courtesy of EMBL Photolab

Ernst Stelzer, Philipp Keller, Jochen Wittbrodt and Annette Schmidt

obtaining a 3D representation of the first 24 hours of a zebrafish embryo's development (Keller et al., 2008). It all started in early 2006, when a fellow scientist suggested that Philipp simply put an embryo in the microscope and track all the cells. Prompted by this conversation, Philipp took a fresh look at *single-plane illumination microscopy* (SPIM) (see glossary for all italicised terms), a 3D imaging technique previously developed by Ernst's group. He refined the basic principles of SPIM to record embryonic development; the result was *digital scanned laser light sheet fluorescent microscopy* (DSLM).

Because cells in a developing embryo are constantly dividing and moving, snapshots must be taken at very short intervals to track the changes. This requires a microscope which combines high imaging speed with high image quality, to distinguish between cells sitting very close

DSLM recording of zebrafish embryogenesis from early cell divisions to gastrulation



to each other. And, of course, in order to follow the embryo's development, the cells must be kept alive and behaving normally over a period of one or two days, and the microscope must not damage the fluorescent stain used to mark the cells.

The solution was to use a very thin laser beam, minimising the damage to both the stain and the embryo. This beam shines through the embryo, exciting the fluorescent stain in the cells and making it emit light. The laser beam moves in a vertical line,

REVIEW

Biology
Development
Embryology
Ages 16-19

This article describes cutting-edge advances in developmental biology. The potential outcome – a virtual embryo which could be shared amongst and annotated by other scientists, just as photos and comments are added to Google Earth – is an exciting example of how research findings can be disseminated, commented upon and, perhaps, extended. This could link well with the ideas about global science and communication that appear in some syllabuses.

There is much in this article that could enthuse interested biology students. The use of sophisticated microscopy in pushing forward scientific boundaries could give rise to discussions about how technology is holding back discoveries, or about how much scientific 'knowledge' is ephemeral and uncertain, being dependent on current technology.

The use of zebrafish embryos could also give rise to an ethical debate. Is it right to experiment on fish embryos? What about mammalian embryos? What about human embryos? This could lead to a discussion of some of the legal aspects of this kind of research.

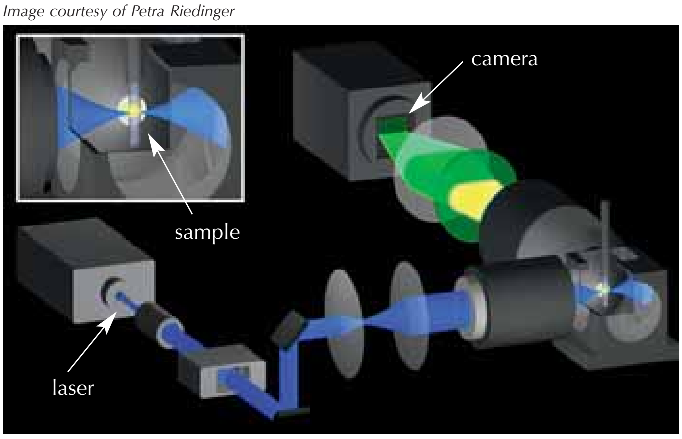
Generally, the article could be useful for biology teachers to update their own knowledge. It may also be used as background reading – possibly for students entering biology olympiads or those with interviews for university places. In addition, the video footage is helpful to illustrate embryonic development for any courses that include this topic.

Suitable comprehension questions include:

- Describe and discuss any ethical issues involved in the work carried out by the scientists.
- Suggest how the work on fish embryos could be of relevance to treating human diseases in the future.

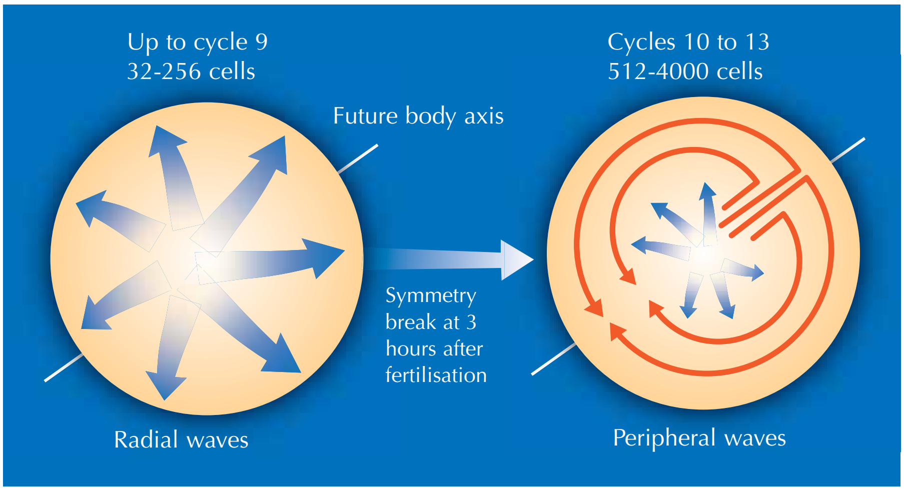
Sue Howarth, UK

Image courtesy of Petra Riedinger



Schematic illustration of a digital scanned laser light sheet fluorescence microscope (DSLM): the laser beam (in blue) illuminates the specimen from the side and rapidly scans a 2D plane. The fluorescent light (in yellow) consequently emitted from the sample is then filtered to select only the signal at the desired wavelength (green) and detected with a camera at right angles to the illuminated plane, to generate the images

Image courtesy of Nicola Graf



The cell division pattern undergoes a symmetry break during early zebrafish embryogenesis: from fast radial waves (cycles 1 to 9) to slow circular peripheral waves (cycles 10 to 13)

Image courtesy of Angharad Jones, Wellcome Images

Zebrafish embryo at the blastula stage, two hours and forty-five minutes after fertilisation

and the fluorescence emitted from the sample at a 90° angle to the laser beam is detected by a camera, creating an image slice thousandths of a millimetre thin (see movie 1[w2]). The embryo is then moved a tiny horizontal step, and the next image slice is scanned. Once the whole embryo has been scanned from one viewpoint, it is rotated by 180° and scanned again, so that a full 3D image can later be composed. The embryo lives and carries on developing, which means the 'slices' can be repeated periodically on the same embryo and compared to track the changes. The EMBL scientists 'sliced' their zebrafish embryos either every 60 or 90 seconds over a 24-hour period, obtaining around 400 000 images per embryo.

The next challenge was to devise a way to analyse all three terabytes of data for each embryo. The scientists chose an automated approach: they used clusters of computers working in parallel, both at EMBL Heidelberg and at the Karlsruhe Institute of Technology, Germany[w3]. "Each computer is given one snapshot of the embryo, and told to look for cellular nuclei in that image," Philipp explains. Each nucleus represents a cell, so by combining the information for all slices, scientists can generate their digital embryo: a visual representation of all the embryo's cells, where they are at a given point in time, where they move to next, and when and where they divide. The result is a 3D time-lapse video of the developing embryo.

This enabled Philipp, Annette and Jochen to shed new light on different stages of the embryonic development of zebrafish. At a very early stage, the zebrafish embryo is basically a group of cells sitting on top of the yolk sac (the embryo's nutrient source). At first, the cells divide in a wave that

BACKGROUND

Glossary

Digital scanned laser light sheet fluorescent microscopy (DSLM): An improved version of *SPIM*, which uses a thin laser beam rather than a full light sheet, thus reducing damage to both specimen and fluorescent dye.

Gastrulation: The phase in early embryonic development during which the three germ layers are formed: ectoderm, mesoderm and endoderm. The timing and molecular mechanism of gastrulation differ between organisms.

Genetic strain: A genetically uniform group of animals, used in laboratory experiments. A genetic strain can be developed by inbreeding, mutation or genetic engeneering.

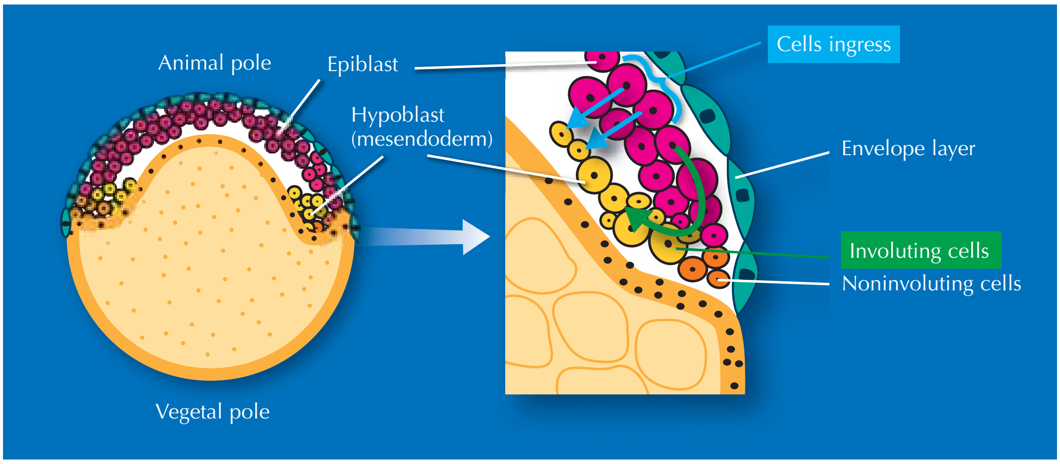
Single-plane illumination microscopy (SPIM): This method allows 3D observation of processes in living organisms, even in deep tissue layers. It detects fluorescence at an angle of 90° relative to the axis of illumination with a sheet of laser light, permitting optical cutting. The specimen is not positioned on a microscope slide but in a liquid-filled chamber which is rotated during observation.

The zebrafish as a model organism

BACKGROUND

For ethical reasons, we can't easily study early (embryonic) development in humans. Conveniently though, the process is similar in all vertebrates, so other animals are used as model organisms to understand our own development. But why zebrafish? We owe it all to George Streisinger, a Hungarian biologist at the University of Oregon, USA. At the beginning of the 1980s, he dreamed of applying the molecular techniques he had previously used for the study of viruses to investigate the genetics and development of a vertebrate. As a fish hobbyist, he chose to work on zebrafish, which he knew were easy to keep and breed. There are a number of practical reasons which make zebrafish an attractive model system: firstly, they are small enough to keep the large numbers required for genetic studies, yet big enough to do classical embryological manipulations such as transplantations. They have a relatively short generation time (3-4 months), produce large numbers of embryos (100-200 per mating) and provide easy access to all developmental stages due to external fertilisation. Because the embryos are optically transparent and develop rapidly, with all the important structures of an adult fish being established after three days, you can easily study their development – using either a simple light microscope or more complex technology, as described in this article. In addition, the zebrafish genome has recently been sequenced, and defined *genetic strains* are available, offering a unique opportunity to study not only embryology, but also genetically inherited diseases and the genetics underlying developmental biology – Streisinger's dream has come true.

Image courtesy of Nicola Graf

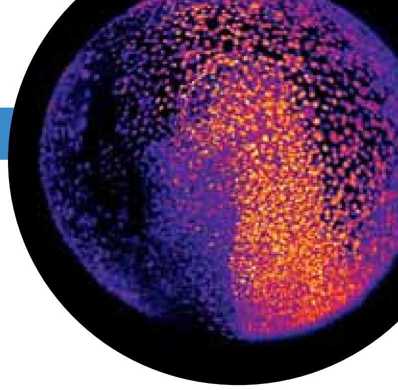


The three germ layers of an embryo are formed during gastrulation. In the zebrafish embryo, this may happen through involution or ingression of the cells

moves out from the centre in all directions, like a ripple in a pool. The reconstruction showed that after the first nine cell cycles, the pattern of cell division changes to a wave that moves out from the centre in only one direction and then splits up to continue along the periphery in two half-circles (see image on page 20) and movie 10[w2]). The line between these two half-circles will later become the animal's body axis, defining the body's symmetry. So the scientists discovered that the zebrafish's body axis is defined at an earlier stage in its development than was previously supposed, at a time when maternal genes (in the form of mRNA deposited in the egg) are still the sole blueprint used for protein production.

The researchers also studied *gastrulation*, the process by which cells from the embryo's original single outer layer migrate inward to form the remaining two germ layers, all three of which will eventually give rise to different types of tissue. "It takes textbooks two or three pages to describe this process, but when you see the movies of the digital embryo, it's suddenly quite easy to understand," Annette says. And what's more – she and her colleagues discovered that the textbooks are actually wrong.

There has been an ongoing, sometimes fervent, debate in the field since the 1980s over how cells migrate to form these layers. The prevailing textbook view was that cells involute –



that is, they migrate to an opening in the embryo and roll over the margin to form a layer underneath, like the edge of a swimming cap rolling up around your head, on the inside. Yet some scientists argued that individual cells on the outer layer simply dive in, or ingress, right where they are, to form a layer beneath.

"We really settled the issue nicely," says Jochen. "It turns out everyone was right!" It's a question of where you look. On one side of the embryo, cells involute, whereas on the other side, they ingress (see movie 16[w2]). The controversy had arisen because different scientists were looking at different areas of the embryo. Since they couldn't watch the whole process unfold, they were, however, unable to determine exactly which area they were looking at. In overcoming these constraints, the EMBL scientists were able to uncover the truth.

The researchers have also used the digital embryo as a developmental blueprint, to find out where the cells contributing to a specific organ or tissue come from. As a first example, they used the eye. In the digital representation, at an advanced developmental stage (i.e. late in the 24-hour video), the scientists marked the cells that they knew were involved in forming one of the zebrafish's eyes. They then tracked the cells back in time to find out where they originated (see movie 11[w2]).

The scientists have made their digital embryos publicly available on the Internet[w2], along with tools for other scientists to analyse their own microscopy data. And what next? With Google Earth, as well as seeing the whole planet and zooming in on different places, users can add their own notes and markers and view those added by other people. Similarly, Philipp, Annette, Jochen and Ernst envision their digital embryos becoming what they call 'virtual embryos': resources in which other scientists can view developmental processes, zoom in for more information, and add their own annotations and results. In the long run, the scientists would like to expand the digital embryo's scope to other species, as this would enable scientists to quantitatively compare how different embryos develop, which would provide valuable insights into evolution. The digital embryo has much room for growth, and with growing numbers of people willing to help it develop, it appears to have a promising life ahead.

Reference

Keller PJ, Schmidt AD, Wittbrodt J, Stelzer EH (2008) Reconstruction of zebrafish early embryonic development by scanned light sheet microscopy. *Science* **322**: 1065-9. doi: 10.1126/science.1162493

Web references

w1 – To learn more about EMBL, the European Molecular Biology Laboratory, see: www.embl.org

w2 – The Digital Embryo website includes videos showing the development of the zebrafish embryo, as well as data to download: www.digital-embryo.org

Movie 1 is a schematic representation of the DSLM's operation principle.

Movies 2 and 3 show the development of a zebrafish embryo during the first 24 hours.

Movie 10 illustrates the symmetry break in the cell divisions after nine cell cycles, and the early determination of the embryo's body axis.

Movie 11 shows the migratory tracks of cells forming the early zebrafish eye.

Movie 16 illustrates how involution and ingression both play a role in zebrafish gastrulation.

w3 – For more information about the Karlsruhe Institute of Technology, Germany, see: www.kit.edu

Resources

For two further *Science in School* articles about evolution and development, see:

Patterson L (2010) Getting ahead in evolution. *Science in School* **14**: 16-20. www.scienceinschool.org/2010/issue14/amphioxus

Hodge R (2006) A search for the origins of the brain. *Science in School* **2**: 68-71. www.scienceinschool.org/2006/issue2/brain

For a collection of learning and research resources on embryonic development, see: http://people.ucalgary.ca/~browder/virtualembryo

To browse all articles on evolution that have been published in *Science in School*, see: www.scienceinschool.org/evolution

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Sonia Furtado was born in London, UK, and moved to Portugal at the age of three. While studying for a degree in zoology at the University of Lisbon, she worked at Lisbon Zoo's education department; there, she discovered that she really enjoys telling people about science. She went on to do an MSc in science communication at Imperial College London, and is now the press officer at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany.

This article appeared in the annual report 2008-2009 of the European Molecular Biology Laboratory, a collection of articles on topics from the most current science. The entire report can be downloaded here: www.embl.de/aboutus/communication_outreach/publications

To receive a print copy of each years's annual report, contact info@embl.org

Programmable metallisation cells: the race for miniaturisation

Gabriel Cuello from the Institut Laue-Langevin (ILL) in Grenoble, France, introduces a new type of digital memory that may revolutionise our USB sticks.

The wish to download, store and carry music and videos from the Internet has led to massive and ever-increasing mobile storage needs. All this information is stored in just two distinct states of a bit: 0 or 1. In the flash memory we all use in USB sticks and memory cards (for example, in digital cameras), these are two distinct voltage or current levels allowed by a semiconductor-based integrated circuit, with millions of tiny transistors or capacitors which can be electrically erased and reprogrammed, storing information as electrical charge.

Importantly, the stored information is retained even when the device isn't powered. But flash memory has a drawback: its storage capacity is usually limited to a few gigabytes. For higher storage capacities, today, external hard drives are used, but unlike flash memory they require an external power supply, so just reducing their size is not ideal. Yet if the storage capacity of USB sticks could be extended to several terabytes, this could be the way forward. A new kind of memory device based on programmable metallisation cells (PMCs) could be the solution.

PMCs not only use less energy than flash memory and have faster access times (a few nanoseconds) due to their nanometric size, they can also be made physically flexible, have a higher storage capacity and longer lifetimes (their data can be overwritten 10^{10} times before the data integrity starts to wear, compared to 10^5 write-erase cycles in flash memory), and can withstand elevated temperatures for more than 10 years (Kozicki et al., 2005).

Essentially, PMCs store information as two different states: high and low electrical resistance. This is achieved through a conducting nanopath of metal atoms (silver or copper), which forms itself through ionic redistribution and electrochemical processes. When an electrical potential is applied in one direction, it remains intact until a potential is applied in the opposite direction, at which point the nanopath dissolves again – this is the 'programmable metallisation'. When the nanopath is present, electricity can flow through the PMC with little resistance: this is state '1'. Without the nanopath, resistance is high: this is state '0'. The complete cycle is schematically represented in Figure 1 on page 26.

How does this work? A PMC has three main components: a solid elec-


Image courtesy of daboost / iStockphoto

trolyte film (an ion-containing medium, commonly silver germanium selenide (AgGeSe), disilver selenide (Ag_2Se), copper germanium selenide (CuGeS) or dicopper sulphide (Cu_2S)), sandwiched between two electrodes, no thicker than 100 nm in total. The anode is an oxidisable layer of metal (silver or copper – the same as the ions in the medium in between), which can release these ions to the central medium. The cathode is a thin layer of a metal such as tungsten (however, not a source of ions, therefore 'inert'), as shown in Figure 1(a).

For them to function effectively, the important feature of PMCs is the characteristics of the central solid electrolyte. Such electrolytes are usually amorphous, and their atoms have an intermediate mobility between that of atoms in liquids and those in crystals. Unlike in a liquid electrolyte (such as those used in common batteries), only the positively charged ions are mobile, while the negatively charged counter-ions are fixed. This is essential for the formation of the conducting nanopath from electrodeposited cations.

REVIEW

- Physics
- Chemistry
- Materials science
- Nanoscience
- Ages 16-19

This article will be of interest to all who use and appreciate state-of-the-art technologies; the development of programmable metallisation cells illustrates the collaborative elements of nanotechnologies, chemistry, physics and materials science. It also shows the transition from research to commercial potential.

The article could be used as a comprehension exercise. Possible questions include:

1. Outline one advantage and one disadvantage of flash memory devices.
2. "For them to function effectively, the important feature of PMCs is ...the central solid electrolyte". Explain the term 'electrolyte'.
3. An integral component in PMCs is a glass. What is a 'glass'?
4. What do you understand by the term 'neutron diffraction'?
5. Much of the activity and construction of these cells is at the nanoscale. What is the nanoscale?

Marie Walsh, Ireland

Figure 1: When a voltage exceeding a few hundred mV is applied to the PMC, electrons are released at the inert cathode, reducing nearby silver or copper cations in the sandwiched medium to metal atoms (grey). At the other end, the anode releases cations (oxidisation), which are eventually also reduced to metal atoms by the migrating electrons. This electrodeposition of metal atoms along a nanopath will cease if the electric potential across the cell drops below a certain value, or if the supply of oxidisable metal in the anode becomes exhausted.
To dissolve the nanopath, an electrical potential is applied in the opposite direction. The inert tungsten electrode (the new anode) will now take up electrons from nearby silver or copper metal atoms, reducing these to ions again. These ions will return to their original positions, separating a little and dissolving the nanopath (note that the movements of the metal ions / atoms are all very small – they were already very close to each other to begin with). In addition, the silver / copper electrode (the new cathode) will take up silver / copper ions.
In just a few nanoseconds the device passes from the state 0 (high resistance, off) to state 1 (low resistance, on), consuming only a few picojoules. This write-erase cycle (a-i) may be repeated many tens of millions of times per second

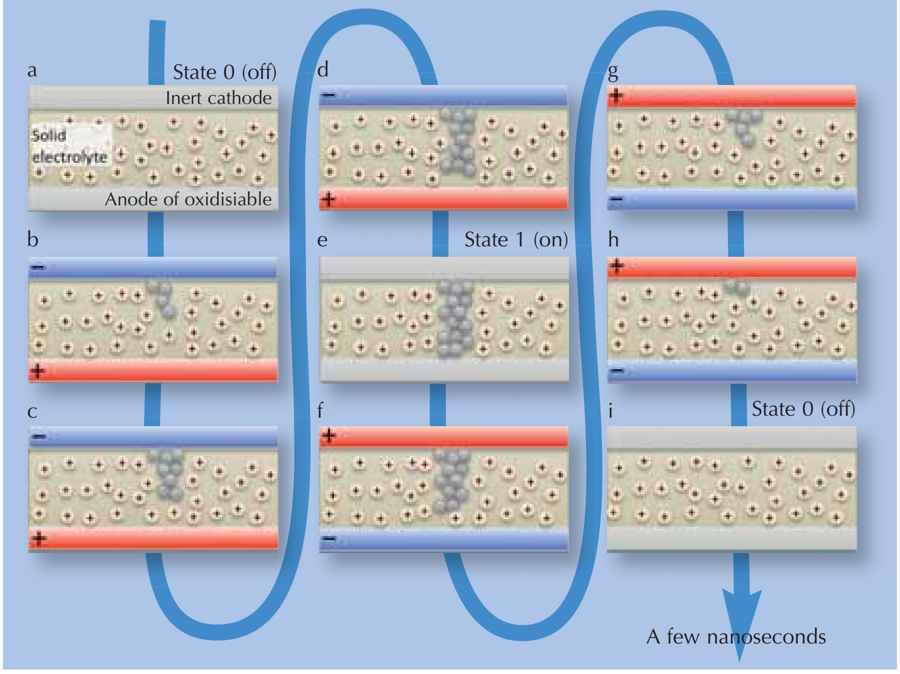

Image courtesy of Gabriel Cuello

Many inorganic and organic (including polymeric) materials can conduct ions, and therefore act as solid electrolytes, but only the chalcogens (Group 16 in the periodic table of elements) are interesting in the context of PMCs, because they have the right electrical properties. Combining elements that make thermally stable compounds (such as oxygen, sulphur and selenium) with copper or silver yields binary electrolytes such as disilver selenide and dicopper sulphide. The conductivity of the material can be improved even further by using ternary electrolytes: chalcogens are combined with other elements such as germanium, to create a glass (an amorphous material in which the atoms are not in a strict order), in which copper or silver can be dissolved. The conductivity is further determined by the concentration of the metal ions in the electrolyte, since nanopaths do not form in the entire cell but only in those regions where the ion concentration is especially high (see Figure 2). Therefore, electrolytes with different metal concentrations are studied to find the ideal composition.

Although ternary electrolytes have better characteristics for use in PMCs, interactions between three types of ions are more difficult to study than those between just two types, which is why, so far, the characteristics of binary solid electrolytes are better known.

Research at ILL

To learn more about these ternary electrolytes, my colleagues and I at ILL[w1] have studied AgGeSe glasses with different silver contents. To understand the electrical properties of a material, it is important to first understand its structure. Hence, we wanted to determine the local order of the atoms grouped around the silver atoms. The order of the atoms in the glass as a whole is random, but if you look locally, it is possible to predict the probability of finding a certain type of atom within a specific (close) range. The further you get away from this silver atom, however, the less certain you can be about the atoms you will find there.

We analysed the glasses using neutron diffraction, a technique regularly used at ILL, in which materials are analysed by the way they diffract a beam of neutrons, and which, importantly, does not necessarily require a regular order of the atoms (see Cuello, 2008). Not only the nuclei of different elements but also the nuclei of different isotopes of an element scatter neutrons with different power. Taking advantage of this, a given type of atom under study can be substituted by an isotope, which does not

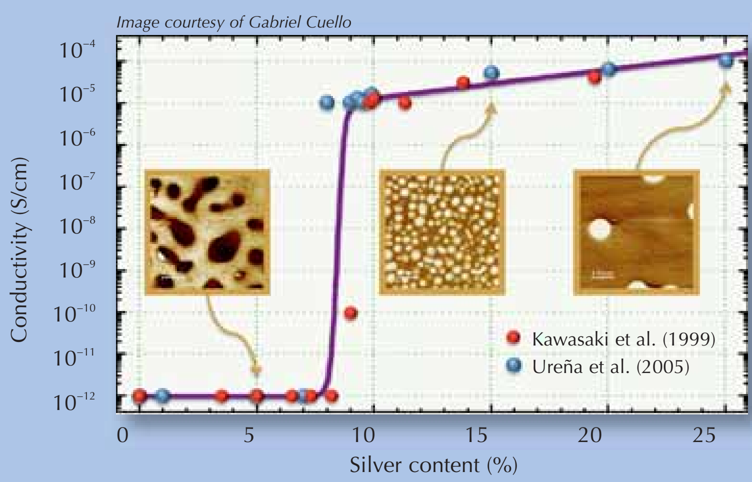

Figure 2: Electrical force microscopy images of AgGeSe glasses containing different concentrations of silver (the dark patches, see Piarristeguy et al., 2008). A certain minimum concentration of silver is required to allow for a good conductivity of the material. Above about 7% silver, however, a further increase in silver concentration does not lead to a substantial increase in conductivity. Measurements were done at room temperature (see Kawasaki et al., 1999; Ureña et al., 2005)

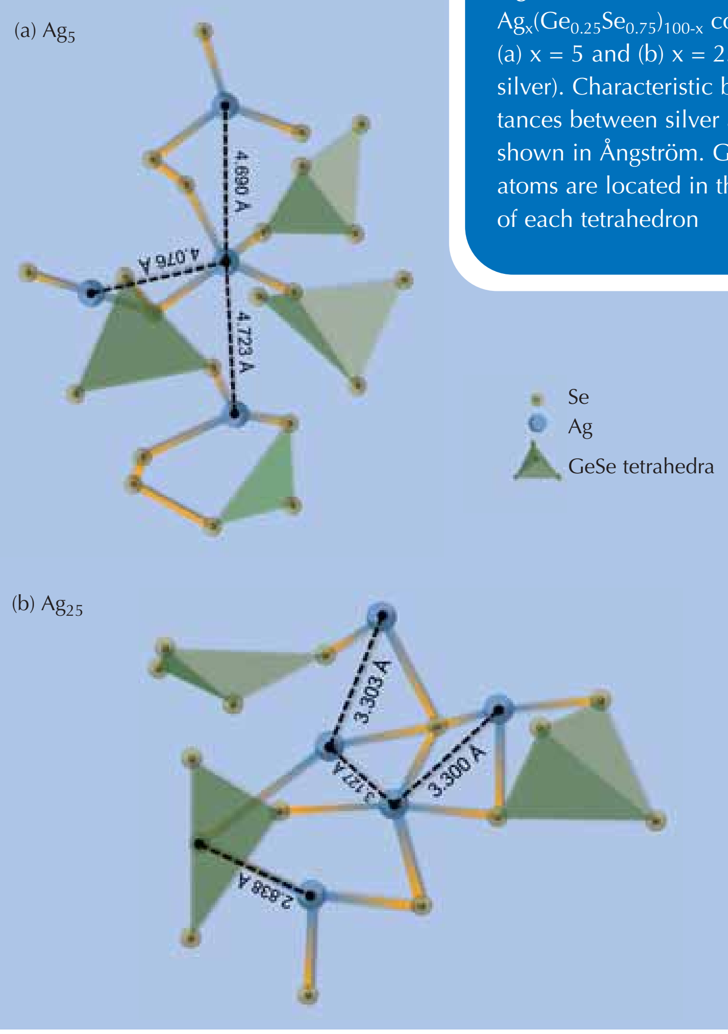

Figure 3: The structures of $Ag_x(Ge_{0.25}Se_{0.75})_{100-x}$ containing (a) x = 5 and (b) x = 25 (percent silver). Characteristic bond distances between silver atoms are shown in Ångström. Germanium atoms are located in the centre of each tetrahedron

change the structure of the material. In this case, we were interested in the silver atoms, so we replaced ^{nat}Ag with ^{107}Ag and ^{109}Ag, the two stable isotopes that comprise natural silver (^{nat}Ag). Comparing the diffraction patterns obtained from $^{nat}AgGeSe$, $^{107}AgGeSe$ and $^{109}AgGeSe$, we were able to identify which parts of the diffraction pattern were related to the silver atoms.

Using a neutron beam of short wavelength allows the determination of the short-range order – the probability of finding a specific type of atom at a given (short) distance from another. To calculate the correlations between three different species of atoms (silver, germanium and selenium), a ternary system, you would ideally do six independent measurements. Three measurements, however, as were performed here, provide a good approximation (this is why two different silver isotopes were used), which can then be complemented using computer simulations of molecular dynamics.

This combination of neutron diffraction experiments and computer modelling allows us to propose a local structural image of the ternary electrolyte (see Figure 3). There is a clear phase separation between the conducting (silver-rich) regions and the non-conducting ones (silver-poor) (Piarristeguy et al., 2008), which is important for the distinct establishment of the low- and high-resistance states. In the case of 25% atomic silver dissolved in germanium triselenide ($GeSe_3$), i.e. $Ag_{25}(Ge_{0.25}Se_{0.75})_{75}$, there is a continuous glassy digermanium triselenide Ge_2Se_3 backbone and a dispersed nanoscale disilver selenide (Ag_2Se) phase. The metal-rich Ag_2Se phase is both an ion and an electron conductor, important for the establishment of a low-resistance state with a nanofilament through which a current can flow. The Ge_2Se_3 backbone, by contrast, which separates each of these conducting regions, is a good dielectric (a non-conductor material which becomes a conductor if you apply a strong enough electric potential), so the overall resistance of the material prior to electrodeposition, i.e. before a forward current is applied to form a conducting nanofilament, is high.

In AgGeSe containing only 5% silver, although the basic phase separation is the same, the distances between silver atoms are higher (see Figure 3), which explains the lower conductivity of the material.

There is still much to learn about the exact process that creates these nanopaths, but this is a promising new technology which could certainly improve the performance of digital memory devices in the near future. However, nano-ionic memory such as PMCs is only one of many possibilities being explored, and it remains to be seen which one of them will eventually make its way into our homes.

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Web reference

w1 – To learn more about ILL, see: www.ill.fr

Resources

To read further articles about the use of ILL's neutron beams and explaining neutron diffraction in more detail, see:

Cicognani G (2006) Defying the laws of physics? *Science in School* **1**: 19-21. www.scienceinschool.org/2006/issue1/defying

Cicognani G, Capellas M (2007) Silken, stretchy and stronger than steel! *Science in School* **4**: 15-17. www.scienceinschool.org/2007/issue4/spidersilk

Hughes D (2007) Taking the stress out of engineering. *Science in School* **5**: 61-65. www.scienceinschool.org/2007/issue5/stress

Zaccai G (2009) The intracellular environment: not so muddy waters. *Science in School* **13**: 19-23. www.scienceinschool.org/2009/issue13/water

Research into the application of PMCs in memory devices is done at IBM and Sony, and by Michael Kozicki, a researcher at Arizona State University, USA. See: www.engineering.asu.edu/people/57492

If you enjoyed reading this article, take a look at other chemistry articles published in *Science in School*. See: www.scienceinschool.org/chemistry

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Gabriel Cuello is a research physicist at ILL, where a high-flux research reactor provides neutron beams for the study of condensed matter. He is responsible for the dedicated neutron diffractometer used for liquid and amorphous systems. His research focuses on the structural characterisation of non-crystalline materials, such as glasses. This also includes studying the short-range order of ions in liquids or nanoparticles, with applications in predicting the fate of contaminants in the environment.

Images courtesy of daboost / iStockphoto

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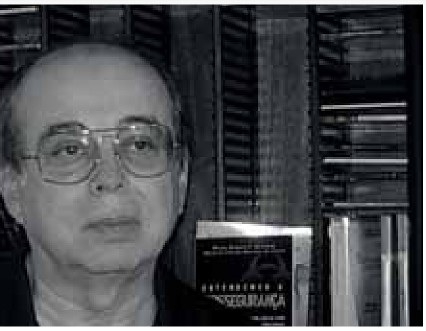
Using news in the science classroom

Image courtesy of Marco Costa



Marco Costa

Fernanda Veneu-Lumb and **Marco Costa** show how news reports – even inaccurate ones – can be used in the science classroom.

Image courtesy of Fernanda Veneu-Lumb

Fernanda Veneu-Lumb

News is available to us everywhere, all the time – in newspapers and magazines, on television and via the Internet – and this includes science news. Some scientists complain about the accuracy of scientific information in the media and for this reason, some teachers are reluctant to use it in the classroom. However, we'd like to encourage teachers to do exactly this, for two reasons.

1. There are some very good and accurate science stories in the media.
2. Looking for mistakes in scientific news can be the starting point of a classroom activity.

We will begin by illustrating some of the differences between news reports and research articles, then offer some ideas for using science news in the classroom. Although we talk mostly about newspaper articles, you could equally well use other sorts of popular science reports: magazine articles, podcasts or video clips of the television news, for example.

Getting started

News reports generally follow an established pattern. In the first paragraph, you will find all the information you need to understand the story: who, what, where, when, why and how.

Let's look at an example from the BBC website[w1].

How cities drive plants extinct

By Matt Walker, Editor, Earth News

An international team of botanists has compared extinction rates of plants within 22 cities around the world. Both Singapore and New York City in the US now contain less than one-tenth of their original vegetation, reveals the analysis published in Ecology Letters. *However, San Diego, US and Durban, South Africa still retain over two-thirds of their original flora….*

A global synthesis of plant extinction rates in urban areas

By Amy K Hahs, Mark J McDonnell, Michael A McCarthy, Peter A Vesk, Richard T Corlett, Briony A Norton, Steven E Clemants, Richard P Duncan, Ken Thompson, Mark W Schwartz, and Nicholas SG Williams

Plant extinctions from urban areas are a growing threat to biodiversity worldwide. To minimize this threat, it is critical to understand what factors are influencing plant extinction rates. We compiled plant extinction rate data for 22 cities around the world. Two-thirds of the variation in plant extinction rates was explained by a combination of the city's historical development and the current proportion of native vegetation, with the former explaining the greatest variability. As a single variable, the amount of native vegetation remaining also influenced extinction rates, particularly in cities > 200 years old. Our study demonstrates that the legacies of landscape transformations by agrarian and urban development last for hundreds of years, and modern cities potentially carry a large extinction debt. This finding highlights the importance of preserving native vegetation in urban areas and the need for mitigation to minimize potential plant extinctions in the future.

Matt Walker, *Earth News* editor, describes the results of an international study involving scientists from various countries. Did you notice that the main information is available in the first paragraph?

This is one of the biggest differences between news articles and other types of text. In scientific research articles, for instance, the results and conclusions are presented in separate sections, towards the end. Even in the abstract, the short version of the scientific paper, the structure follows the same pattern: introduction, methods, results and conclusions.

Let's take a look at how the same story was presented in a scientific journal – in the abstract of an article published in *Ecology Letters* (Hahs et al., 2009).

REVIEW

- General science
- Ages 10-19

Most science teachers probably already use recent news in lessons to motivate students; this article highlights the importance of scientific reporting and offers advice on how to do it 'scientifically'. It considers different ways of writing and interpreting science news and offers a list of questions for any classroom situation.

The article could be used simply with younger students (ages 10-13): one student could give a two-minute report about a scientific topic he or she has read about in a newspaper or journal or seen on television, after which the class could have a short discussion about the topic. This could create more interest in science outside school.

Additionally, the article could be used to teach more advanced students (ages 13-19) how to write their own reports about some breaking science news. Using the Internet to check the accuracy of the topics reported in the news and comparing the contents with the original article should become a regular part of science lessons.

Friedlinde Krotscheck, Austria

As you can see, the abstract finishes with the conclusions: 'the importance of preserving native vegetation in urban areas and the need for mitigation to minimize potential plant extinctions in the future.' You could discuss the differing structures of news and scientific articles with your students, including which style they prefer and why.

Another difference between news stories and scientific articles is that, in news reports, some of the facts may be presented as quotes by people involved in the subject. Let's read a bit more of the news story:

> *"The rapid and ongoing growth of cities and towns significantly threatens global biodiversity," says Dr Amy Hahs, a scientist working at the Australian Research Centre for Urban Ecology at the Royal Botanic Gardens in Melbourne, Australia.*

This explains why Hahs and her collaborators came together to try to understand the threat and how it could be minimised.

Another important point to observe in news stories is who is doing the 'talking' in the text: researchers, politicians or members of the public? Why? Is there a further point of view that is missing? Whose?

Many researchers complain about distortions in news reports: that the information presented is wrong or that the scientists are misquoted, for example. As a teacher, you could try to identify such problems in a news report, using your own knowledge of the subject. Or you could ask your students to look for distortions, searching for accurate information on the Internet.

Where can you find the accurate information? Start by looking again at the beginning of the news report; the original information source is generally there. In our news example, the information is taken from a research article published in the journal *Ecology Letters* (we examined the abstract of this article, above). Many scientific journals charge for online access to their articles, but access to the abstracts, and sometimes to older articles, is free. Furthermore, open-access journals[w2] (for example, *PLOS Biology*[w3]) offer free access to the full text of all of their articles.

Other sources for news reports might be scientific organisations such as universities, NASA[w4], the European Space Agency (ESA)[w5] or other EIROforum organisations[w6]. On their websites, you should be able to find the original information (for example, in a press release – information provided especially for journalists and checked by the scientists involved) and compare it to the news story. Many organisations' websites have a section for journalists (sometimes called the press or media centre), and access is free.

By comparing the news report and the original research article (or press release), you can not only see the difference in how the article is structured and the data presented, but also consider differences in the writing style.

Trying it out: using news in the classroom

Here are some suggestions for how to examine and compare news and scientific articles in the classroom.

1. What is the story about (e.g. a piece of research, a discovery or a scientist's statement)?
2. Where did the story come from (which country, what sort of organisation)?
3. Who did the journalist quote (e.g. scientists or politicians), if anyone? Where are they from?
4. What was the involvement of the scientists quoted? For example, were they commenting on someone else's research or on their own?
5. Did the scientist work alone or as part of a group?
6. By examining the news report, is it possible to tell who funded the research? If this information cannot be found in the text, why do you think it is not there?
7. What was the source of the information? This is an important issue

if you want to find out more about the subject.

8. Has the topic of the report been published in a peer-reviewed scientific journal (see Raphael, 2007)? If so, which one? Do you think this information is important? Why or why not?
9. Were you familiar with the subject before reading the story? If you were, does the text contain new information for you? What, if anything, conflicts with what you knew or thought before?
10. Try to find the original source of the information and check the details. Did you find any mistakes? If so, what kind of mistake (wrong information, wrong explanation, other kinds of mistake)? How would you rewrite this part, to correct the mistakes you found?
11. Who do you think this text was written for (e.g. students, teachers, researchers or the general public)? What makes you think that?
12. What was the journalist's / newspaper's aim in writing / publishing this article? Purely to provide information? Or is there an ulterior motive, such as scaremongering, a political aim, or trying to sell more newspapers?
13. Find a news report from a different newspaper on the same science story and compare them. Does that help you to answer some of the previous questions?
14. If the news story is about research results or a discovery, try to convert it into a scientific article, and then compare it to the original source.

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The abstract of the article is freely available from the Wiley Interscience website: http://www3.interscience.wiley.com/journal/118545752/home

Raphael E (2007) Developing a teaching resource on peer review. *Science in School* **5**: 70-73. www.scienceinschool.org/2007/issue5/peer

Web references

w1 – The full article is available on the BBC website: (http://news.bbc.co.uk) or via the direct link: http://tinyurl.com/yah6a5v

w2 – Many open access journals can be searched and accessed through the Directory of Open Access Journals: www.doaj.org

w3 – *PLOS Biology* is an open-access, peer-reviewed general biology journal. See: www.plosbiology.org

w4 – To learn more about NASA, the US National Aeronautics and Space Administration, see: www.nasa.gov

w5 – The European Space Agency (ESA) is a member of EIROforum, the publisher of *Science in School*. For more information about ESA, including press releases about recent ESA developments, see: www.esa.int

w6 – EIROforum, the publisher of *Science in School*, is a collaboration between seven European intergovernmental scientific research organisations. To learn more and read the recent press releases from the seven organisations, see: www.eiroforum.org

Resources

When searching for press releases, AlphaGalileo is a good place to start. You can search the online database of thousands of press releases and other material on recent European developments in science, technology, health and other fields. See: www.alphagalileo.org

The American science society, AAAS, runs a similar online, global news service for scientific topics, Eurekalert. See: www.eurekalert.org

To learn more about how news stories are written, see the website of the Media Awareness Network (www.media-awareness.ca) or use the direct link: http://tinyurl.com/d3hwss

If you enjoyed this article, you might like to browse the other teaching activities that have been published in *Science in School*. See: www.scienceinschool.org/teaching

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Fernanda Veneu-Lumb is a Brazilian science journalist. She began writing for the media in 1992, when she was still at college. Her experience interviewing scientists led in 2009 to a PhD on different perceptions of human life and how these views could be used in science lessons.

Marco Costa is a Brazilian chemical engineer with a PhD in biosafety education. He works in biosafety, has a professorship in scientific methodology at Fundação Oswaldo Cruz (Oswaldo Cruz Foundation), Brazil, and develops new strategies for science teaching.

Image courtesy of alexsl / iStockphoto

GIS: analysing the world in 3D

Earthquakes, global climate or the placement of wind farms – with the help of geographic information systems, these can all be investigated dynamically in the classroom. **Joseph Kerski** describes how.

GIS: a spatial perspective

For more than 2500 years, people have been fascinated by geography, the study of our planet. Geography is also the science of spatial thinking – how phenomena interact and change over space, at the local, regional and global scale. Today, this spatial science is particularly significant, as issues such as climate change, biodiversity loss, sustainable agriculture, water quality and quantity, energy and natural hazards not only grow in importance but also affect our everyday lives. To grapple with these issues, we need to see patterns and trends at anything from a global scale to the level of a local community.

To investigate such trends, geographers turn to geographic information systems (GIS). Unlike traditional maps, GIS goes beyond static, two-dimensional objects: instead, individual maps can be manipulated and combined with other maps, charts, databases and multimedia.

The G in GIS represents geography – the map: for example, a 2D or 3D topographic map, a map of soil pH, ecosystems, or watersheds, or a satellite image. The I represents the information behind the map, which is stored in a database. For rivers, for example, the information could describe whether the river is perennial or intermittent, or how its conductivity or salinity varies with time or along its course. The S – the system – connects the map and the database. By selecting components on the map, the user simultaneously selects the associated attributes in the database (and vice versa), allowing them to be manipulated.

With the help of hundreds of GIS-specific tools, the data can be manipulated and combined in many different ways. For example, the proximity tool could find all of the earthquakes that occurred within 100 km of Frankfurt am Main, Germany, and the overlay tool could narrow the search down to those earthquakes that occurred under alluvial soil and that are on highly populated land.

Using GIS at school

In schools, GIS can be used not only in geography, but also in biology, chemistry, earth science, environmental science, history, mathematics and other subjects. It can help students at all levels to think critically and use real data, as well as appealing to visual learners.

A wide variety of topics can be explored: the relationships between people, climate, land use, vegetation, river systems, aquifers, land forms, soils, natural hazards and much more. For example, how will climate change affect global food production? What is the relationship between birth rate and life expectancy? How does acid mine drainage in a mountain range affect water quality downstream? How does the changing demography associated with smaller household size affect urban sprawl? What is the best location for new wind energy farms? How will a proposed retail centre affect community traffic patterns and land use?

GIS can be used in three ways.

- Geography
- Biology
- Earth science
- Environmental science
- Development
- History
- Ages 14-18

Everybody has heard about GIS as the ultimate resource in cartography; this article gives teachers the opportunity to exploit this resource for addressing geographic phenomena.

I recommend this article to secondary-school teachers who are willing to investigate more deeply the geographic aspects of earth science (plate tectonics, volcanoes, earthquakes), environmental science (geomorphology, climate, natural resources, pollution, natural hazards), biology (biodiversity, species distribution) and even history (demography, migrations) from the local scale to the planetary level. There are many opportunities for interdisciplinary work.

The use of the proposed software requires some computer skills and it is subject to specific software requirements.

The article would provide valuable background reading before a geological school trip or as a warm-up activity before addressing earth science topics. It could be used as the basis of discussion on many topics related to the subjects mentioned above, in particular, important events such as the recent earthquakes in Haiti and Chile.

Giulia Realdon, Italy

REVIEW

1. Using desktop GIS software, such as the professional software ArcGIS or the freely available programmes ArcGIS Explorer[w1] and ArcExplorer Java Edition for Education[w2], students can analyse data they have collected and then stored locally. For example, they could analyse the height and species of trees in their school's grounds.
2. Using GIS via a web browser, students could analyse a much wider range of data, for example, they could use the This Dynamic Planet website[w3] to study the relationship of earthquakes and volcanoes to tectonic plate boundaries and the rate of plate movement. They could use Worldmapper[w4] to view the distribution of more than 700 variables online, including forest loss and mineral distribution and extraction, or download the data.
3. Finally, students could combine GIS desktop software and its associated tools with data downloaded from the Internet. For example, to analyse the flood potential of rivers in their community and current wildfires around the world using real data and base maps in three dimensions, they could use ArcGIS and also download local satellite imagery and topographic maps from ArcGIS Online[w5].

Each of the methods has its advantages. Desktop software offers a more powerful analytical toolkit, whereas web-based GIS is easier to use and requires only a web browser.

Below are two example of analyses with GIS that could be carried out at school.

Analysing recent earthquakes with GIS

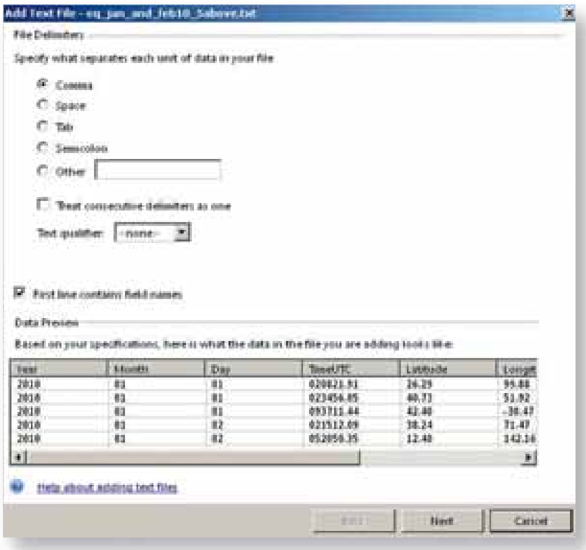
Let us say that you have read an article stating that the Haiti earthquake and its aftershocks in January 2010 were unusual because they were large in magnitude and because earthquakes are rare in Haiti. You want to test whether this is true. This can be done with desktop GIS software and data downloaded from the Internet.

1. Because earthquakes are inherently 3D phenomena, you will need to download 3D GIS software, for example ArcGIS Explorer[w1] (free; for Windows only).
2. From the US Geological Survey (USGS)'s seismic catalogue[w6], access a comma-separated text file of earthquake data covering January and February 2010. Do this by selecting 'Earthquakes' on the left, and then 'Search for an earthquake'. Run a global search, selecting spreadsheet format (comma delimited), with magnitudes 6 and above (use 10 as the maximum magnitude), from 1 January to 28 February 2010. Copy and save the resulting text data, which will include the dates, locations, magnitudes and depths of earthquake epicentres around the world.
3. In a text editor, remove the lines above and below the data except the header line. In the header line, remove the parenthesis and re-save the file.
4. In ArcGIS Explorer, use the Tools menu to add your earthquake data as X-Y co-ordinates in their correct locations (see image overleaf).

What do you notice about the spatial pattern of global earthquake locations? Why are earthquakes not distributed evenly around the world?

5. From ArcGIS Online[w5], open the plate boundaries layer and the 'Earthquakes January 2004 to

Image courtesy of ESRI

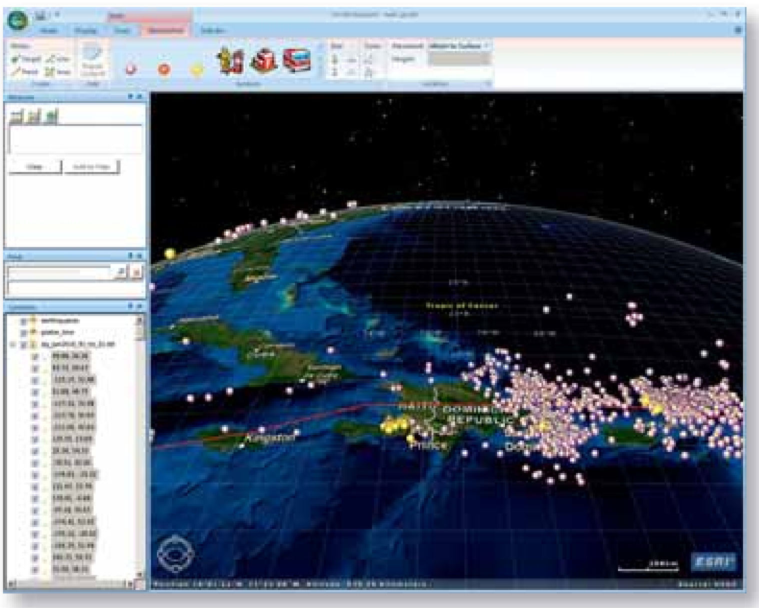


Adding earthquake data to ArcGIS Explorer

Image courtesy of ESRI

Opening layers from ArcGIS Online in ArcGIS

Image courtesy of ESRI



Earthquakes in and around Haiti

April 2007' layer in ArcGIS Explorer so that you can investigate the relationship between plate boundaries and the locations, magnitudes and depths of more than 60 000 earthquakes (see middle image, left). By clicking on an earthquake, you can see the date, time, magnitude, location and depth of that earthquake.

Why are some plate boundaries frequented by earthquakes while others are relatively quiet? Along what type of plate boundaries are the deepest earthquakes? And the shallowest? Why?

You will see that mid-ocean ridges have a moderate number of earthquakes that are less than 10 km deep, whereas subduction zones (where one plate sinks beneath the other) are associated with more frequent earthquakes that are both deeper and more intense.

Zoom to Haiti and you will see that the newspaper article was correct: most earthquakes in the region over the three-year period occurred in a wide, scattered pattern off the northeast coast of Hispaniola (shown by the purple dots in bottom image left) but the January and February 2010 earthquakes were focused in a narrow cluster on the western side of the island, in Haiti (shown by the yellow dots). Which earthquakes would you consider aftershocks, and why?

Further questions that the students could address include:

1. How and why do plate boundaries differ, and how do their movements result in different kinds and numbers of earthquakes?
2. How do plate movements impact populations living in close proximity, and also those far away (through tsunamis)?
3. What is the average distance that most earthquakes occur from the subduction zone along the western edge of South America, and what does this distance, and depth of the earthquakes, tell you about the type of plate boundary that exists there?
4. Do you think that the fact that there had been no earthquakes in Haiti between 2004 and 2007 contributed to tectonic pressure that resulted in the magnitude 7.0 earthquake of January 2010?
5. How common are aftershocks?
6. The earthquake a month later in Chile was much larger than the Haiti earthquake, but the death toll was much less. What effect do building codes have on earthquake damage in a region? (See also Marazzi & Tirelli, 2010.)

Analysing world climate with GIS

Another GIS investigation for the classroom would be to analyse world climates.

1. Download the free GIS software ArcExplorer Java Edition for Education[w2] (for Windows or Mac).
2. Open the worldclimate_hd project to view data layers that include vegetation, maximum and minimum temperature for July, maximum and minimum temperatures for January, mean precipitation, elevation, countries and a 30 degree latitude-longitude grid (see image right).
3. Click on the country layer and use the menu that appears to label the countries.

Why is the pattern of maximum temperatures for January different from that for July? From the map, can you see at what time of year it is summer in the northern hemisphere and when it is summer in the southern hemisphere? What influence does latitude have on temperature?

What is the difference between the minimum and maximum temperatures for July? Do any regions of the world experience daily temperature swings of more than 20°C? Where are these regions? What is the effect of the ocean on daily temperature swings and on the maximum temperatures around the world?

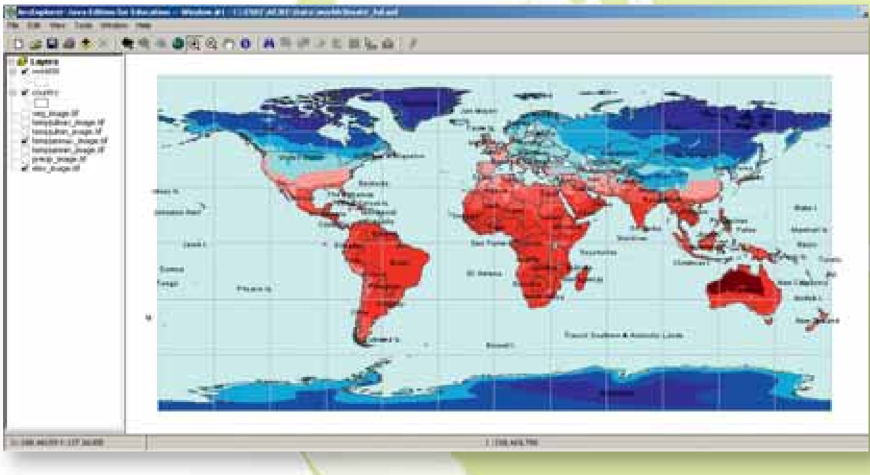
4. Turn on the elevation map layer (see image right).

What effect does elevation have on temperature? Is elevation as important as latitude as a determinant of temperature?

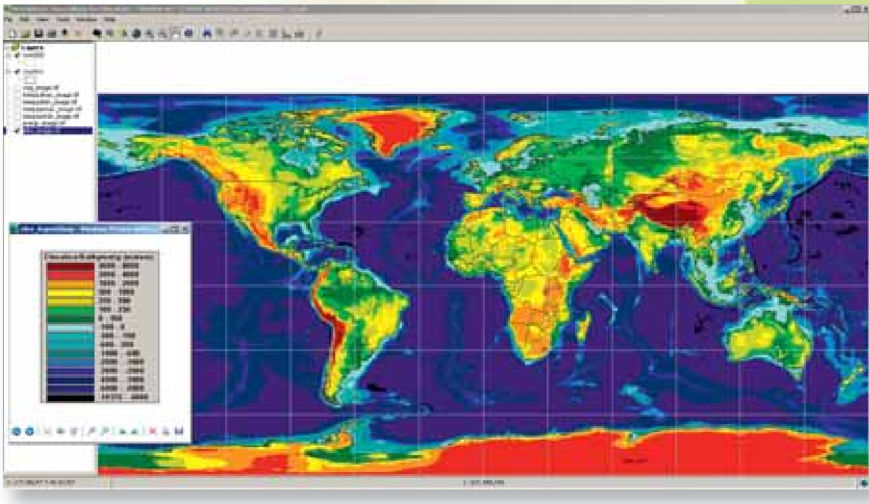
5. Next, examine the vegetation map layer (see image right).

What primary vegetation types cover Gabon, Oman and Japan? How is climate linked to vegetation? What is the predominant vegetation in regions that are more than 2000 m in elevation? Move your mouse until it rests on the Equator, and describe how the vegetation changes as you move across South America, Africa and south-east Asia along the Equator. How does vegetation and climate change as you move north

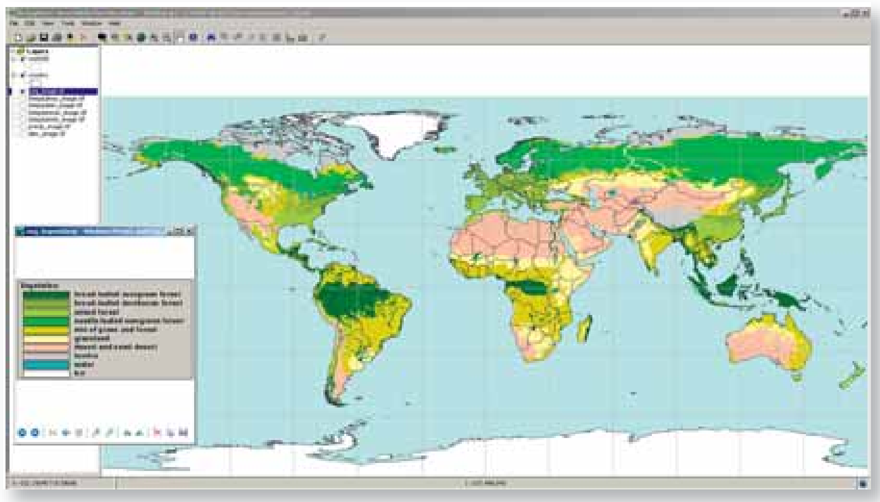
Images courtesy of ESRI



Worldclimate_hd project



Elevation map layer



Vegetation map layer

along the Prime Meridian from Ghana to the UK?

6. Zoom in on the region where you live. Determine the daily temperature variations in January and July and compare the maximum temperatures for January and July for your region.

How does the temperature, precipitation, vegetation and elevation compare with other regions of the world? Is there another part of the world that experiences a similar climate, elevation and vegetation to your region? If so, where is it?

References

Marazzi F, Tirelli D (2010) Combating earthquakes: designing and testing anti-seismic buildings. *Science in School* **15**: 55-59. www.scienceinschool. org/2010/issue15/earthquakes

Web references

w1 – ArcGIS Explorer is free, downloadable 3D GIS software for Windows, with which you can explore, visualise and share GIS information. You can add your own data to your ArcGIS Explorer maps and combine them with free data. You can also customise your maps by adding photos, reports, videos and other information. To download ArcGIS Explorer, watch some demonstrations and learn more about how to use it, visit: www.esri.com/arcgisexplorer

An evaluation of the professional GIS software ArcGIS can be requested here: www.esri.com/software/arcgis/arcview

w2 – ArcExplorer Java Edition for Education (AEJEE) is free, downloadable GIS software for Mac and Windows platforms that you can use to examine spatial patterns from a local to a global scale. You can classify, symbolise and analyse maps and images. To download AEJEE, visit: http://edcommunity.esri.com/aejee

w3 – Data on volcanoes, earthquakes, impact craters and plate boundaries can be analysed and downloaded from the This Dynamic Planet website. See: http://mineralsciences.si.edu/tdpmap

w4 – Worldmapper is a collection of maps showing the worldwide distribution of more than 700 variables. The data can be examined visually online or downloaded for further analysis. See: www.worldmapper.org

w5 – Base maps, such as those showing topography, satellite imagery, streets, and current weather, can be downloaded and integrated into ArcGIS Explorer and ArcGIS projects from the ArcGIS Online website: www.arcgisonline.com

w6 – The US Geological Survey (USGS)'s Earthquake Hazards Program provides a seismic catalogue from which earthquake data can be downloaded. See: http://earthquake.usgs.gov

Resources

Connect with other educators using GIS around the world and find lessons, data sets, online mapping tools, software, events and more via the ESRI Education Community: http://edcommunity.esri.com

Teachers can share and use lesson plans for using GIS via the ArcLessons library. See: http://edcommunity.esri.com/arclessons

ESRI has published four books containing lessons, data, software and assessment for students of all levels. The lessons include topics in biodiversity, natural hazards and climate, among others. To discover more about these books, see: www.esri.com/ourworldgiseducation

Gewin V (2004) Mapping opportunities. *Nature* **427**: 376-377. doi: 10.1038/nj6972-376a

Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2010/issue15/gis#resources), or subscribe to *Nature* today: www.nature.com/subscribe

National Academy of Sciences (2006) *Learning to Think Spatially—GIS as a Support System in the K-12 Curriculum*. Washington, DC, USA: The National Academies Press. ISBN: 0309092086

Sui DZ (1995) A pedagogic framework to link GIS to the intellectual core of geography. *Journal of Geography* **94**: 578-591. doi: 10.1080/00221349508979371

If you enjoyed this article, take a look at other earth science articles published in *Science in School*. See: www.scienceinschool.org/earthscience

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Joseph Kerski is the education manager at the Environmental Systems Research Institute (ESRI), where he develops GIS-based curriculum, conducts professional development for educators, develops and nurtures educational partnerships for the advancement of spatial analysis in education, and conducts research on the implementation and effectiveness of GIS in education. Before joining ESRI, Joseph worked as a geographer at the US Geological Survey and the US Census Bureau, and taught GIS and geography at several secondary schools and universities.

ESRI is a company dedicated to the development of GIS software that millions of people around the world use daily to make better decisions in government agencies, non-profit organisations, private industry and academia. The ESRI education team supports GIS at all levels of education, in instruction, educational policy-making and educational administration.

Down to Earth: ideas for the earth science classroom

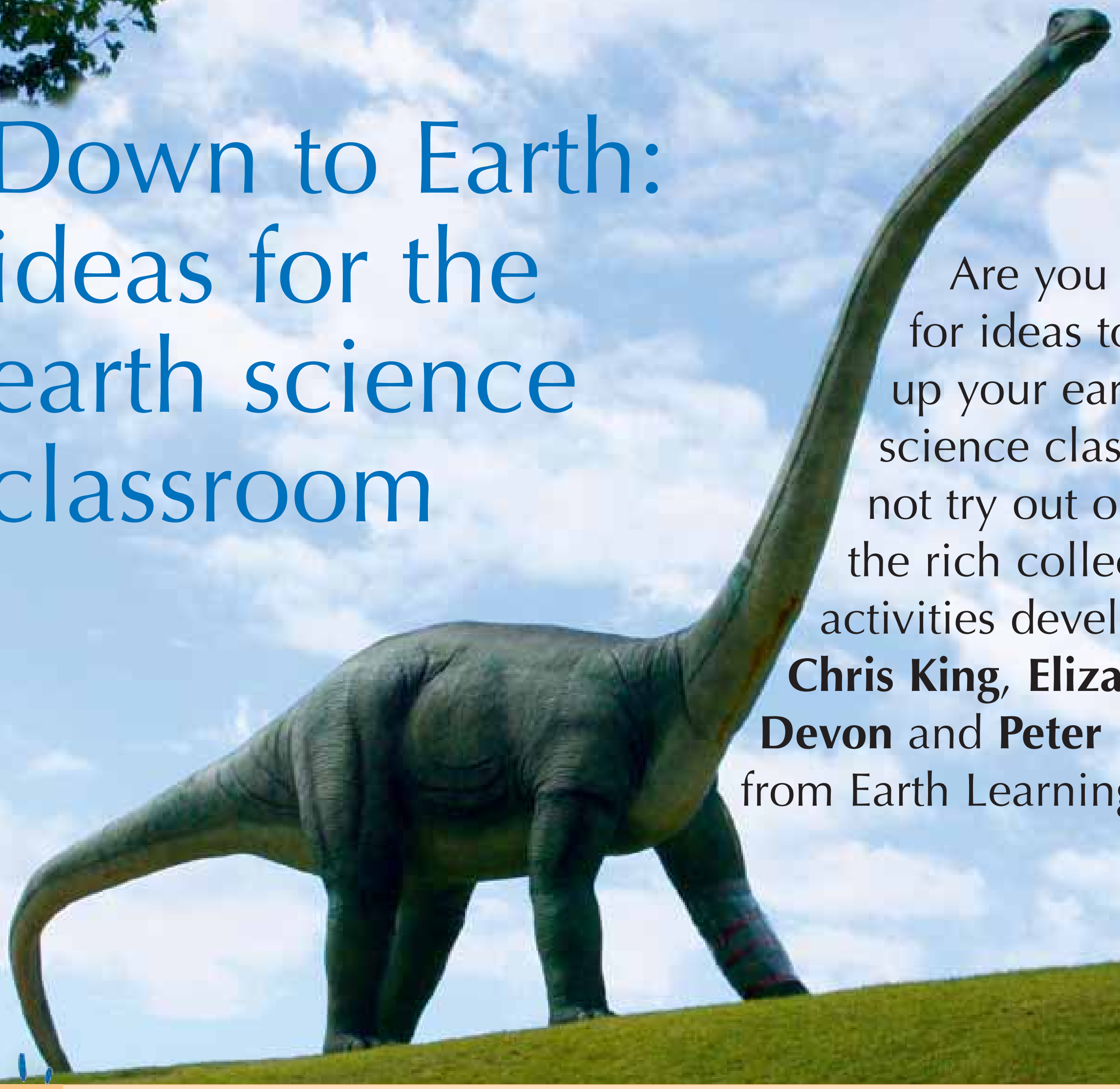


Image courtesy of shizzine / iStockphoto

Are you looking for ideas to spice up your earth science class? Why not try out one of the rich collection of activities developed by **Chris King**, **Elizabeth Devon** and **Peter Kennett** from Earth Learning Idea.

REVIEW

- Earth science
- Physics
- Biology
- Mathematics
- Energy
- Evolution
- Ages 5-19

As an earth science teacher I frequently found it difficult to address some topics without being able to do experiments in the classroom. The Earth Learning Idea resources gave me a valuable instrument to overcome this problem and make my lessons livelier.

The project offers a set of hands-on activities for a wide range of topics related to earth science and geology from primary to upper secondary school. These activities can be easily carried out at school in a limited period of time (usually less than one hour) and with nearly no lab equipment; the required materials are very cheap and easy to get. In addition, every activity is complemented with a back-up section to fit them well into the science curriculum.

The article presents two activities which make it possible to link earth science with physics (density, pressure), biology (evolution, history of life) and mathematics (calculations). The article may be used as a starting point to discuss related topics such as energy resource management, the theory of evolution and its evidence (e.g. the fossil record). It can also provide valuable background reading before a visit to a natural history museum, a fossil exhibition or an oil or gas well (if applicable in your country).

Many more activities can be found on the project website[w1], where a keyword index and a category list help the search. I would recommend this article, together with the website, to earth science teachers looking for novel didactic materials to enrich their lessons: both they and their students would really enjoy and profit from the experience.

Giulia Realdon, Italy

To coincide with the UN International Year of Planet Earth (2007-2009), three earth science teachers from the UK compiled a website with a vast, varied and still expanding collection of teaching activities: Earth Learning Idea[w1].

The simple activities require few resources (but can be readily adapted for use with standard school lab equipment) and are designed to encourage students aged 8-18 to investigate how Earth works (the recommended age range is given in each activity). There is an online discussion around every idea in order to develop a global support network, and each activity is accompanied by 'back-up' notes for teachers. The activities are also being translated into Spanish, Norwegian, Italian, Chinese and Tamil.

You can help the team (and yourself), if you are a teacher trainer or school teacher in science, geography or earth science, by subscribing free of charge on the project website to receive two new earth learning ideas each month during 2010. You can then discuss the idea with other interested people across the globe on the associated blog. All activities are free to download at any time, but if you subscribe, you will be notified when a new activity is published.

The activities on the website are divided into nine different categories: 'Earth as a system', 'Earth energy', 'Earth in space', 'Earth materials', 'evolution of life', 'geological time', 'investigating the Earth', 'natural hazards' and 'resources and environments'. They include activities on volcanoes, tsunamis, dinosaurs, oil and gas, earthquakes, permeability of soil and many more. Most are practical activities, whereas others can be thought experiments, such as a paper-folding activity to help students visualise how Darwin developed his theory of how coral atolls formed. Many protocols include an extra section of additional follow-up experiments.

Examples of two of the activities are given below (without the back-up details, which appear on the website).

Trapped! Why can't oil and gas escape from their underground prison?

This experiment is used to demonstrate how oil and gas can be trapped in reservoir rocks beneath the surface[w2].

Age range: 14-18 years

Required time: 10 min

Learning objectives: Students should be able to:
- Explain that oil and gas float on top of water, because of their lower density;
- Explain that oil and gas may become trapped underground, if they rise until they reach an impermeable layer of rock;
- Appreciate the need to control the drilling for oil and gas, to avoid 'blowouts' at the surface.

Context: This could form part of a lesson on the world's resources. It could follow a lesson on porosity and permeability.

Materials

- Any large container, e.g. a bucket, preferably with clear sides, nearly full of water
- The top end cut off a clear plastic bottle (e.g. 2 l bottle) to be used as a funnel
- A thin tube, e.g. the barrel of an old ball-point pen, with a bung
- Clay, to seal the tube into the neck of the bottle
- A drinking straw or tubing for blowing air into the funnel
- Cooking oil (if possible)

Images courtesy of Peter Kennett

Home-made funnel using the top of a bottle, a tube from a ball-point pen and some clay

Home-made apparatus showing the model oil trap in action

Procedure

1. Insert the thin tube or ball-point pen into the funnel or top of the bottle, so that most of it is sticking out, and seal the bottle with clay (see image).
2. Push the funnel well down into the water in the container.
3. Only then seal the top part of the thin tube with a bung.
4. Blow air underneath the lip of the funnel with a piece of tubing or a straw, displacing roughly half the water. The air represents gas.
5. Put some cooking oil into the tubing and blow it up into the inverted funnel, to represent oil.
6. Explain that the inverted funnel (or the top of a clear plastic bottle) represents the impermeable cap rock forming a trap in a permeable layer containing natural gas and oil.

7. Ask the students the following questions, the answers to which are in the PDF[w2]:
   - In what order do the different 'layers' of gas, oil and water occur?
   - Why does the gas (and oil) lie on top of the water and not the other way round?
   - Are the bases of the 'layers' of gas and oil above the water horizontal or not?
   - What will happen when the bung is removed from the funnel?
   - Why might this be a problem in a real oil or gas well?
8. Remove the bung sharply and see what happens.
9. Ask why this might be a problem in a real oil or gas well.

Note: If no cooking oil is available, the principles can be demonstrated using only the air blown through the tubing.

How to weigh a dinosaur

How can the relationship between pressure, force and area be used to estimate the mass of a two-legged dinosaur from the area and depth of one of its fossilised footprints? Dinosaurs sometimes left footprints in wet mud or sand, which hardened to leave trace fossils. We can work out how heavy the dinosaur was, if we compare the footprint with the mark made by a known weight in the classroom.

We are giving a worked example here, to make it easier to follow the calculations, but other values may be obtained at school, depending on the equipment available[w3].

Age range: 14-18 years

Time required: 30 min

Learning objectives: Most students should be able to:

- Calculate the pressure from a given force and area;
- Invert the equation and calculate an unknown force from a known pressure and area;
- Debate whether the result gives the mass of the dinosaur, or if it needs to be doubled to account for it being two-legged;
- Appreciate that such calculations can only be an approximation.

Context: The lesson introduces the concept that an imprint (trace fossil) is just as much a fossil as the remains of the actual body – and can sometimes give very valuable information on the lifestyle of the organism. It provides a useful link between physics, mathematics and geology.

Materials

- Soft, very wet sand in a deep (e.g. 10 cm) container
- A 1 kg mass, or a 1 l plastic bottle full of water (which imposes a force of 10 N)
- A calculator and a ruler
- A rectangular block, 2 cm x 2 cm (i.e. 4 cm^2 cross-section) by, say, 10 cm long, preferably marked at 1 cm intervals
- A diagram showing an outline drawing of a single dinosaur footprint on a 5 cm grid for estimating the area (overleaf, or to be printed from the PDF[w3])

Procedure

1. Fill the container with sand, and soak it thoroughly with water. Pour off any excess water.
2. Stand the rectangular block upright on the wet sand.
3. Place the 1 kg mass on top of the block and let it sink into the wet sand. It imposes a force of about 10 N. Ideally, you would also calculate the weight of the rectangular wooden block, but it is small compared to the 1 kg mass, so it can be ignored, given that the total force is only approximately 10 N.
4. Measure the depth in centimetres to which the bottom of the block sinks into the sand (1.5 cm).
5. Pressure = force/area, so the pressure exerted by the block = 10 N / (2 cm x 2 cm) = 2.5 N/cm^2.
6. The diagram (see image overleaf, half actual size) shows one footprint left by a small two-legged dinosaur.

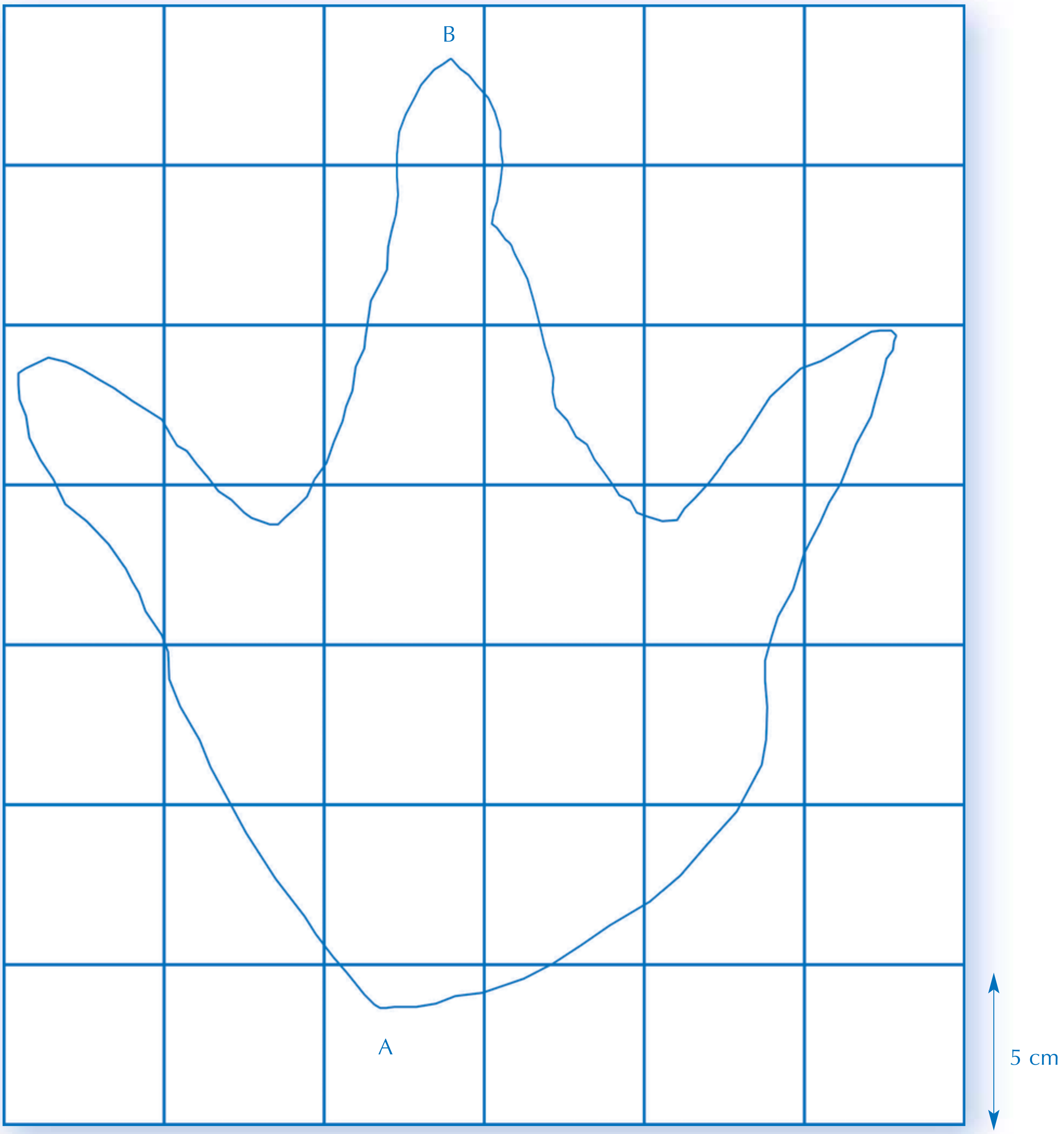
Image courtesy of Peter Kennett

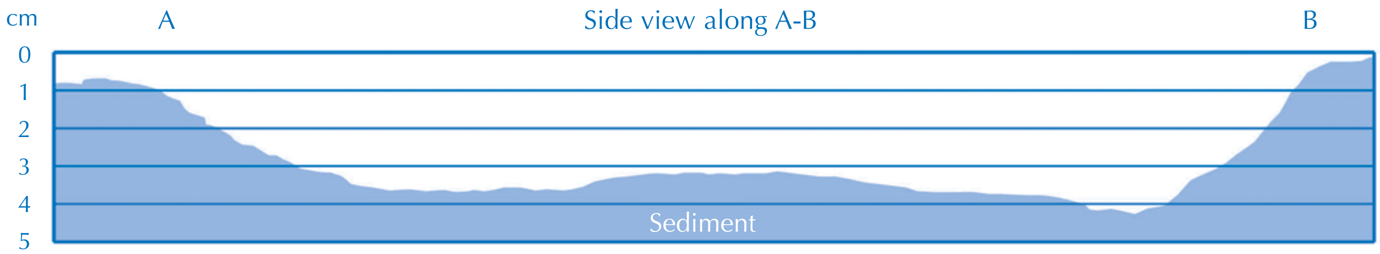
A teacher demonstrates how to measure pressure in the sand container

7. Measure the area of the dinosaur footprint, by counting squares on the diagram, where each square represents 25 cm^2. (Answer: 325 cm^2.)
8. Estimate the average depth in centimetres of the footprint from the side view in the diagram (3 cm).
9. Assume that the 'sinking depth' is proportional to pressure (i.e. if pressure is twice as great, the dinosaur's foot will sink in twice as deeply). Calculate the pressure exerted by the dinosaur's foot (2.5 N/cm^2 x 3 cm / 1.5 cm = 5 N/cm^2).
10. Force = pressure x area, so force (i.e. weight) = 5 N/cm^2 x 325 cm^2 = 1625 N.
11. There are about 10 N per kg, so the mass of the dinosaur acting on one foot would have been 1625 N / 10 N/kg = 162.5 kg. This is the mass of a person about 2.7 metres (9 feet) tall – a giant!
12. Does this represent the total mass of the dinosaur? What other explanation could there be?

For a further investigation, students could devise ways of investigating whether the sinking depth is indeed proportional to pressure, using a variety of objects on a range of substrates. The effect of the water content of the substrate could also be investigated.

Footprint of a two-legged dinosaur (shown at half actual size)





Acknowledgements

The activity on trapped oil and gas is based upon an original idea by DB Thompson, published in Earth Science Teachers' Association (1992).

The dinosaur activity is based on part of a teacher-training workshop run by the Earth Science Education Unit.

In addition, thanks are due to Dr Martin Whyte of Sheffield University for his helpful comments on a draft of this activity.

References

Earth Science Teachers' Association (1992) *Science of the Earth 11-14 Power Source: Oil and Energy.* Sheffield, UK: Geo Supplies Ltd. ISBN 1873266057

Reynaud M (2009) The Beagle. *Science in School* **12**: 82-84. www.scienceinschool.org/2009/issue12/beagle

Web references

w1 – The website of the Earth Learning Idea project is: www.earthlearningidea.com

w2 – You can download the full PDF of the activity, 'Trapped – why can't oil and gas escape?', from the Earth Learning Idea website (www.earthlearningidea.com) or via the direct link: http://tinyurl.com/yd82s3w

w3 – For the PDF of the 'How to weigh a dinosaur' activity, see the Earth Learning Idea website (www.earthlearningidea.com) or use the direct link: http://tinyurl.com/yaw6c6k

Resources

Suggested Earth Learning Idea activities to complement the 'Trapped oil and gas' activity include:

Modelling for rocks: what's hidden inside and why
www.earthlearningidea.com/PDF/Modelling_for_rocks.pdf
www.earthlearningidea.com/PDF/05_Extension.pdf

The space within: the porosity of rocks
www.earthlearningidea.com/PDF/Space_within.pdf
www.earthlearningidea.com/PDF/Porosity_extension.pdf

Where shall we drill for oil? Sorting out the sequence – oil prospect
www.earthlearningidea.com/PDF/Sorting_Sequence.pdf

Make your own oil and gas reservoir
www.earthlearningidea.com/PDF/64_Oil_gas_reservoir.pdf

In addition, you might find the following articles on energy and fossil fuels useful:

De Vries G (2009) Powering the world. *Science in School* **11**: 58-63. www.scienceinschool.org/2009/issue11/energy

Van Dijk M (2009) Hydrocarbons: a fossil but not (yet) extinct. *Science in School* **12**: 62-69. www.scienceinschool.org/2009/issue12/energy

To complement the 'How to weigh a dinosaur activity', there is a vast selection of Earth Learning Idea activities on dinosaurs and fossils, including:

The meeting of the dinosaurs – 100 million years ago
www.earthlearningidea.com/PDF/Dinosaur_Footprints.pdf

Dinosaur death - did it die or was it killed?
www.earthlearningidea.com/PDF/Crime_scene_final.pdf

A dinosaur in the yard
www.earthlearningidea.com/PDF/Dinosaur_in_the_yard.pdf

What was it like to be there? - bringing a fossil to life
www.earthlearningidea.com/PDF/37_What_like_be_there_fossil.pdf

For more information on dinosaur footprints, see:

www.sorbygeology.group.shef.ac.uk/dino.html

www.enchantedlearning.com/subjects/dinosaurs/dinotemplates/Footprint.shtml

www.uc.edu/geology/geologylist/dinotracks.html

www.scienceviews.com/dinosaurs/dinotracks.html

For further suggestions of teaching fossils and dinosaurs in the classroom, see:

Barnes E (2006) The Bone Trail: generating enthusiasm for earth sciences in the classroom. *Science in School* **3**: 52-55. www.scienceinschool.org/2006/issue3/bonetrail

Demoncheaux E (2007) Review of *Fossils: A Very Short Introduction* and *Dinosaurs: A Very Short Introduction*. *Science in School* **6**: 85. www.scienceinschool.org/2007/issue6/fossils

If you enjoyed this article, you might like to browse the other earth science articles published in *Science in School*: www.scienceinschool.org/earthscience

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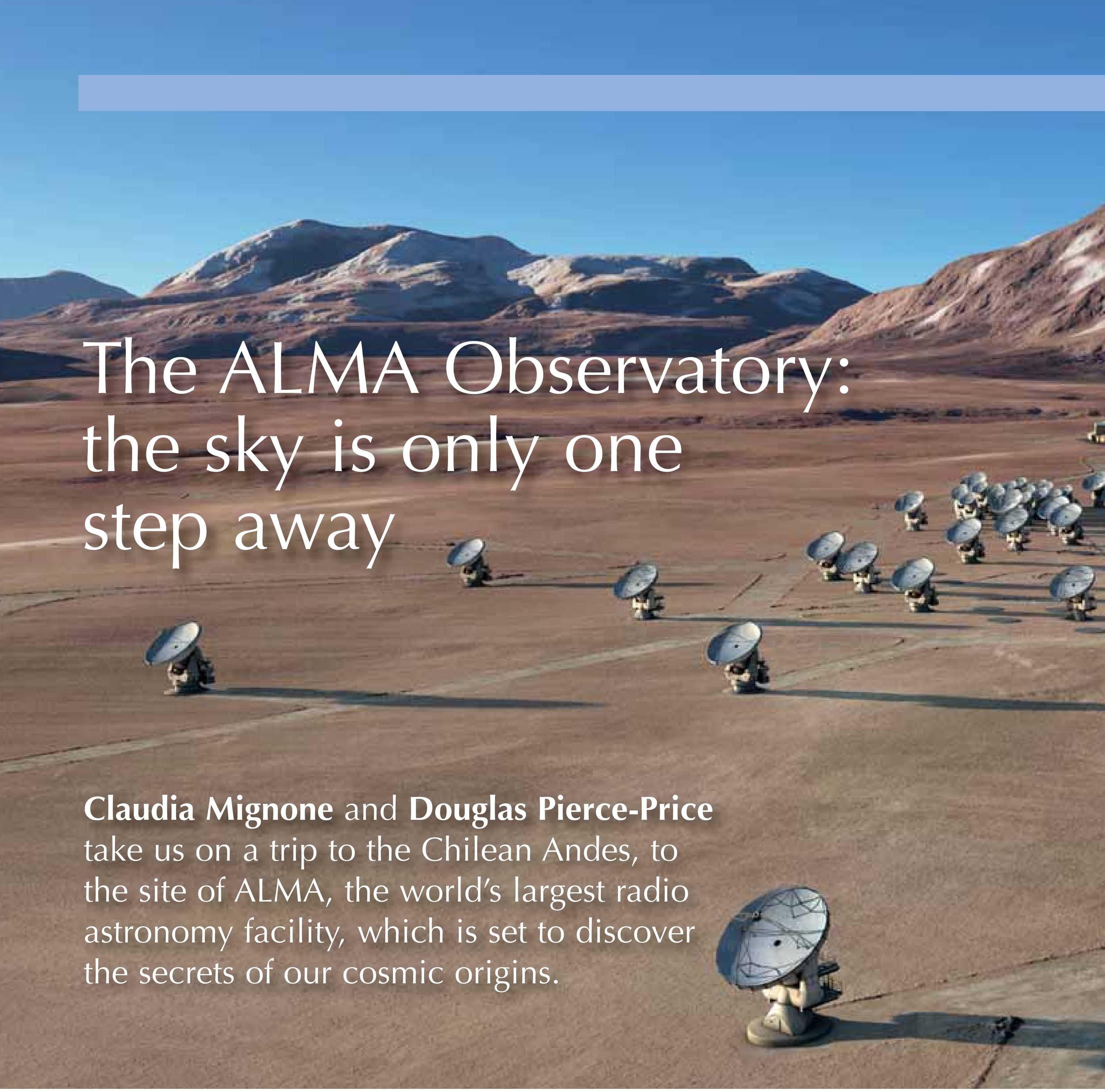
Earth Learning Idea is run voluntarily by Chris King, Elizabeth Devon and Peter Kennett from the UK. Chris King is a professor of earth science education at Keele University, with prior experience in school teaching and in industrial geology. Elizabeth Devon and Peter Kennett are retired geology teachers, the latter having first worked as a geophysicist for the British Antarctic Survey. All are members of the Earth Science Education Unit, administered by Keele University, the professional role of which is to lead free workshops for continuing professional development of teachers throughout the UK.

Contact the Earth Learning Idea team at: info@earthlearningidea.com

Image courtesy of ava09 / iStockphoto



The ALMA Observatory: the sky is only one step away

Claudia Mignone and **Douglas Pierce-Price** take us on a trip to the Chilean Andes, to the site of ALMA, the world's largest radio astronomy facility, which is set to discover the secrets of our cosmic origins.

Imagine hiking in the Atacama region, high in the Andes of northern Chile, one of the driest and remotest spots on Earth. At altitudes of 5000 m and higher, life is not easy here: the atmospheric pressure is much lower than at sea level, and oxygen is scarce. The landscape, dominated by large volcanoes and other mountain peaks, occasionally decorated by salt flats and picturesque formations of ice and snow, hardly resembles a typical view of our planet. Then, in the midst of this arid and abandoned region, you become aware of a gigantic construction – could those be huge satellite dishes?

Not exactly. This is the Atacama Large Millimeter/submillimeter Array (ALMA), an ensemble of huge, high-precision antennas that is currently being built on the Chajnantor plateau by an international partnership between Europe, North America and East Asia in cooperation with the Republic of Chile. The European partner in ALMA is the European Southern Observatory (ESO). ALMA is a revolutionary observatory which, when complete in around 2012, will allow astronomers to observe the light coming from some of the coldest and most distant objects in the Universe, with much better resolution and sensitivity than is presently possible.

ALMA is the largest ground-based astronomy project in existence. Three antennas have already been installed

REVIEW

- Physics
- Astronomy
- Ages 15-19

It is not uncommon for teachers to mention optical telescopes during physics lessons but references to telescopes that make use of other types of radiation are less common. This article is interesting as it gives an insight into an ongoing project to build a radio telescope.

Teachers would find this article particularly useful and applicable in a discussion about the resolving power of an instrument. Suitable comprehension questions include 'Why do the antennas need to be spread out over a large area?' and 'Why can't a single instrument be used?'

Paul Xuereb, Malta

An artist's impression of the ALMA array, in an extended configuration

Image courtesy of ALMA (ESO / NAOJ / NRAO) / L Calçada

– an impressive enterprise given the challenging conditions of the site. However, those who visit the Chajnantor plateau a couple of years from now will encounter 66 antennas, 54 of which will have 12 m diameter dishes, and 12 smaller ones, with a diameter of 7 m each.

The most visible part of each antenna is the dish, a large reflecting surface. The dish is what lenses and mirrors are to 'traditional', or optical, telescopes: it collects radiation coming from distant astronomical objects, and focuses it into a detector which measures the radiation. The difference between the two types of telescopes is the wavelength of the radiation detected. Visible light, captured by optical telescopes, is just a small part of the spectrum of electromagnetic radiation (see box on page 46), with wavelengths between 380 and 750 nm (millionths of a millimetre). ALMA, in contrast, will probe the sky for radiation at longer wavelengths from a few hundred micrometres to about 1 mm. This is known as millimetre and submillimetre radiation, a subset of radio waves.

ALMA's dishes differ from the mirrors of a visible-light telescope in both smoothness and size. The reflecting surfaces of any telescope must be virtually perfect: if they have any defects that are larger than a few per cent of the wavelength to be detected, the telescope will not produce accurate measurements. The longer wavelength to be detected by ALMA's antennas means that although they are accurate to much less than the thickness of a single sheet of paper, the dishes do not need the mirror finish used for visible-light telescopes. So although ALMA's dishes look like giant metallic satellite dishes, to a (sub)millimetre-wavelength photon, they are still almost perfectly smooth reflecting surfaces, focusing the photons with great precision.

Image courtesy of ESO

The European antenna prototype for ALMA

The resolution (or degree of detail in the image) of a telescope depends both on the wavelength at which it operates and on the size of its aperture – the diameter of the main dish or mirror. The longer the wavelength, the worse the resolution; and the larger the diameter, the better the resolution. The relationship between the angular size of the smallest details that can be distinguished (θ), the wavelength (λ) and the diameter (D) is given by: $\theta \approx \lambda / D$. Note that small θ

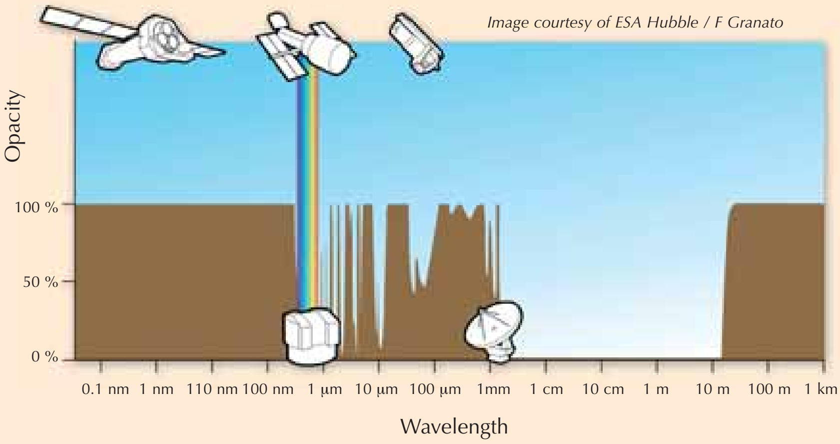
BACKGROUND

Detecting astronomical objects along the electromagnetic spectrum

Visible light is just a small part of the whole spectrum of electromagnetic radiation. The different parts of the spectrum, or spectral bands, are, in order of decreasing wavelength and increasing frequency: radio waves (including microwaves and (sub)millimetre radiation), infrared, visible, ultraviolet, X-rays and gamma rays.

Because different physical processes in the Universe emit light at different wavelengths, each class of objects in the Universe shines most brightly in one or several particular spectral bands. Modern astronomers often try to target many bands, using different telescopes, since each set of observations provides a complementary piece of the puzzle; this approach is called multi-wavelength astronomy.

However, Earth's atmosphere complicates matters, because it absorbs most of the radiation. Although this protects us, it makes life difficult for astronomers: only a tiny fraction of the electromagnetic spectrum is observable from the ground, and often in these cases, the quality of the observations strongly depends on the geographical site. This is why choosing an excellent site such as Chajnantor for ALMA is so important. In other spectral bands, especially at very short wavelengths, astronomers need telescopes aboard satellites in orbit around our planet, outside the obscuring layer of the atmosphere.



Atmospheric opacity: the level of the brown curve represents how opaque the atmosphere is at the given wavelength. The major windows are at visible wavelengths (marked by the rainbow) and at radio wavelengths from about 1 mm to 10 m. ESO's Very Large Telescope operates in the visible and infrared light region and ALMA operates in the (sub)millimetre region, where the opacity depends strongly on how high and dry the site is. Observations at wavelengths where the atmosphere is opaque require space telescopes (shown at the top of the image)

Colour composite image of the star-forming region RCW120. It reveals how an expanding bubble of ionised gas about ten light-years across is causing the surrounding material to collapse into dense clumps where new stars are then formed. The cold and dense clouds emit light at submillimetre wavelengths, shown in blue, and are an ideal target for telescopes such as ALMA.
In this image, the 870 µm submillimetre-wavelength data were taken with the LABOCA camera on the 12 m Atacama Pathfinder Experiment (APEX), a single-dish telescope based on a prototype ALMA antenna, also on the Chajnantor plateau

Image courtesy of ESO / APEX / DSS2 / SuperCosmos / Deharveng (LAM) / Zavagno (LAM)

(angle) values represent finer details and hence better resolution. Consequently, a (long-wavelength) radio telescope with the same-sized dish as a (short-wavelength) visible-light telescope would have a worse resolution.

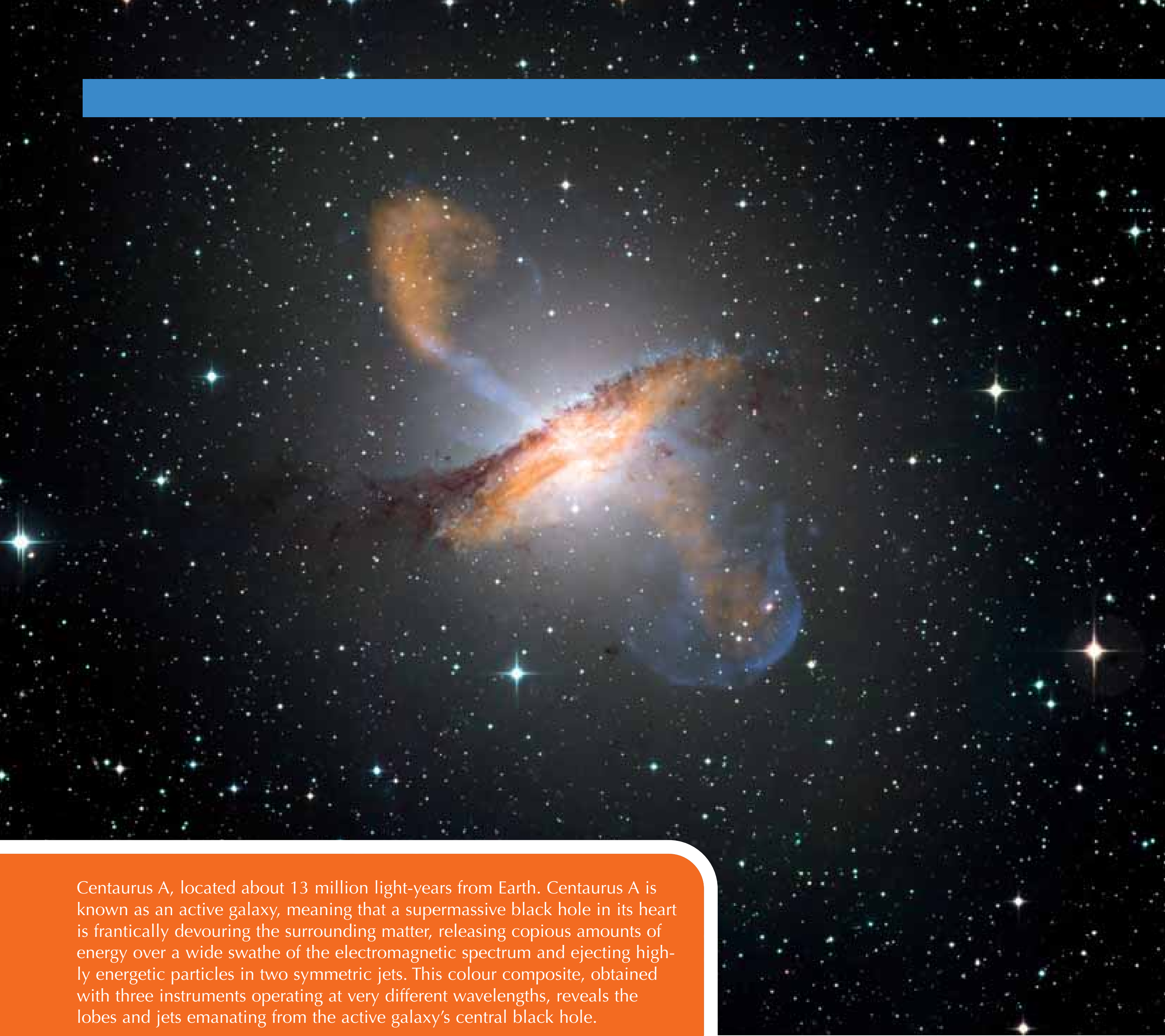
Therefore, to achieve a resolution comparable with that of state-of-the-art visible-light telescopes, a radio telescope like ALMA would need a reflecting surface with a diameter of a few kilometres – clearly unfeasible. This is why ALMA consists of an array of many individual antennas spread out over a very large area, working together in what is known as an interferometer.

The resolution of an interferometer is given by $\theta \approx \lambda/B$, where θ is the resolution, λ the wavelength and B the maximum baseline, the separation between a pair of antennas in the array. In other words, an interferometer acts like a single telescope as large as the whole array.

Increasing the maximum distance between the antennas increases the resolving power of the interferometer, allowing it to detect smaller details. The ability to link antennas over baselines of many kilometres is crucial to obtain extremely good resolution and a high degree of detail in the images.

ALMA's main array will have fifty 12 m antennas, arranged in configurations spread over distances from 150 m to 16 km. The array will thus simulate a giant, single telescope much larger than any that could actually be built. In fact, ALMA will have a maximum resolution which is even better than that achieved at optical wavelengths by the Hubble Space Telescope.

The remaining four 12 m antennas and the twelve 7 m antennas will form the Atacama Compact Array. The smaller 7 m antennas can be clustered more closely together; because of the way interferometers behave, this compact arrangement allows them to see the broader structure or 'big picture' of the astronomical



Centaurus A, located about 13 million light-years from Earth. Centaurus A is known as an active galaxy, meaning that a supermassive black hole in its heart is frantically devouring the surrounding matter, releasing copious amounts of energy over a wide swathe of the electromagnetic spectrum and ejecting highly energetic particles in two symmetric jets. This colour composite, obtained with three instruments operating at very different wavelengths, reveals the lobes and jets emanating from the active galaxy's central black hole.

The 870 µm submillimetre data, from LABOCA on APEX, are shown in orange. X-ray data from the Chandra X-ray Observatory are shown in blue. Visible light data from the Wide Field Imager (WFI) on the MPG / ESO 2.2 m telescope located at La Silla, Chile, show the background stars and the galaxy's characteristic dust lane in close to 'true colour'

Image courtesy of ESO / WFI (optical); MPIfR / ESO / APEX / A Weiss et al. (submillimetre); NASA / CXC /CfA / R Kraft et al. (X-ray)

objects that are observed. In addition, the four 12 m antennas will be used separately to measure the absolute brightness of the objects observed, which is a quantity that cannot be measured with an interferometer.

The different configurations of the telescope allow astronomers to probe both the broad structure of an astronomical source and its very finest details. However, to switch between compact and wide configurations of the array, the antennas must be physically moved. This is done with two custom-built transporters, designed to lift the antennas, which each weigh more than 100 tonnes, move them kilometres across the desert, and position them on concrete docking pads with millimetre precision.

One of the goals of ALMA is to capture radiation from very distant galaxies: they were among the first to form in the history of the Universe, and we see the light that they emitted over ten billion years ago. The wavelength of the light emitted by these remote galaxies is 'stretched' as it travels toward us, because the Universe is expanding: what starts as infrared light eventually reaches Earth with millimetre or submillimetre wavelengths. This makes a telescope like ALMA the ideal tool to hunt for the very first galaxies and explore how structure formed in the Universe.

ALMA will also explore in unprecedented detail many stellar nurseries –

the vast, cold clouds of gas and cosmic dust grains in interstellar space where new stars are born. The light produced by these young stars is absorbed and re-emitted, at longer infrared and (sub)millimetre wavelengths, by the dust. Observed through an optical telescope, these regions are often obscured by the dust grains and therefore dark, but they shine brightly in the (sub)millimetre part of the spectrum. ALMA will be the most powerful telescope for observing these extremely cold clouds, and it will deliver images of them with an unprecedented degree of detail. Thanks to ALMA, astronomers will be able to make detailed images of stars and planets being born in gas clouds near our Solar System and to better understand how stars, planetary systems and even life itself formed.

(Sub)millimetre radiation, therefore, opens a window onto the cold and the distant Universe, but it is very challenging to detect because it is heavily absorbed by the water vapour in the Earth's atmosphere. For this reason, telescopes for this kind of astronomy must be built on high and dry sites, where the atmosphere is rarefied and its water vapour content minimal. This is why the Chajnantor plateau at 5000 m altitude, one of the driest places on Earth, was chosen for ALMA. Here, astronomers will enjoy unsurpassed conditions for observing the Universe, but the price to pay is high, as they must operate a frontier observatory under very difficult conditions. Working at these high altitudes, the astronomers will be exposed to the same problems that mountaineers experience, such as altitude sickness, low atmospheric pressure and lack of oxygen to breathe. To make technical operations and everyday work easier, a base camp has been built at a lower altitude of about 2900 m. In short, if a site is good for (sub)millimetre astronomy, you most certainly do not want to live there.

Although the village of San Pedro de Atacama is located just some 50 km away, walking around the ALMA site feels almost like visiting another planet. The plateau of Chajnantor is so high up that the frantic routine of urban life is but a pale memory, and this helps make it a unique location on Earth to explore the hidden and distant mysteries of the cosmos. From here, space is just one step away.

Resources

The website of *In Search of our Cosmic Origins*, a planetarium show about ALMA, provides teachers and educators with a series of worksheets, including detailed information and practical exercises about the scientific and technical topics presented in the article. See: www.cosmicorigins.org and www.cosmicorigins.org/education.php

For more information about ALMA, see www.eso.org/alma and www.almaobservatory.org

To watch ESO's video podcast about ALMA, see: www.eso.org/public/videos/eso0849b

For a short video introduction to ALMA, see: www.eso.org/public/videos/almatrailer2009

For more videos about ALMA, see: www.eso.org/public/videos/archive/category/alma

To learn more about the Atacama region and how, as part of the ALMA project, the historical and environmental aspects of the region are being respected, see the ALMA website (www.almaobservatory.org) or use the direct links: http://tinyurl.com/ydg2usl and http://tinyurl.com/yamfh77

If you enjoyed this article, you might like to browse all astronomy articles previously published in *Science in School*. See: www.scienceinschool.org/astronomy

Claudia Mignone studied astronomy at the University of Bologna, Italy, and then moved to Germany for a PhD in cosmology at the University of Heidelberg. Her research focused on methods to infer the properties of the expansion of the Universe. She enjoys writing about science and society, and explaining science to people who are not closely involved with it. These interests led her to move into science communication, first as a communications intern at the European Southern Observatory (ESO) and now as a science writer at the European Space Agency (ESA).

Douglas Pierce-Price is the public information officer for ALMA and APEX at the ESO headquarters in Germany. Before joining ESO, he completed his PhD at the astrophysics group of the University of Cambridge, UK, and worked in astronomical outreach at the Joint Astronomy Centre in Hawaii, USA.

Image courtesy of ALMA (ESO / NAOJ / NRAO)

The first three ALMA antennas, on the Chajnantor plateau in late 2009

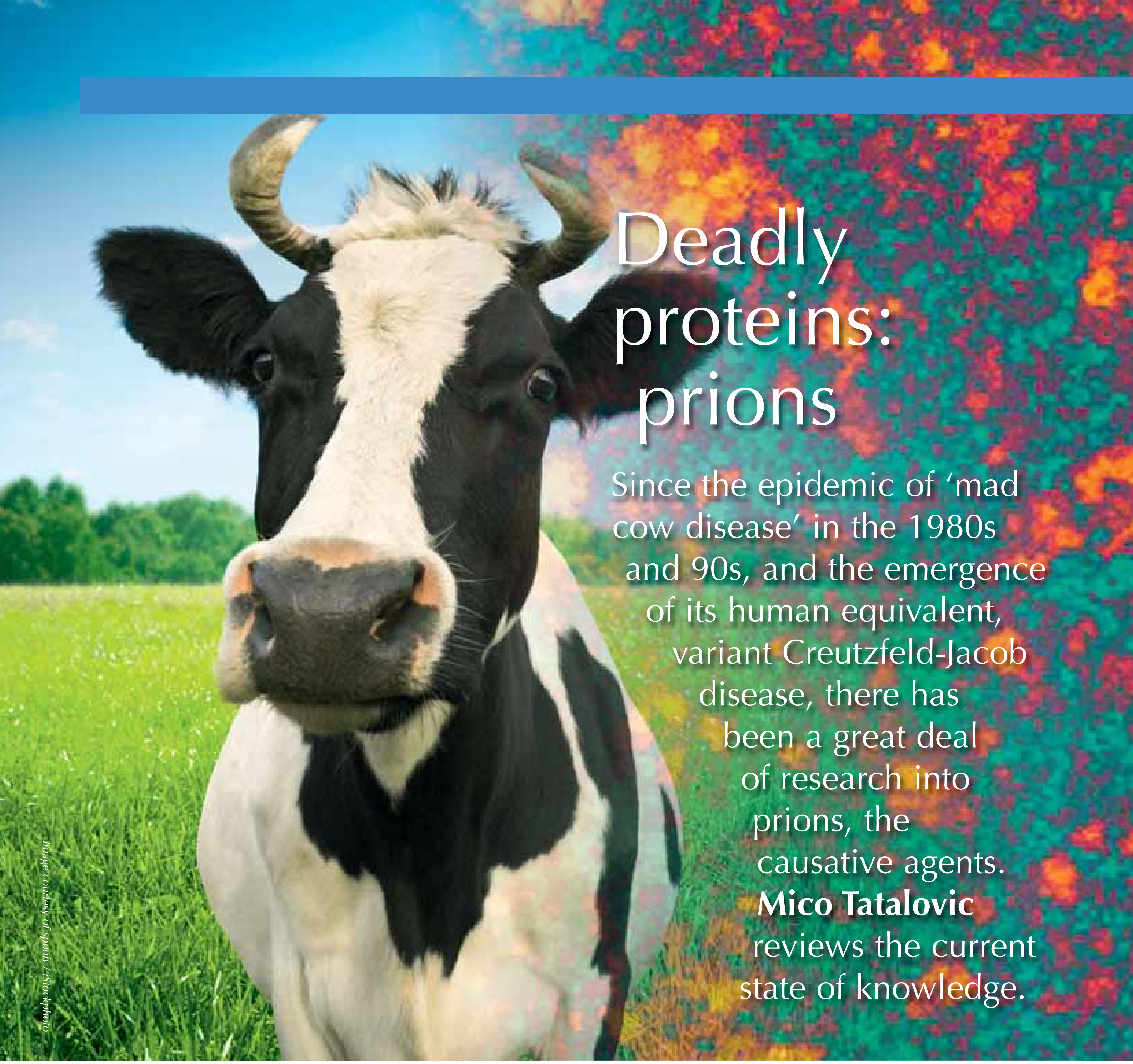


Image courtesy of spooh / iStockphoto

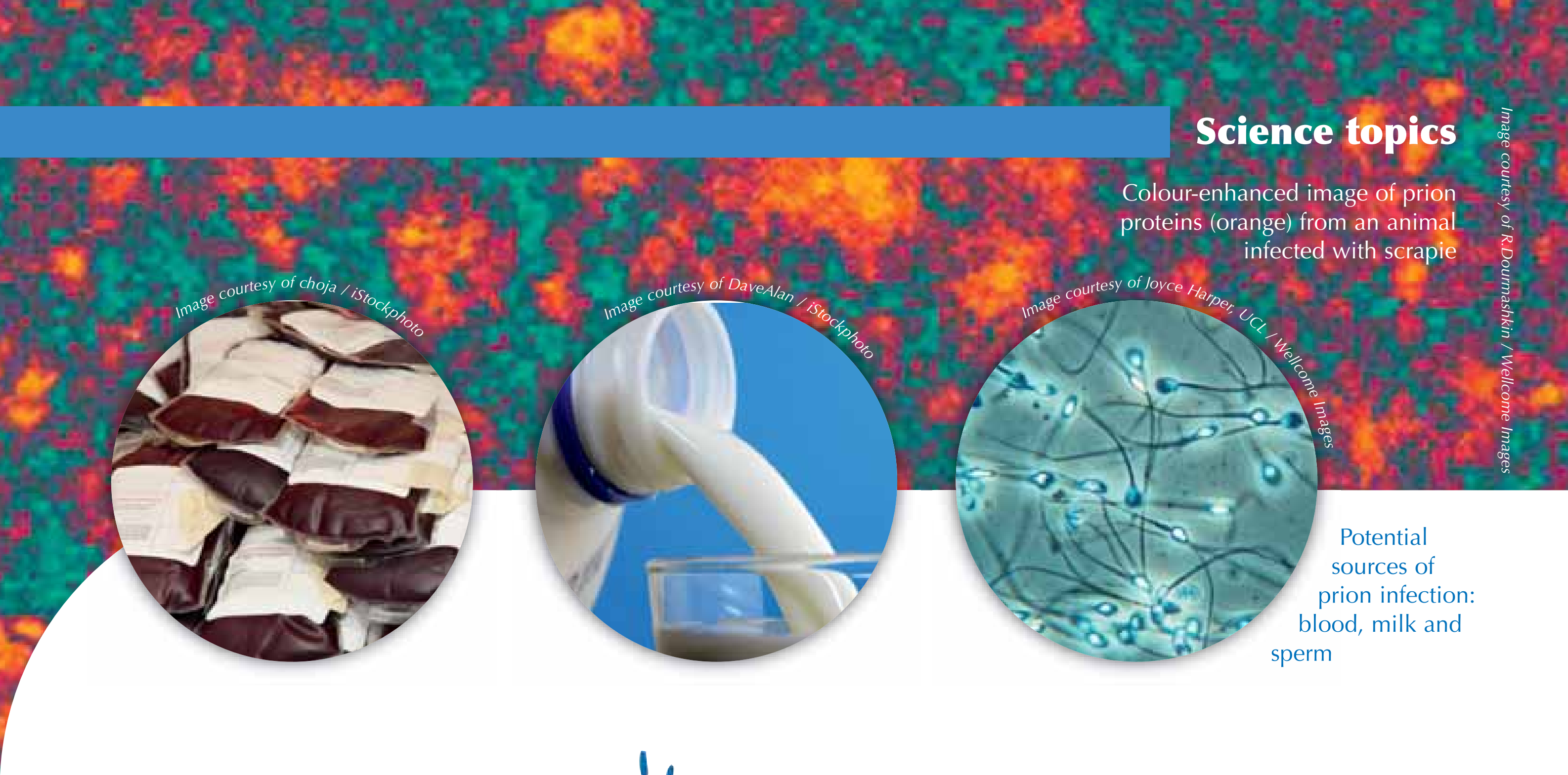
Deadly proteins: prions

Since the epidemic of 'mad cow disease' in the 1980s and 90s, and the emergence of its human equivalent, variant Creutzfeld-Jacob disease, there has been a great deal of research into prions, the causative agents. **Mico Tatalovic** reviews the current state of knowledge.

There may be a hidden epidemic waiting to occur, with millions of people already infected; we cannot prevent or cure it, and we cannot even diagnose it until the fatal symptoms appear. The disease is variant Creutzfeld-Jacob disease (vCJD), one of a group of diseases known as transmissible spongiform encephalopathies (TSEs), which are caused and transmitted by abnormal forms of prion proteins. Examples of TSEs include not only vCJD, but also scrapie in sheep, bovine spongiform encephalopathy (BSE or mad cow disease) in cattle and kuru[w1] in humans. These diseases create large fluid-filled holes in the brain tissue because the accumulation of aberrant prions causes the neurons (nerve cells) to die. It is these characteristic holes that give the diseases their names: spongiform (sponge-like) encephalopathies (brain diseases).

TSEs affect the central nervous system, with symptoms including problems with co-ordination and balance, shakiness and uncontrollable jerking movements. In humans, TSEs also cause personality changes and depression, and sufferers may experience confusion, memory problems and insomnia. As the diseases progress, most mental functions are lost, including the ability to speak. All TSEs are fatal, and as yet, there is no cure.

Prions are specific proteins found mainly in the nervous system, where – in their normal forms – they may have important functions. For example, studies on sea slugs, *Aplysia*, sug-



Colour-enhanced image of prion proteins (orange) from an animal infected with scrapie

Potential sources of prion infection: blood, milk and sperm

gest that prions have a crucial role in memory formation (Kausik et al., 2010). Infectious prions are abnormal (aberrant) forms of prion proteins that replicate inside the host by forcing normal proteins of the same type to adopt the aberrant structure. This has a domino effect whereby a small number of aberrant prions can affect many normal ones and eventually lead to disease. As the aberrant prions form amyloids – aggregates of protein – in the cells, the cells die, creating holes in the brain.

Prions are the only known case of self-propagating pathogenic (disease-causing) proteins, and they are able to cause severe illness even though they seem to be just protein molecules: unlike bacteria, viruses or other known pathogens, they have no information encoded in nucleic acids (DNA or RNA) about how to invade and replicate within the host. There is still a veil of mystery around prions and exactly how they replicate, cross the blood-brain barrier and cross the species barrier – i.e. infect different species of host.

It was in the 1960s that investigators first found that TSE disease-causing agents appeared to lack nucleic acids; Tikvah Alper suggested that the agent was a protein. This idea sounded heretical because all other known disease-causing agents contained nucleic acids and their virulence and

REVIEW

- **Biology**
- **Mathematics**
- **Genetics**
- **Health care**
- **Age 14+**

Many people have heard of vCJD or mad cow disease but know little about the causative agent and the disease itself. This article explains the disease and cites up-to-date research on the causative agent, a prion. This will be useful for the infectious diseases topic in many science curricula and for general knowledge in other subjects. The links to data on BSE could be used in mathematics lessons or for learning to draw relevant graphs from data. The article lends itself to discussions about food safety, the effect of the disease outbreak on the British beef farmers, as well as comprehension and extension work. Some comprehension ideas include:

1. Over how many years have prions been researched?
   a) 10 years
   b) 25 years
   c) 30 years
   d) 40 years
2. Who won a Nobel Prize for research into prions?
3. What is a prion?
4. Describe the effects of spongiform encephalopathies.
5. Which tissues have prions been discovered in?
6. How could prions be spread?

Ideas for extension work are:

1. Research the BSE outbreak in the UK in the late 1980s and describe the measures that were introduced to limit it.
2. State Koch's postulates. Explain why prions did not fit into this hypothesis until recently.

Shelley Goodman, UK

Image courtesy of ImageMediaGroup / iStockphoto

pathogenesis were genetically determined. However, three decades of subsequent investigations, pursued most notably by Stanley Prusiner, who was awarded the Nobel Prize in Physiology or Medicine in 1997 for his work with prions and TSEs, resulted in the wide acceptance of this 'protein-only hypothesis'[w2].

Nevertheless, there are still those who believe that prion diseases are actually caused by unconventional viruses and that prion proteins are just part of this mysterious virus. Koch's postulates describe what is needed to prove that a certain agent causes a particular disease; one of the necessary steps is to use that agent to induce the disease in a healthy organism. To prove that a TSE is indeed caused by the prion protein itself, the isolated, purified aberrant prions must be used to transmit the disease. It wasn't until February 2010 that exactly

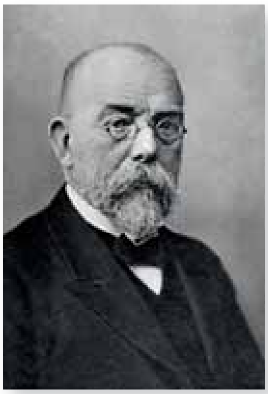


Image courtesy of Wellcome Library, London

Portrait of bacteriologist Robert Koch (1843-1910)

this was done, adding further substantial evidence for the protein-only hypothesis (Wang et al., 2010).

Why do some scientists fear a vCJD epidemic?

The most worrying prion strain is the one that causes vCJD – a form of mad cow disease that has crossed the species barrier to infect humans (see box). The first case of vCJD appeared in the UK in 1996 and has since killed 168 people there, with a peak in 2000 when 28 people died[w3], and there have been small numbers of cases in other countries including France, Italy, Ireland, Canada and the USA. Exact numbers of people infected or dying from this disease around the world are not known and although there is still uncertainty about how people become infected, the main infection route is thought to be through eating infected beef.

Most other prion diseases, including 'normal' CJD, are genetic or occur for unknown reasons, and affect elderly people. Variant CJD differs from CJD in that it affects young people and the aberrant prions are found not only in the brain but also in tissues such as blood, tonsils and appendices; this opens new ways of transmission to the entire population and not only the elderly.

For example, prions could be spread through blood transfusions. In the UK, donated blood is leucodepleted (the leucocytes, which may har-

BACKGROUND

i

BSE (mad cow disease)

BSE came to scientists' attention in 1986 when the first cases of a new neurological disease in cattle were discovered in the UK. The cause was traced to the use of beef products in cattle feed. In the resulting BSE epidemic, 181 376 cases of BSE were recorded in the UK by November 2002 and millions of cattle were culled to halt the epidemic. The first cases outside the UK appeared in 1989 and since then there have been several thousand cases in other countries, including most of the European countries, the USA, Canada, Japan and Israel. However, cattle feed with bovine parts was banned in the UK in 1988 and there are strict monitoring procedures in place to keep track of BSE.

Cases of BSE peaked in the UK in 1992 (37 280 cases) and have decreased dramatically since then (12 cases in 2009). The number of cases in other countries peaked some years later (2001-03) but has also decreased dramatically since then[w5].

bour infectious prions, are removed). Many other countries (e.g. Germany) ban blood donations from people who have lived in the UK.

The disease may also be spread by surgical instruments: infectious prions are resistant to high temperatures, irradiation and common chemical treatments that destroy other known pathogens. Estimates of how serious the risk is vary.

Furthermore, prions have also been found in the epididymis and seminal plasma tissues of rams (Gatti et al., 2002). Such findings led to concern about prion infection via sperm donations and even resulted in a US ban on sperm donations by Europeans and men who have lived in Europe. Nonetheless, a survey of experts worldwide estimated that the chance of prion transmission via sperm was less than 1:10 000 000 (Mortimer & Barratt, 2006).

But tissue contact – whether via sperm or blood or on surgical instruments – is not the only potential source of transmission: most of us consume milk and dairy products. In 2006, a team of scientists from Switzerland detected low levels of the normal form of prions in milk bought in European shops (Franscini et al., 2006). Another study found that aberrant prions were able to replicate within mammary glands of scrapie-infected sheep (Ligios et al., 2005). Taken together, these results suggest that aberrant prions might be present in the milk of animals suffering from prion diseases. As prion disease symptoms take several years to develop, aberrant prions may be present in milk that is sold before the animals are diagnosed with the illness. Nonetheless, although it is not yet possible to give a clear estimate of the risk, it is generally thought that milk is safe until proven otherwise.

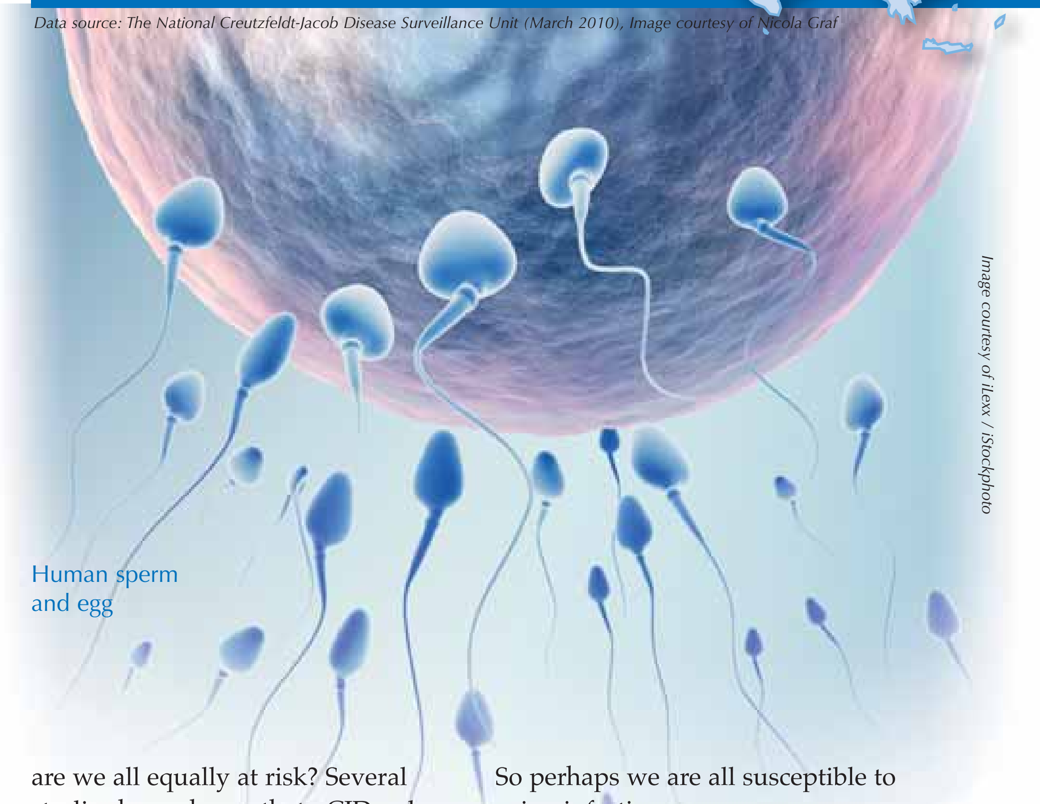
It seems, therefore, that we could contract vCJD via several routes although the risk is probably low. But are we all equally at risk? Several studies have shown that vCJD only affects people with certain variants (alleles) of a particular gene (*prnp*); other people seem to be resistant or do not develop the symptoms as fast[w4]. Worryingly, about 40% of the Western European and North American population and up to 92% of the Japanese population are homozygous for these susceptibility alleles. Furthermore, research on kuru suggests that even individuals without the susceptibility allele may become infected but simply take much longer to develop symptoms. So perhaps we are all susceptible to prion infection.

Because of all of these possible transmission routes and uncertainties in how important they are, the results of studies predicting the number of people dying from vCJD in the UK range from several hundred to more than ten million people. Even though it now looks as though the vCJD epidemic in the UK is diminishing, this may be just because many infected people are still developing symptoms. No one knows for sure. Ongoing research will elucidate just how risky prion diseases are to public health.

Number of cases of vCJD (number alive)

UK	172 (4)
France	25 (0)
Republic of Ireland	4 (0)
Italy	2 (1)
USA	3 (0)
Canada	1 (0)
Saudi Arabia	1 (1)
Japan	1 (0)
Netherlands	3 (0)
Portugal	2 (0)
Spain	5 (0)

Data source: The National Creutzfeldt-Jacob Disease Surveillance Unit (March 2010), Image courtesy of Nicola Graf



Human sperm and egg

Image courtesy of ilexx / iStockphoto

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Ligios C et al. (2005) PrP^{Sc} in mammary glands of sheep affected by scrapie and mastitis *Nature Medicine* **11**: 1137–1138. doi: 10.1038/nm1105-1137

Franscini N et al. (2006) Prion protein in milk. *PLoS ONE* **1**: e71. doi: 10.1371/journal.pone.0000071
All *PLos ONE* articles are freely available online.

Gatti JL et al. (2002) Prion protein is secreted in soluble forms in the epididymal fluid and proteolytically processed and transported in seminal plasma. *Biology of Reproduction* **67**: 393-400. doi: 10.1095/biolreprod67.2.393

Kausik S et al. (2010) *Aplysia* CPEB can form prion-like multimers in sensory neurons that contribute to long-term facilitation. *Cell* **140**: 421-435. doi: 10.1016/j.cell.2010.01.008

Mortimer D, Barratt CLR (2006) Is there a real risk of transmitting variant Creutzfeldt–Jakob disease by donor sperm insemination? *Reproductive BioMedicine Online* **13**: 778–790

To view articles in *Reproductive BioMedicine Online*, it is necessary to register, but registration is free. See: www.rbmonline.com

Wang F et al. (2010) Generating a prion with bacterially expressed recombinant prion protein. *Science* **327**: 1132-1135. doi: 10.1126/science.1183748

Web references

w1 – Information about kuru is available on the website of the US National Institute of Neurological Disorders and Stroke: www.ninds.nih.gov/disorders/kuru

In 1976, Carleton Gajdusek received the Nobel Prize in Physiology or Medicine for his work on kuru. More information is available in the press release, his autobiography, Nobel Prize lecture and other materials on the Nobel Prize website. See: http://nobelprize.org/nobel_prizes/medicine/laureates/1976

w2 – To learn more about Stanley Prusiner's work, see the press release, his autobiography and other materials on the Nobel Prize website: http://nobelprize.org/nobel_prizes/medicine/laureates/1997

w3 – Statistics on the reported cases of BSE and deaths from vCJD are available on the website of the European Centre for Disease Prevention and Control: (www.ecdc.europa.eu) or via the direct link: http://tinyurl.com/yjbx8tn

w4 – To learn more about the genetic disposition to develop prion diseases, see the website of the prion unit at the UK's Medical Research Council (www.prion.ucl.ac.uk) or use the direct link: http://tinyurl.com/yaqau4a

w5 – Statistics on BSE and many other animal diseases are available on the website of the World Organisation for Animal Health: www.oie.int

Resources

More information about prions is available on the websites of the US Centers for Disease Control and Prevention: www.cdc.gov/ncidod/dvrd/prions

To learn more about BSE, see the website of the World Health Organization: www.who.int/zoonoses/diseases/bse/en

Research papers that may be of interest include:

Aguzzi A, O'Connor T (2010) Protein aggregation diseases: pathogenicity and therapeutic perspectives. *Nature Reviews Drug Discovery* **9**: 237-248. doi: 10.1038/nrd3050

Collinge J, Clarke AR (2007) A general model of prion strains and their pathogenicity. *Science* **318**: 930-936. doi: 10.1126/science.1138718

Di Guardo G, Marruchella G (2010) Prions and neuronal death. *Cell Death and Disease* **1**: e6. doi: 10.1038/cddis.2009.9

Welberg L (2010) Prions: a protective role for prions. *Nature Reviews Neuroscience* **11**: 151. doi: 10.1038/nrn2812

Koch's postulates were published in the late 19^{th} century by Robert Koch. For a more recent discussion of the postulates and their validity, see:

Evans AS (1976) Causation and disease: the Henle-Koch postulates revisited. *The Yale Journal of Biology and Medicine* **49**: 175-195
The article can be downloaded free of charge from PubMed Central (www.ncbi.nlm.nih.gov/pmc) or via the direct link: http://tinyurl.com/y9t2pd8

To browse all biology-related articles in *Science in School*, see: www.scienceinschool.org/biology

Image courtesy of spooh / iStockphoto

Combating earthquakes: designing and testing anti-seismic buildings

Global seismic hazard map

Image courtesy of the Global Seismic Hazard Program

Earthquakes can be devastating. Is there anything we can do to resist them? **Francesco Marazzi** and **Daniel Tirelli** explain how earthquake-proof buildings are designed and tested.

On 3 February 2010 in Haiti, approximately 200 000 people were killed and 280 000 buildings collapsed or were severely damaged by an earthquake. Closer to home – in Abruzzi, Italy – an earthquake in the early morning of 6 April 2009 caused more than 300 deaths and prompted the evacuation of 60 000 people.

Seismic: related to an earthquake or earth vibration

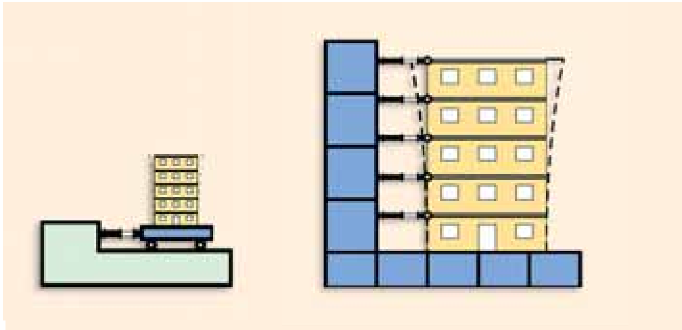
Because they are the consequence of tectonic motions, earthquakes cannot be controlled or easily predicted; we can only analyse the intensity and frequency of earthquakes statistically (for more information, see Latchman, 2009). For a given region, the expected intensity of earthquakes is inversely proportional to their frequency of occurrence: minor earthquakes are more frequent than strong ones.

Although we cannot escape earthquakes, we can resist them, for example by designing earthquake-proof – or *anti-seismic* – buildings.

An earthquake is a ground motion characterised by oscillations in three dimensions; the effects of this motion on buildings can be considerable. Earthquakes cause buildings to move very rapidly; the building's mass multiplied by the acceleration caused by the earthquake produces very large forces, as described by Newton's second law of motion (force = mass x acceleration). Because houses and other common structures are designed to support their own weight, they can usually resist the additional vertical forces caused by the vertical movements of the earthquake. Horizontal forces, however, are often underestimated or overlooked during the design phase, so buildings may collapse when subjected to an earthquake.

For economic and practical reasons, anti-seismic buildings need to have appropriate levels of earthquake resistance: even the strongest earthquake should not cause the building to collapse, although a certain level of damage would be acceptable. A minor earthquake, in contrast, should not cause even minor damage, such as repairable cracks. The design of an anti-seismic building should also take into account its importance and function: a hospital or a fire station, for example, must remain operative even after the strongest earthquake.

Image courtesy of ELSA



Earthquake simulation methods: a shaking table (left) and a reaction wall and strong floor system (right)

REVIEW

The article is particularly interesting because it explains clearly what is being done to design and test earthquake-proof buildings. The article can be used as an introduction to the topic of general waves or seismic waves in physics and in geography lessons. It is ideal for introducing the theme of earthquakes because it explains their nature and shows why severe damage occurs to buildings as a result of Newton's laws. It could be used to start a discussion about the destruction caused by earthquakes, their impact on society and what can be done to limit the damage.

Moreover, this article provides valuable background reading and recommends websites to make students aware of how science can benefit society. It also makes both students and teachers aware of scientific organisations such as ELSA that work to enhance the safety of citizens. Sometimes we tend to get lost in formulae and theories and treat science as a purely academic subject. This article, however, gives a concrete example of how the science studied in class is applied in real situations, such as earthquakes, which unfortunately lately have occurred in various countries, creating destruction and havoc.

The article could be used as a comprehension exercise for subjects in which earthquakes are part of the syllabus or if earthquakes (not specifically part of the syllabus) are used to discuss waves. Suitable questions include:

1. What is an earthquake?
2. With reference to Newton's second law of motion, why is the force acting on a building so large during an earthquake?

- ✔ **Physics**
- ✔ **Geography**
- ✔ **Waves**
- ✔ **Ages 10-19**

3. Name two techniques used to test anti-seismic buildings. Explain briefly how these work.
4. In view of the natural disasters that have devastated some countries recently, do you think that these techniques should be used more widely? Explain your answer.

The article could be used in different ways for different age groups:

10-12: to give a general description of what an earthquake is and keep the students informed about what is happening in European and other countries.

12-15: to introduce the topic of earthquakes and inform students of their nature and how they occur. The article could also be used to demonstrate that a whole branch of science is dedicated to studying these events and minimising their effects.

16+: to introduce the topic, which could then lead to a more detailed study of seismic waves. The article could also show how science is used for the benefit of citizens. Moreover, students could discuss how countries deal with earthquakes and understand how the science studied in class is applied in real contexts.

Catherine Cutajar, Malta

Despite the enormous progress in computer modelling and simulation of buildings' responses to earthquakes, experimental testing is still an important part of the development of anti-seismic buildings. Engineers use small- or full-scale models to investigate a structure's response to an earthquake: how safe would the building be in an earthquake and how could it be improved?

There are currently two complementary experimental techniques to simulate the effect of an earthquake on a structure: one based on the *shaking table* and the other on the *reaction wall and strong floor* system (see image on page 56). A shaking table is a platform that mimics an earthquake by producing vibrations in one, two or three dimensions. The test building – normally a scaled-down model – is placed on the shaking table and exposed to the 'earthquake' and the effect is noted. Does the building fall down? Do cracks appear in the walls? How does the damage occur? How long an earthquake can the building withstand? The drawback of this simulation is that it cannot be halted partway through the 'earthquake': only the final damage can be assessed.

The reaction wall and strong floor system, in contrast, allows full-scale buildings to be tested. The building is placed on the floor of the system and hydraulic arms attached to the reaction wall exert pressure on the building, corresponding to an earthquake. The earthquake can be simulated in slow motion – a real-life earthquake lasting only a few seconds can take hours to simulate. This allows the damage to the building to be closely monitored; the test can be paused for engineers to examine the building more closely or to prevent it from collapsing completely. Sensors record the effects of the simulated earthquake on the building, including deformation, stress, inclinations and force.

Europe's largest reaction wall and strong floor system is at the European Laboratory for Structural Assessment (ELSA)[w1], where it is used to test ways in which large-scale structures (such as bridges and buildings) can be strengthened and repaired.

As can be demonstrated experimentally, the likely damage caused by an earthquake to a building (its *seismic vulnerability*) can be reduced in several ways. One is to separate the building from the ground, so that vibrations caused by the earthquake are not transmitted to the building. Base isolation, for example, involves introducing a sliding system between the foundation and the lower part of the building. Another approach is to concentrate the damage in pre-defined parts of the structure: this allows the dissipation of the earthquake's energy

The ELSA laboratory

Transporting a building inside the ELSA laboratory

Seismic testing at ELSA of a full-scale 3D building

Images courtesy of ELSA

Passive energy dissipator

Actively controlled actuators

Images courtesy of ELSA

BACKGROUND

School activities at ELSA

Teaching activities at ELSA

Image courtesy of Francesco Marazzi

ELSA has an interactive laboratory for children, which includes a small shaking table; as it can be easily transported, shaking-table demonstrations can be conducted either during school visits to ELSA, in Ispra, Italy, or directly in schools (see Anthoine et al., 2010).

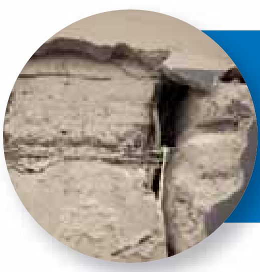
A demonstration of the principles of structural dynamics first introduces children to concepts such as natural frequency, mode shape and vibration, and to the basic ideas of sensors and data collection. The students are then invited to assemble structures made of special stone bricks and to test them on the shaking table. They can give free rein to their imagination: some houses have several doors and windows, while others are more similar to bunkers, pyramids or Greek temples.

The model houses are then placed on the shaking table and exposed to a simulation of a real, recorded earthquake. The students are asked to describe what they observe and to explain why houses behave differently when subjected to the same earthquake. This introduces the concept of seismic risk: the combination of seismic vulnerability (how sensitive the house is to earthquakes) and seismic hazard (how strong is the largest earthquake expected in a given location). The only way to reduce the seismic risk is to reduce the vulnerability; we have no power over hazard!

One of the most effective methods for reducing vulnerability – base isolation – can be seen on our little shaking table, which has three rolling tubes of small radius supporting the base of the model. These tubes separate the building from the ground and ensure that vibrations from an earthquake are not transmitted upward. The effectiveness of this system is easily shown when two identical models, one with base isolation and the other without, are tested at the same time: the earthquake will destroy the non-isolated building whereas the other will remain intact.

Church of Concezione, Paganica, L'Aquila, Italy

Images courtesy of Francesco Marazzi



'Close confinement stirrups' would have helped this house in L'Aquila to withstand the earthquake in 2009

and prevents unexpected behaviour. For example, if iron parts are inserted at structural nodes (e.g. where beams are connected to columns), these pieces will be deformed during the earthquake instead of the building itself.

The design of a building is extremely important. Regular designs, for example, are more resistant to earthquakes than irregular ones because they are less subject to torsional effects (twisting) and thus to local stresses and deformations. Smaller details are also very important. Walls should be well connected to each other and to the floors, making the house resist the earthquake as a whole (the structure is said to exhibit 'box behaviour'). In old masonry houses, inserting tie-rods at floor level links the structural walls and the floor together, so that they function as a single element, sharing deformations and stresses. This improves the overall energy dissipation capacity of the building. In new buildings, concrete elements may be held firmly together by 'close confinement stirrups'; this significantly improves the earthquake resistance of the building at a negligible cost.

Anti-seismic devices are important not only to save lives but also to protect our cultural heritage: ELSA carried out tests on a full-scale model of part of the monastery of Saõ Vicente de Fora in Lisbon, Portugal, and on a half-scale reconstructed façade of the Palazzo Geraci in Palermo, Italy. As a result of these tests, ELSA was able to contribute to general guidelines for protecting historic monuments from earthquake damage.


Testing a passive energy dissipator

Image courtesy of ELSA

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Latchman S (2009) Modelling catastrophes. *Plus Magazine* **53**. http://plus.maths.org/issue53/features/latchman

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w1 – For more information about ELSA, visit: http://elsa.jrc.ec.europa.eu

w2 – To learn more about the Eurocodes, see: http://eurocodes.jrc.ec.europa.eu

Resources

Kirschbaum T, Janzen U (2006) Tracing earthquakes: seismology in the classroom. *Science in School* **1**: 41-43. www.scienceinschool.org/2006/issue1/earthquakes

The United Nations International Strategy for Disaster Reduction has developed an online disaster simulation game (Stop Disasters!). See: www.stopdisastersgame.org

The BBC website has some good animations about earthquakes. See: http://news.bbc.co.uk/2/hi/4126809.stm

The website of the United States Geological Survey's Earthquake Hazards Program has very extensive information about earthquakes, including animations. See: http://earthquake.usgs.gov/earthquakes

For a video (Demonstration of Friuli Earthquake effects on buildings) recorded at ELSA, see: http://elsa.jrc.ec.europa.eu/publications/Friuli1976_2.wmv

Available on Google books, this is a technical but clear explanation of the main aspects of seismic engineering:

Committee on Earthquake Engineering Research (1982) *Earthquake Engineering Research – 1982*. Washington DC, USA: National Academy Press. http://books.google.it

For a collection of photographs of earthquake-damaged structures, with a very brief explanation of how the damage happened, see the Earthquake Engineering Slide Information System website: http://www.ikpir.com/easy/html/ang/index.htm

For a list of the main earthquakes in Italy (as an example), see: http://en.wikipedia.org/wiki/List_of_earthquakes_in_Italy

For more information about earthquakes, see also the main Wikipedia page on this topic: http://en.wikipedia.org/wiki/Earthquake

If you enjoyed reading this article, why not browse the full collection of earth science articles published in *Science in School*? See: www.scienceinschool.org/earthscience

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Dr Francesco Marazzi is a high-school teacher temporarily on secondment, doing post-doctoral research on dynamics and seismic testing at ELSA. When he returns to the classroom, his experience in such a large and advanced laboratory will enable him to demonstrate to his pupils how important physics, mathematics and information technology are to the 'real world'. In his work at ELSA, mathematics is useful for modelling particular phenomena or analysing data. Physics is useful for properly conducting the experiments, for developing new protection devices and for judging the results of the simulations and data analysis. Finally, informatics is the tool used in all aspects of his research work. In short, he plans to use his experience to motivate his students.

Dr Daniel Tirelli is a researcher at the European Laboratory for Structural Assessment (ELSA), part of the European Commission's Joint Research Centre in Ispra, Italy. One of the current collaborative activities at ELSA is the development of the Eurocodes[w2], common standards for the design of buildings and other civil engineering works, to be introduced in 2010. One of these standards (Eurocode 8) is dedicated to the design of appropriate anti-seismic structures, including how the structures should be designed, tested and modified.

The winners of the *Science in School* writing competition

Eleanor Hayes introduces the winners of the *Science in School* writing competition.

In Issue 11 of *Science in School*, we interviewed science writer Rebecca Skloot and launched a competition for students to write a science story suitable for publication in a magazine or newspaper (Furtado & Rau, 2009). We asked Rebecca what made a good science story. Her answer? "To me, good science writing is really just good writing that happens to be about a scientific topic. At the basic story level there is no difference." So, she says, you need the same basic ingredients in science writing as in any kind of storytelling: characters, scenes, actions and a plot. These were some of the features we were looking for in the 117 entries submitted by students from across Europe.

It seems that the challenge we set in our competition was a tough one: many entrants (or their teachers) seemed to find the idea of writing an engaging story about science difficult. We received a lot of experimental reports – many of them good, but not what we were looking for. And we received quite a few engagingly written stories – but not about science. Fortunately, we also received plenty of entries that met all our criteria, and then the fun really began: our jury of six editors and science writers read, re-read, discussed and argued over the entries. We'd like to congratulate all of the students and teachers who took the time and made the effort to put pen to paper and send us their entries. We enjoyed reading all of them.

Our particular congratulations go to:

- Thomas Johnson, winner of the under-16 category, for his readable, thoughtful and well structured story of Mary Leakey's discovery of early human footprints
- Annika Marx, winner of the 16+ category, for her thought-provoking story about the implications of research into telomerase.

Image courtesy of blackred / iStockphoto

Image courtesy of Alan Mair

Thomas Johnson

One day in Africa in 1978

By **Thomas Johnson**, aged 13, Trinity Catholic High School, Woodford Green, UK

It was dry, and the afternoon heat bore heavily down on the plains below. It was a moment of fun, and the laughter rang out across the camp. A man ducked as another tossed the dried-up lump of elephant dung at him, then he stumbled, landing awkwardly on the hard, grey earth. Another figure, smaller and possibly female, bent double with laughter and moved towards him, sinking helplessly down to the ground. The country was Africa, and the people were scientists. The woman was Mary Leakey, a famous anthropologist, and beneath them, as they were just about to find out, were the first-ever known footsteps of man.

Let us leave them on the verge of this great discovery and find out a bit more about Mary Leakey and the part she has played in telling us about our past.

About Mary Leakey

Mary Leakey was born a long time ago, in 1913, in England. Her father was an artist, and the family lived in many different countries, including France and Italy. When she was a child, Mary's father took her to see the bone tools and beautiful pre-historic cave paintings that had recently been discovered in southern France. Mary was excited by what she saw, and it made her think deeply about the people who had made and used the tools and created the paintings. Mary was inspired, and she talked about the joy of collecting and unearthing objects of beauty and interest. Together with her husband Louis, she began a journey of discovery, driven by her determination and curiosity to find out more about how we, the human race, came to be. She described what she did quite simply: "I dug things up. I was curious. And then I liked to draw what I found."

She wanted to discover more about our beginnings, how we used to look and live and how we have evolved to look as we do now. She saw the past as a jigsaw: as each piece is found and added, it slowly builds up a clearer and more complete picture. Mary herself found some very important pieces of the jigsaw, as we shall see.

About me

We all know that we are human beings and part of the human race. We are an intelligent species, and we have spread all over the world, changing it in many ways. We have invented new technology, explored space and can cure many illnesses. Maybe we have come to see ourselves as different and separate from the natural world, but perhaps we are not that different after all. By beginning to understand who we are and where we have come from, we might start to see our relationship with other life on our planet.

We already know that we are descended from our parents, our grandparents, our great-grandparents, our great-great-grandparents and so on. These are our ancestors. If we could rewind time over millions of years, like a videotape, we would see a fascinating pictorial history emerge of how we have evolved. The further back we go, the more ape-like in appearance we become. All the evidence we have today suggests that far back in our remote and distant past, we shared a common ancestor with the ape family.

Back to the footprints

Mary and her team noticed some strange markings in the ground beneath them. They began to dig, and found indentations that had set hard in the volcanic ash. Further excavations showed a clear footprint, the first of many in a trail of prints disap-

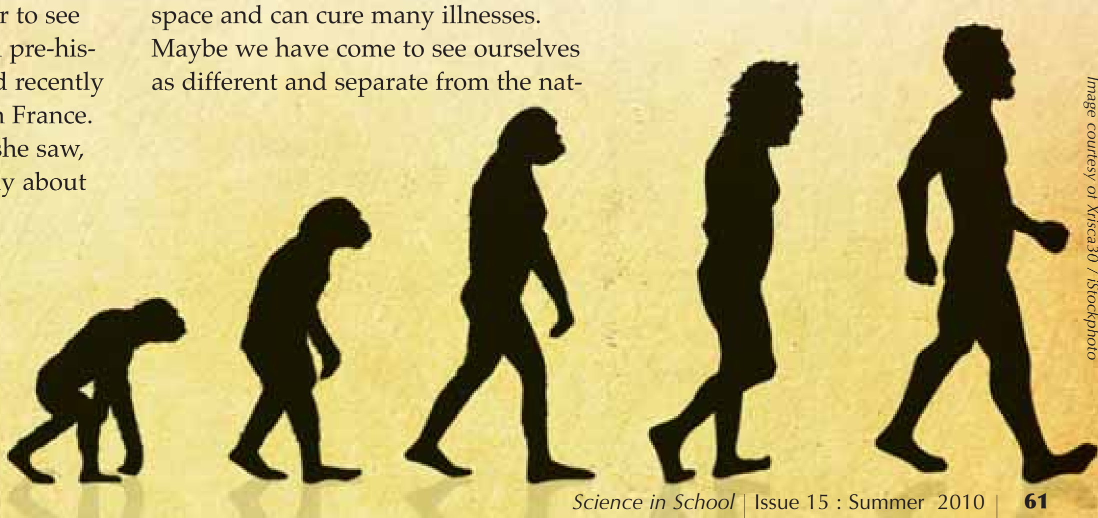
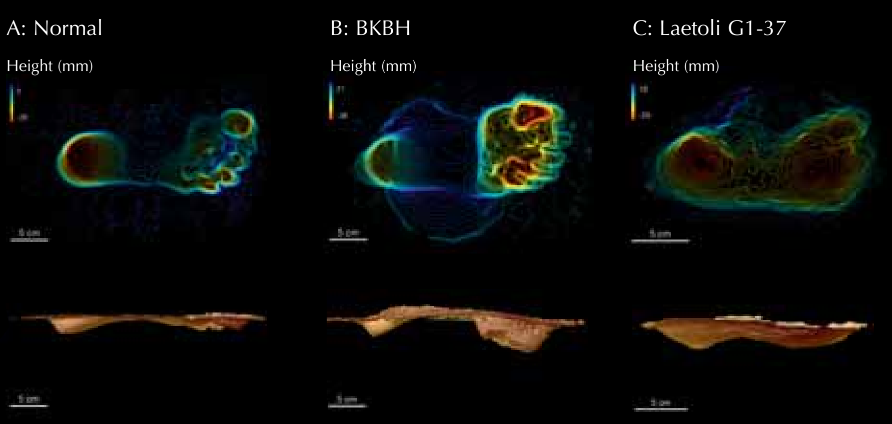


Image courtesy of Xrisca30 / iStockphoto



Three dimensional scans of experimental footprints and a Laetoli footprint. A) Contour map and side view of modern human footprint walking with a normal, extended limb gait. B) Contour map and side view of modern human footprint walking with a BKBH gait (bent knee, bent hip). C) Contour map and side view of Laetoli footprint. Note the difference in heel and toe depths between modern humans walking with extended and BKBH gaits. Laetoli has similar toe relative to heel depths as the modern human extended limb print

Image courtesy of Raichlen DA, Gordon AD, Harcourt-Smith WEH, Foster AD and Haas WR; image source: Wikimedia Commons

I have always been interested in palaeontology and human evolution, so when the opportunity to write this essay arose, that was the first subject I thought of. I chose to write about Mary Leakey because I believe she should be better known for the contribution she made to what we know about our origins.

pearing off across the plains. The prints showed that three people, one larger, one smaller, and one quite tiny had walked together that way over 3 million years ago. Was it a father, mother and child? Every now and then the tiny prints are superimposed on the others. At one point along the way, the medium-sized figure paused and turned to her left. Were they escaping from danger? Had she heard an animal, or maybe even the rumbling of the volcano nearby? We don't know. We can only guess. This family may have looked very different to how we do today, but that moment of doubt, hesitation and checking for danger is something that, three million years later, we can still understand and share.

One thing is clear from this discovery, and that is that we know that three million years ago, man was walking on two legs and not four. This is much earlier than scientists had previously thought.

Mary Leakey has been able to find us some of the most important information about our past, and help us understand how we came to be. She has also shown us how important Africa is in understanding our origins. Many people now believe that Ethiopia (in Africa) is the birthplace of humans. As a woman, it was difficult for Mary to be fully appreciated and accepted as a scientist, and she received very little credit for what she did. She worked quietly and skilfully, often in the shadow of her husband, yet her biggest discovery, that of the footprints in Laetoli, was made after he died. Her enormous contributions to our understanding of how our human race has evolved are still being measured.

Replica *Paranthropus boisei* skull. The skull was discovered by Mary Leakey in the Olduvai Gorge, Tanzania, in 1959 and is 1.75 million years old. The jaw was discovered by Kamoya Kimeu in 1964 and is 1.5 million years old. Displayed at the Museum of Man, San Diego, California, USA

Image courtesy of Durova; image source: Wikimedia Commons

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Image courtesy of Mathias Schaeben

Annika Marx

Eternity…?!

By **Annika Marx**, aged 17, Werner-Heisenberg-Gymnasium, Leverkusen, Germany

Image courtesy of NejroN / iStockphoto

"John?" shouted Martha as she went upstairs to my office. The staircase shook with each footstep. I put my head in my hands and sighed. I was working at my iMac, but she didn't care.

"Yes, Martha, darling, what happened?" My voice was friendly and patient, as always. It is the best way to get through this every time.

Always complaining and never satisfied. Like the woman in the tale of the man who caught a fish that granted him three wishes. At the end they were sitting in the same old hut as before, just because the woman couldn't moderate her avarice.

"The freezer is broken again... Can't you just come for a minute and fix it? I need my frozen strawberries to stay frozen. I wanted to make this delicious dessert for Chris and Liz when they come with Jack and Toby. Jill will also come and bring lil' Sarah, too. You shouldn't spend your Thanksgiving up here in this dark room. Come downstairs and celebrate with your family!"

"No, thanks. It's every year the same. I'm fed up with it, believe me. And the freezer is from 2050... you can throw it away, I don't think that I can fix it once again. You'll have to freeze your strawberries somewhere else."

"You would expect that they could preserve strawberries now, with all that new technology, but not at all. What do these AOLs [i.e. ameliorants of life] get paid for?!"

"Please hon, be quiet, you don't know what you are talking about. Go to our neighbours and ask if you can store your strawberries in their freezer, okay?" Whew, now she's going away... at last. As I said, always complaining.

To tell the truth, science has come a long way in the past few decades. Cancer therapy was invented, and now people are able to live hundreds of years, just because of one small enzyme, telomerase. People see their grandchildren raise their kids and them raise their kids and so on. Every family celebration costs thousands of dollars now. And who has to pay for it?! The oldest male member of the family. Me!

After 137 years of work in the same business, doing the same things as always, it gets terribly boring. I'm one of hundreds of scientists who work for the 'Ameliorants of Life' – the people who tried to be superior to God. We are selected researchers from many different countries, brought together to realise the new ideas of the AOLs, while they sell our products. We get the work, they get the glory and the money.

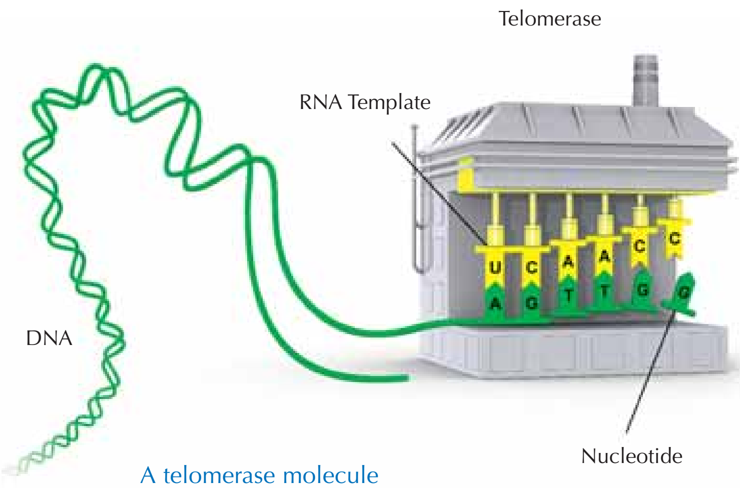
It was very interesting at the beginning to explore the cells and telomerase to find new, better ways to make cells immortal, but after a while it seemed senseless. The discovery was made in 2009* – real cutting-edge science, 'leading to a new world without death', to eternal life and stuff. Elizabeth Blackburn, Carol Greider and Jack Szostak discovered how chromosomes are protected against degradation during cell division. They found out that the telomeres, the caps on the ends of chromosomes, are shortened with every cell division. If the telomeres are shortened, cells age. But there is an enzyme, telomerase, which can build up the telomeres, so that the cells don't age. That's why cancer cells never stop growing, and why so many people died because of cancer before telomerase was discovered. Now everyone takes standard medication in order to stimulate the body to produce more telomerase, and everybody lives to the age of more than 500 without ageing.†

> I wrote the story and chose this topic after I read an article about the Nobel laureates, just a few days before the deadline of the competition. The discovery of telomerase and the opportunities it offers appealed to me in our lessons, so I found it very interesting to get more into the topic. When I started writing, the character of an old, annoyed man came into my mind and I used it to fill the story with life.

No more white hair, no wrinkles, no lumbago and no menopause. Everlasting fertility for men and women. The human population grows so much that half of all humans have no home or just one small room, shared with three or more other people. Unfortunately, it will still take some time before we can live somewhere out in space, but the scientists are working on this problem. In my opinion, most of us will die of hunger and thirst first, not really an encouraging prospect, is it?

That's why I decided to stop taking the medicine and to let nature do its work. It's just that I can never tell Martha about it. She annoys me very often, it's true, but it's hard to live together for over 150 years, and I still love her. Most of the other people of my age who I know were already married five to six times. It's now 20 years since I stopped taking the medicine, and I can feel how I'm ageing. My hair is getting thin and white, but fortunately I've found an old hair tinting lotion that still works. We certainly don't have any hair tinting lotions any more, nobody needs it, but I do, so that nobody notices what is happening to me. Martha would be terribly discomposed. And my back hurts. I'll get an analgesic to stop the pain.

Eternal life, who cares?! My life has already been long enough for all eternity...



A telomerase molecule

Image courtesy of Sierra Sciences, LLC; image source: Wikimedia Commons

Editorial comments

* Although Elizabeth Blackburn, Carol Greider and Jack Szostak were awarded the Nobel Prize in Physiology or Medicine in 2009, their discoveries were actually made in the 1980s.

† Scientists studying cancer are looking for ways to turn telomerase off in cancer cells to try to prevent them from being immortal, whereas scientists studying ageing speculate that telomerase could give us greatly extended lifespans. Managing to extend lifespan while at the same time controlling cancer is the big challenge, and it would require very sophisticated medication to achieve both aims at the same time.

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Resources

To learn more about the research for which Elizabeth Blackburn, Carol Greider and Jack Szostak were awarded the Nobel Prize in Physiology or Medicine in 2009, read the press release and other material available on the Nobel Prize website: http://nobelprize.org/nobel_prizes/medicine/laureates/2009

Dr Eleanor Hayes is the Editor-in-Chief of *Science in School*.

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For all of the activities published in *Science in School*, we have tried to check that all recognised hazards have been identified and that suitable precautions are suggested. Users should be aware however, that errors and omissions can be made, and safety standards vary across Europe and even within individual countries.

Therefore, before undertaking any activity, users should always carry out their own risk assessment. In particular, any local rules issued by employers or education authorities MUST be obeyed, whatever is suggested in the *Science in School* articles.

Unless the context dictates otherwise, it is assumed that:

- Practical work is carried out in a properly equipped and maintained science laboratory
- Any electrical equipment is properly maintained
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- Eye protection is worn whenever there is any recognised risk to the eyes
- Pupils and / or students are taught safe techniques for activities such as handling living organisms, hazardous materials and equipment.

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Homo sapiens – an endangered species?

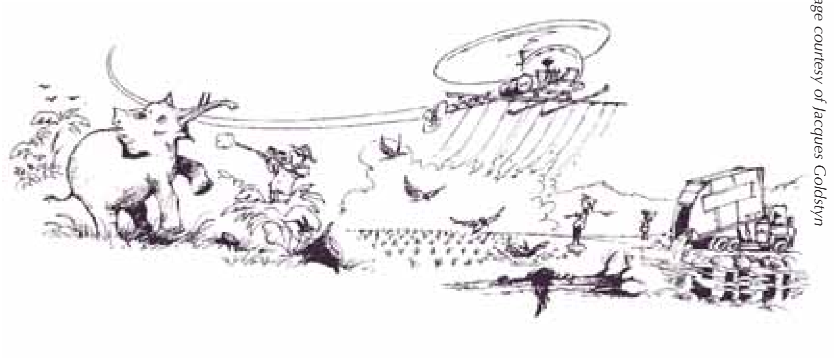

Image courtesy of Jacques Goldstyn

This year has been proclaimed the International Year of Biodiversity. During 2010, governments will seek to reach agreement on a new biodiversity target, to be decided at the Nagoya summit in October. Will this enable us to save not only whales and tigers, but also our own species? **Marlene Rau** investigates.

Climate change, oil shortages, economy crisis, population growth, natural disasters, loss of biodiversity – we are facing an uncertain future, and so far, we do not seem to be doing a great job in meeting the challenge. The world's leaders failed to agree on how to limit climate change at the UN Climate Change Conference in Copenhagen, Denmark, in December 2009. Next on the list is biodiversity, with the 10th meeting of the Convention on Biological Diversity (CBD) scheduled for October 2010 in Nagoya, Japan. But frankly, that is not looking good either.

What is the CBD?

In 1992, the largest ever meeting of world leaders took place at the UN Earth Summit in Rio de Janeiro, Brazil. This is where the CBD saw the light of day. It gained rapid and widespread acceptance: 168 countries signed the Convention in Rio, a further 26 countries signed later, and all but the USA have ratified it. With a total of 193 member states, it has near-universal participation. Importantly, the CBD is legally binding; countries that join and ratify it have committed themselves to implement its provisions. However, no sanctions are in place in cases where a country does not comply with the agreed rules.

The idea behind the CBD

The CBD covers all ecosystems, species and genetic resources. Contrary to previous, more rigorous, conservation efforts, the CBD recognises that ecosystems, species and genes will and should be used for the benefit of humans, if only in a sustainable way, at a rate that does not lead to the long-term decline of biological diversity.

An essential part of the biodiversity debate involves the commercial use of genetic material. Most of the world's

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Image courtesy of Jacques Goldstyn

biodiversity is found in developing countries. Historically, however, bioprospectors from the developed world have collected micro-organisms, plants or animals to develop new commercial products, such as drugs, often without fair benefits to the source country. The CBD recognises national sovereignty over all such genetic resources, so the country of origin will receive its fair share in the form of money, samples or training of national researchers.

The CBD also covers the rapidly expanding field of biotechnology, specifically with the Cartagena Protocol on Biosafety, a supplementary agreement adopted in January 2000, which seeks to protect biodiversity from the potential risks posed by genetically modified organisms. Although most of Europe has joined, a total of 39 of the CBD member states, including Australia, Canada, Iceland, Israel, Liechtenstein, the Russian Federation and the USA, have not ratified the Cartagena Protocol.

REVIEW

Biodiversity is being destroyed at an alarming rate, yet somehow, many individuals are still unaware of the threats we are facing due to this loss. What are the authorities doing and what are we doing? Are there any actions we should be taking? Is it really true that we are destroying our planet?

This topical article can be used in biology and chemistry classes, especially when teaching ecology and environmental science topics.

Possible comprehension questions and points for discussion include:

- What do you understand by the term 'sustainable development'?
- What is biodiversity?
- List three major crises the world is currently facing.
- What is a convention, and what grounds are usually laid during a convention of this kind?

- **Biology**
- **Chemistry**
- **General science**
- **Ecology**
- **Environmental science**
- **Ages 14-19**

- Mention three objectives of the CBD.
- Which stages does the CBD go through to tackle environmental problems?
- What is your opinion about how the CBD handles environmental problems? Is any good coming from this convention?
- Discuss how the loss of biodiversity impacts our lives.

Andrew Galea, Malta

Image courtesy of Lingbeek / iStockphoto

> Sustainability is no longer just a moral issue; it is also becoming an issue of self-interest. It is not just about how we will leave our planet to future generations, but also about ensuring there are sufficient resources for our own generation.
>
> *EU Environment Commissioner Janez Potočnik*

How does the CBD work?

As an international treaty, the CBD identifies a common problem; sets overall goals, policies and general obligations; and organises technical and financial co-operation. But the responsibility for achieving its goals rests largely with the countries themselves, and it is up to the national governments to implement changes. Individual countries need to find effective incentives for their landowners, fishermen, farmers and private companies to adhere to the treaty, and to inform the public. Ultimately, however, their success is our own responsibility – by carefully choosing the products we buy and the government policies that we support, we can begin to steer the world towards sustainable development.

The CBD's definitive authority is the Conference of the Parties (COP), consisting of all governments that have ratified the treaty. The COP reviews progress, identifies new priorities, and sets work plans for the members. It is the COP that will meet in Japan in October 2010.

Progress and the problems faced

After a surge of interest in the wake of the Rio Summit in 1992, progress has been disappointingly slow. Attention to environmental problems was distracted by a series of economic crises, budget deficits, and local and regional conflicts. Despite the promises made in the CBD, drafted in Rio, little has been done to curb the environmental effects of economic growth. The biggest hurdle for sustainable development decisions is the conflict between short- and long-term benefits: it still pays to exploit the environment by harvesting as much as possible as quickly as possible, because the rules of a free market economy do little to protect long-term interests.

Another fundamental challenge for the CBD lies in the broad scope of its objectives: getting all sectors of the national economy, society and the government to work together is a complex task. This would require co-operation between many different actors, such as regional bodies and organisations. And, remember – countries that do not meet the set goals do not actually face any sanctions.

In 2002, 10 years after the CBD was opened for signature, its success was

BACKGROUND

Why is biodiversity important?

The biodiversity we see today is the result of billions of years of evolution, shaped by natural processes and, increasingly, by the influence of humans. As of 18 April 2010, the human population was estimated to be about 6.8 billion, and was predicted to reach 9 billion by 2050, according to UN experts. Our demands on the world's natural resources grow even faster than that: whereas the population has more than doubled since 1950, the global economy has quintupled, with most of this economic growth occurring in relatively few industrialised countries.

For many, nature seems remote from their everyday lives – food is associated with shops, rather than with its natural source. Yet biological resources are the basis of our existence: they support such diverse industries as agriculture, cosmetics, pharmaceuticals, pulp and paper, horticulture, construction and waste treatment.

The ability of ecosystems to deal with natural disasters, as well as with pressures caused by humans such as pollution and climate change, is weakened. Loss of biodiversity also means reduced productivity of ecosystems. Food is one of these products, and its supply is facing serious disruption: for thousands of years, we have been developing a vast array of domesticated plants and animals. However, modern commercial agriculture focuses on relatively few crop varieties, and about 30% of breeds of the main farm animal species are currently at high risk of extinction. For example, an astonishing 90% of cattle in industrialised countries come from only six very tightly defined breeds. Maintaining animal genetic diversity would be essential to allow future generations to select stocks or develop new breeds to cope with emerging issues, such as climate change, diseases and changing socio-economic factors.

Although loss of species has always occurred naturally, human activity has dramatically accelerated this loss: we are creating the greatest extinction crisis since the natural disaster that wiped out the dinosaurs 65 million years ago. These extinctions are irreversible and, given our dependence on food crops, medicines and other biological resources, pose a threat to our own survival.

not exactly overwhelming: national action plans had been developed in more than 100 of the 193 member countries, but the loss of biodiversity was accelerating. As a result, the member states committed themselves to a significant reduction of the rate of biodiversity loss by 2010. However, the COP admitted that this was rather theoretical: "Unprecedented additional efforts would be needed to achieve, by 2010, a significant reduction in the rate of biodiversity loss at all levels… Most of the direct drivers of biodiversity loss are projected to either remain constant or to increase in the near future. Moreover, inertia in natural and human institutional systems results in time lags – of years, decades, or even centuries – between actions being taken and their impact on biodiversity and ecosystems becoming apparent."

Image courtesy of portishead1 / iStockphoto

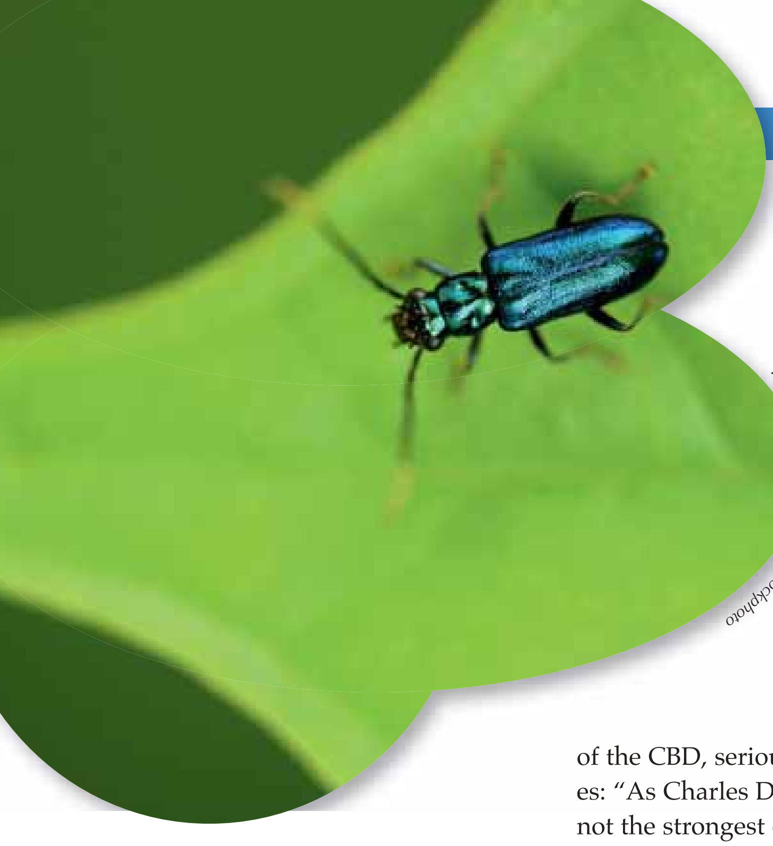

Image courtesy of erforscher / iStockphoto

So what is the situation in the run-up to the 2010 meeting? Has the challenge been met after all? Unsurprisingly, the answer is no. The world is still losing biodiversity at an ever-increasing, hence unprecedented, rate. There are at least some partial or regional successes to be reported, however: they include a slowing in the rate of Brazilian Amazonian deforestation by 74% (although an area about the size of Northern Ireland is lost there every year; worldwide, an area the size of Costa Rica is deforested each year) and a reduction of 45% in the annual rate of mangrove losses (but still, about 6% of the global mangrove areas are lost per year). The number of Important Bird Areas (IBAs)[w1] has approximately doubled since 2002; these now cover between 5 and 8% of each continent except Antarctica, although not all IBAs are protected. More than 12% of terrestrial areas are now under some form of protection.

The task for the Nagoya summit will be to prepare, adopt and implement a new strategic plan for 2011-2020, including a '2050 biodiversity vision'. The idea is to improve the previous plan: more realistic goals, based on scientific results and with better logistic support.

So, let's hope that the world takes Ahmed Djoghlaf, Executive Secretary of the CBD, seriously, who admonishes: "As Charles Darwin stated, 'It is not the strongest of the species that survives, nor the most intelligent... It is the one that is most adaptable to change.' This is valid not only for human beings but also for institutions and processes. The world has changed, and the global partnership for biodiversity will need to adapt to these changes… As Darwin also said, 'In the long history of humankind…those who learned to collaborate and improvise most effectively have prevailed.'"

Web reference

w1 – To find out more about Important Bird Areas, see: www.birdlife.org/action/science/sites/index.html

Resources

For complete information on the Convention on Biological Diversity, including all national profiles, see: www.cbd.int

The CBD runs a biodiversity website for children, including games, a glossary and an educator's corner: http://kids.cbd.int

The European Commission has launched a biodiversity campaign, 'We are all in this together', to show the real implications that biodiversity loss will have on our daily lives, and to promote actions that people can take to protect nature. It is available in many European languages. See: http://ec.europa.eu/environment/biodiversity/campaign

For a review of the most inspiring discoveries in the field of biodiversity that were made in 2009, see:

Kaplan M (2010) Biodiversity: a look back at 2009. *Science in School* **14**: 28-31. www.scienceinschool.org/2010/issue14/biodiversity

If you enjoyed reading this article, you might like to take a look at the full collection of articles on biology that have been published in *Science in School*. See: www.scienceinschool.org/biology

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Dr Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been the editor of *Science in School.*

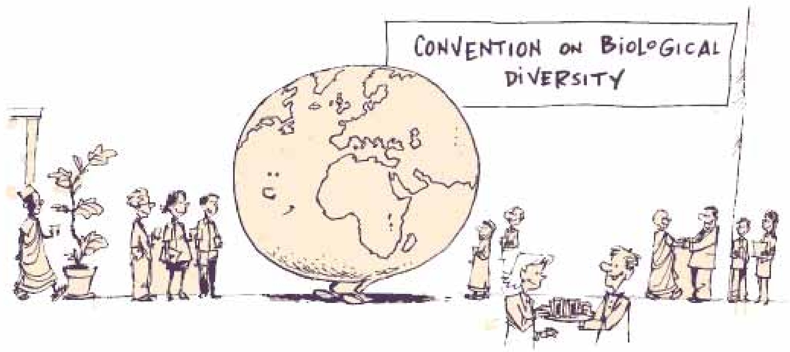


Image courtesy of Jacques Goldstyn

Nick Barker, linking schools and universities in the UK

Lucy Patterson spoke to Nick Barker, a former secondary-school chemistry teacher and head of year who, after 12 years in the classroom, landed a dream job as a Royal Society of Chemistry (RSC) Teacher Fellow.

With a passion for teaching and working with young people, Nick Barker has set up and continues to run an active schools outreach programme in the chemistry department of Warwick University[w1], UK. There, he bridges the gap between the classroom and the research bench, bringing chemistry alive for thousands of local school children.

The teacher fellowship scheme is run by the RSC[w2] to strengthen the links between schools and higher-education institutes, and to help inspire the next generation of chemists. Answering an advertisement in a national newspaper, Nick was hired in January 2008, agreeing to base his fellowship at Warwick University, where he already had contacts. Such was the success of his first six months that, when the RSC funding for the position ran out, the university agreed to continue supporting the programme, which provides a range of different activities aimed at school students between the ages of 6 and 18.

Free to design his own outreach programme, Nick spends a lot of his time visiting local schools to deliver lectures and give demonstrations. For younger students, these cover the fundamentals of chemistry, along with less basic yet impressive concepts such as chemiluminescence, and accompanied by all the bangs and explosions of dramatic pyrotechnic displays.

"Very little is actually banned in schools," explains Nick. "You just have to complete the paperwork and you can do all sorts of fun things. One primary-school class was particularly delighted when I blew a ceiling tile out with one demonstration, and children always seem very happy when a banana frozen in liquid nitrogen shatters rather than hammers a nail into a piece of wood as I intend. I did once get shouted at by a primary-

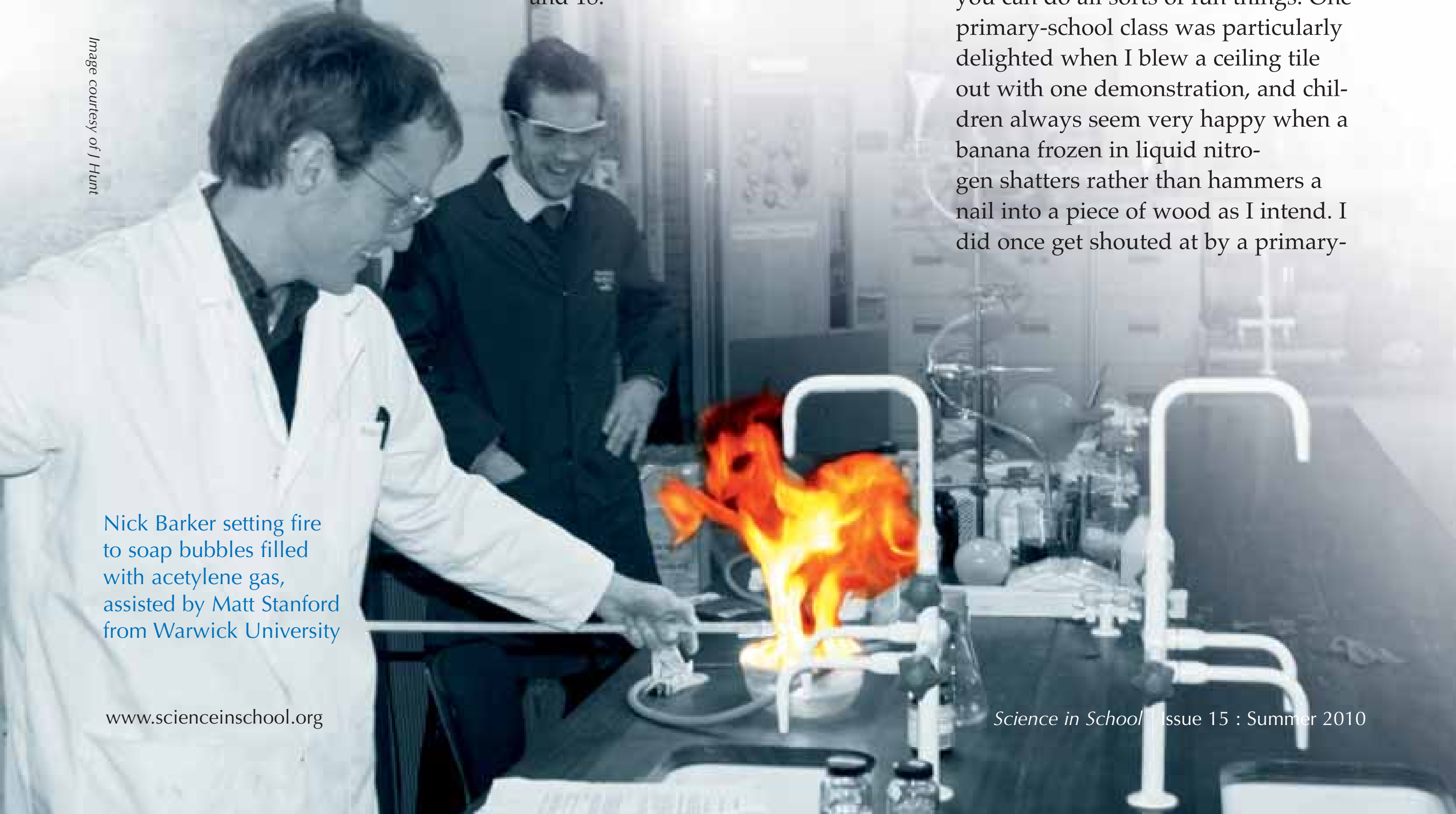


Image courtesy of J Hunt

Nick Barker setting fire to soap bubbles filled with acetylene gas, assisted by Matt Stanford from Warwick University


Image courtesy of Nick Barker

Nick Barker

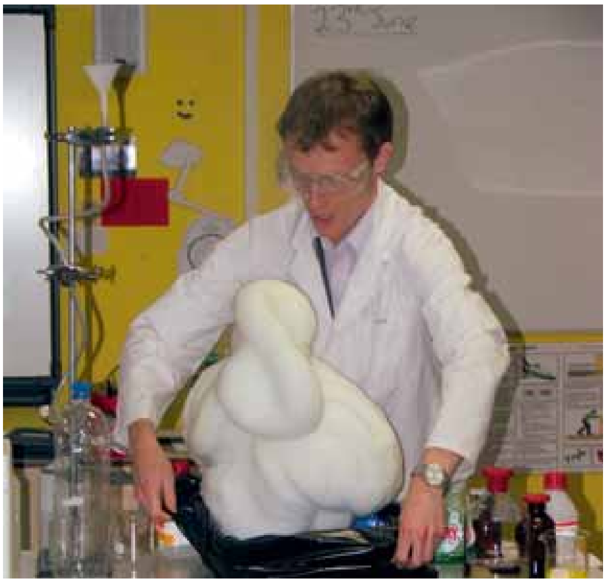


Image courtesy of Nick Barker

Nick Barker trying to contain the famous 'elephant's toothpaste' reaction at a secondary school in Coventry, UK

school teacher when I hit a small child with a steel bar. He was protected with a thick sheet of foam rubber and a sheet of wood. It is a classic demonstration of the concept of pressure. You can whack the wood and the force is spread over a large area, so the person being hit barely feels anything. The child thought it was brilliant, but the teacher got very cross and told me that she had not put anything like that on her risk assessment form!"

For older students, Nick gives lectures with a more academic focus, describing some of the work that goes on at the university, to give a taste of what real-life scientific research is all about. And, when not out and about, Nick organises visits for school groups to the university chemistry department. This not only gives students the opportunity to see the inside of a real research facility but, with access to the university teaching laboratories, also offers them hands-on experience of university-level chemistry with specially designed practical modules. His efforts have been very well received.

"Last academic year the programme reached around 3500 children. They come from all backgrounds, ranging from elite independent schools to a pupil referral unit for children who have been removed from mainstream school. I organise and plan every last detail of this work myself, but I have a huge amount of support. The university and the school staff appreciate this work and want to be involved. In particular, academic staff from the department like to come with me to schools, to work with children and to tell them about their work – so we can say that we'll even put a professor in your lesson! I teach the audience some chemistry, and then it's the real scientist's turn to explain what they do in the lab and why they enjoy science – I think that is more inspiring for the children than my lecture any day. It's great to have the support of such motivated and talented people."

Having spent 12 years teaching chemistry to A-level students (aged 16-18), as well as all three sciences to 11-16 year-olds, Nick feels strongly about where priorities in education should lie. "I think that children should get a broad education that seeks to create rounded people who are interested in the world around them. Teaching is genuinely important to society. In fact, I think it may be one of the most important jobs of all. I was brought up to appreciate the value of education and to enjoy finding things out. What doesn't work is when we become fixated by testing and measuring progress all the time. This takes the joy out of learning." Concerned with what he sees as an emphasis on examination, inspection and monitoring teaching standards in the British state education system, Nick believes that rather than maintaining standards, such measures serve only to divert energy away from the fundamental business of teaching. To him, the most effective and worthwhile approach is to build a real interaction with the students. "I don't like worksheets, PowerPoint slide shows or teaching from books. I do like discussions, practical work, pushing a class to grasp complex topics, presenting fun practical chemistry demonstrations and laughter. I think genuine laughter is very important in a classroom; people learn better when they are relaxed and happy."

And if that means hitting them with a steel bar, then Nick is the man to do it. Just be sure to check your risk assessment forms first!

BACKGROUND

The School Teacher Fellow scheme

The School Teacher Fellow scheme was initially conceived and developed by the Bristol ChemLabS[w3], at Bristol University, UK. The idea was so successful that it was picked up by the RSC and is currently running with support from the biopharmaceutical company AstraZeneca. Teacher fellows either still in the RSC scheme or funded by their universities are based in several chemistry departments around the UK:

- Newcastle University – Peter Hoare (peter.hoare@newcastle.ac.uk)
- Bristol University – Tim Harrison (T.G.Harrison@bristol.ac.uk)
- Southampton University – David Read (D.Read@soton.ac.uk)
- Northumbria University – Anne Willis (anne.willis@northumbria.ac.uk)
- Surrey University – Penny Bagshaw (P.Bagshaw@surrey.ac.uk)
- Oxford University – Roger Nixon (roger.nixon@chem.ox.ac.uk)
- Sheffield University – Will Davey (w.davey@sheffield.ac.uk)
- Warwick University – Nick Barker (n.m.barker@warwick.ac.uk)

Email the teacher fellows if you would like them to visit your school or if you would like to take your class to visit them.

Web references

w1 – Find out more about the Schools Outreach Programme at Warwick University's chemistry department on their website: www2.warwick.ac.uk/fac/sci/chemistry/schools

w2 – Learn more about the RSC, the largest organisation in Europe for advancing the chemical sciences, here: www.rsc.org

w3 – For more information on the Bristol ChemLabS, see: www.chemlabs.bristol.ac.uk

w4 – Science on Stage is a European initiative designed to encourage teachers from across Europe to share best practice in science teaching. See: www.science-on-stage.eu

Resources

To learn more about chemiluminescence, see:

Furtado S (2009) Painting life green: GFP. *Science in School* **12**: 19-23. www.scienceinschool.org/2009/issue12/gfp

Douglas P, Garley M (2010) Chemistry and light. *Science in School* **14**: 63-68. www.scienceinschool.org/2010/issue14/chemlight

Besides having initiated the School Teacher Fellow scheme, the chemists from BristolChemLabS are very active at Science on Stage[w4], and have reviewed a range of materials in *Science in School*: www.scienceinschool.org/reviews

In addition, they have made some of the teaching activities they developed available through *Science in School*:

Harrison T, Shallcross D (2006) Perfume chemistry, sexual attraction and exploding balloons: university activities for school. *Science in School* **3**: 48-51. www.scienceinschool.org/2006/issue3/perfume

Griffin A, Harrison T, Shallcross D (2007) Primary circuses of experiments. *Science in School* **7**: 28-32. www.scienceinschool.org/2007/issue7/primarycircus

Shallcross D, Harrison T (2008) Climate change modelling in the classroom. *Science in School* **9**: 28-33. www.scienceinschool.org/2008/issue9/climate

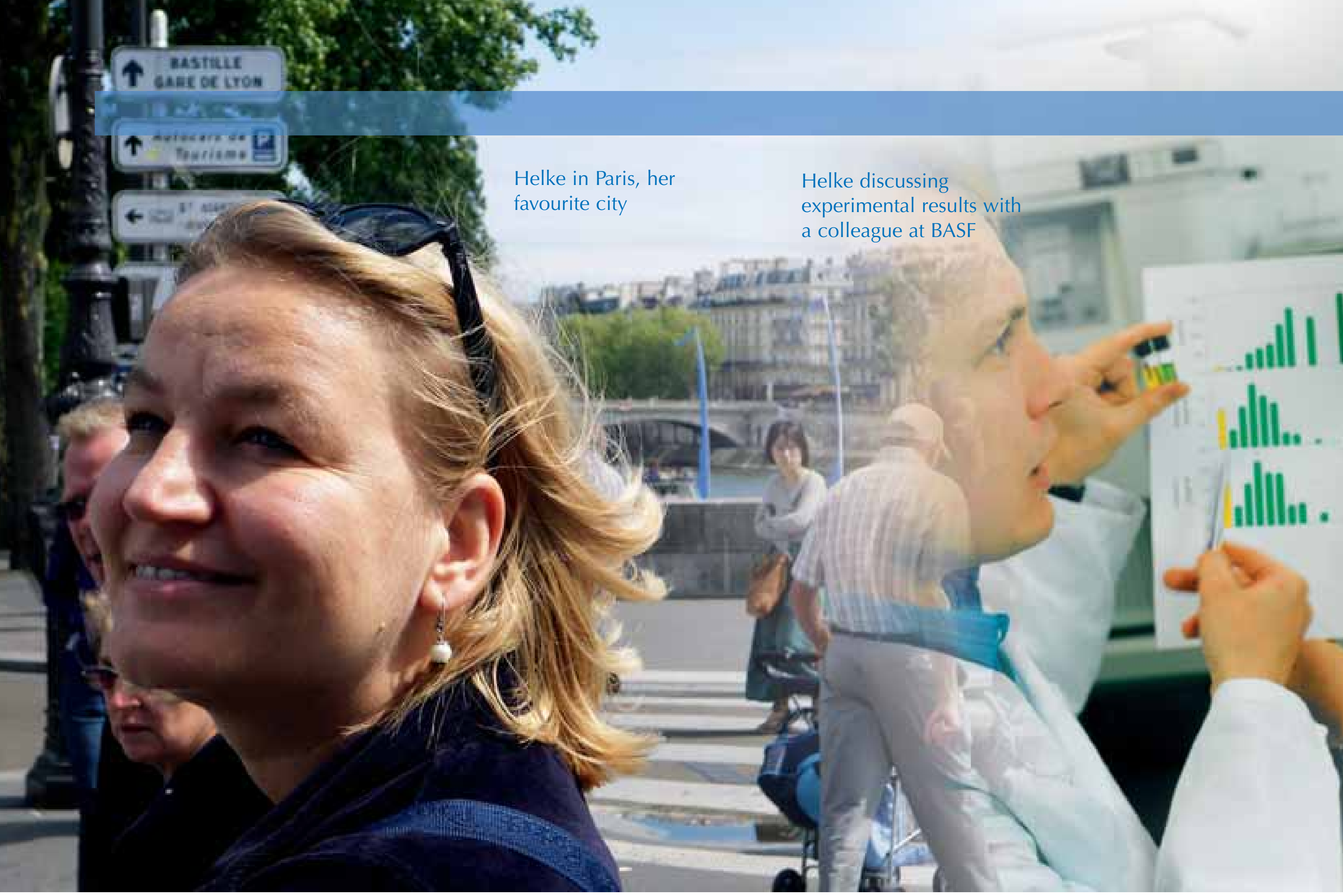
Shallcross D, Harrison T (2008) Practical demonstrations to augment climate change lessons. *Science in School* **10**: 46-50. www.scienceinschool.org/2008/issue10/climate

Shallcross D, et al. (2009) Fuelling interest: climate change experiments. *Science in School* **11**: 38-43. www.scienceinschool.org/2009/issue11/climate

Harrison T, et al. (2009) Looking to the heavens: climate change experiments. *Science in School* **12**: 34-39. www.scienceinschool.org/2009/issue12/climate

If you enjoyed this article, you might like to browse the other teacher profiles published in *Science in School*. See: www.scienceinschool.org/teachers

Lucy Patterson finished her PhD at the University of Nottingham, UK, in 2005, then worked for several years as a postdoctoral scientist, first in Oxford, UK, then in Freiburg and Cologne, Germany. During this time she worked on answering several different questions in developmental biology, the study of how organisms grow and develop from a fertilised egg into a mature adult, using zebrafish embryos. She has a broad interest and enthusiasm for science, and is developing her own embryonic career as a science communicator.



Helke in Paris, her favourite city

Helke discussing experimental results with a colleague at BASF

Image courtesy of Rüdiger Hell

Image courtesy of BASF

Sowing the seeds of science: Helke Hillebrand

Helke Hillebrand has always been fascinated by science, but on the back of a career in plant biology, her urge to work more closely with people helped her decide to go into tending young minds instead of new shoots. **Vienna Leigh** reports.

It seemed a given that the young Helke Hillebrand would go into science. "I fell in love with biology in ninth grade," says the woman who oversees about 200 PhD students at the European Molecular Biology Laboratory (EMBL[w1]), all of whom trust her as an advisor, listener, problem-solver and friend. "I very much appreciated in science that there was no end to asking 'Why?' and 'How does it work?' – and how astonishing our whole world is if one comes to think of it as a constantly evolving system rather than something 'given'."

From there, it was a short hop into plant biology, which also offered something else that Helke, who grew

Image courtesy of EMBL Photolab

Helke awarding an EMBL special prize at Jugend Forscht 2010

Image courtesy of BASF

REVIEW

- Biology
- General science
- Age 13+

This article clearly shows the importance of grabbing students' interest in science from an early age. Once students are hooked on a subject, it is not easy to lure them into other fields. Although studying science may be tough, the article clearly shows that it is still worthwhile, as a science degree opens up numerous avenues for further study and career prospects. The article also shows that scientists are only human, with the same traits and characteristics we might experience in ourselves, including the need to be and work with other people.

The article is suitable for students aged 13 and above, mainly in biology classes, but may also be used for integrated / coordinated science, or with any science students as a model of career prospects or to discuss the (supposed) characteristics of scientists.

Paul Xuereb, Malta

up in the small town of Velbert, close to Essen, Germany, was interested in: a social aspect. "I was amazed by plants' astonishing biochemical capabilities, and from there I discovered an interest in biotechnology and agriculture, with a specific emphasis on food, nutrition and the co-evolution of the history of mankind with agricultural progress," she says. "After my PhD I worked as an assistant professor (*akademische Rätin*) for some time at the university. Then I joined BASF Plant Science[w2] [a section of the world's largest chemical company] in Ludwigshafen, Germany, as a senior scientist, where I built up my own group and ran research projects to develop a 'tool kit' for plant genetic engineering. I especially liked to get into very basic science deeply but at the same time to have the opportunity to develop a broad overview of agricultural requirements."

Before long, Helke had become the head of the 'enabling technologies' division, switching from her own research activities into technology management. "My work had a very broad strategy – to serve current needs as much as developing a vision on future applications and cutting-edge technology," she explains. "I enjoyed striving for expertise and excellence on a broader level in one of my favourite research areas: understanding how cells get to 'know' what to do when, and how this communication flow is triggered on a biochemical level inside a cell, a tissue or a whole organism."

However, there was one thing that Helke was still missing as a research scientist. "I very much enjoy working with people," she says. "When I was running research labs I enjoyed having good and close colleagues who turned into dear friends – we had common goals and common targets to meet, and we pursued them by supporting each other – but I often felt that I was missing out a little on really engaging with many different types of people."

To combat this, Helke got involved with as many outreach and teaching opportunities as possible. "The biggest reward is to see a student's face glowing with interest for the topic or seeing one of the less interested ones becoming enthusiastic," she says. "It is great to see talent flourish and to help that process. I especially like explaining complex scientific stories to the public.

"During my last two years at BASF I took on a position as a financial spokesperson with the investor relations department. I also acted as the main contact for investors in Asia and very much enjoyed the contact with people, especially with Japanese professionals, who have a fascinating business culture."

So, when an opportunity at EMBL came up, Helke jumped at the chance. "In my position as the dean of graduate studies I look after all aspects of EMBL's PhD programme, which takes about 50 students from all over the world every year," she explains. "In addition to the administrative and 'business' side, my role here is to act as a mentor and confidant. I have an open-door policy towards EMBL students, who may turn to me with academic or personal problems.

"I'm also very active as part of the 'external face' of EMBL, building alliances and establishing partnerships with universities towards the awarding of joint PhD degrees, promoting the PhD programme[w3] at conferences, and so on."

With this, Helke has found the perfect mix of science and people skills. "I'd never before thought about turning what I had always enjoyed as a side activity into my profession; in fact I'd never even realised that this might be possible," she says. "What matters most to me is to be able to contribute to the significance or importance of something I believe in. Situations in which commitment counts, where mutual help is appreciated, where people listen to each other and where team success matters are important to me. Even as a researcher I always kept ties with things I liked doing a lot – like mentoring, especially for young or future female researchers, teaching and interviewing students for fellowships – even though it was far away from my professional scientific assignment." For example, since 2005, Helke has been a judge for the biology-related submissions to *Jugend Forscht*[w4], the German young scientist contest for students up to the age of 21.

Helke may have chosen to move away from research, but those who stay at the bench can also find their jobs evolving into something that requires a great deal of understanding, diplomacy and a knack for communication. "One of the most challenging aspects of a scientific career is the point where one has to turn from being 'just' an excellent researcher at the bench into a team leader guiding a group of people who will invest a period of their lives and careers into your research ideas," she says. "All of a sudden – often without any training – researchers need to turn into teachers, supervisors, managers, fundraisers – and all at once. True excellence in science requires a lot of people skills, and it's clear that teachers, universities, institutes and government initiatives should be aware that these skills can and should be learned and trained and could be continuously improved."

Web references

w1 – To learn more about EMBL, the European Molecular Biology Laboratory, see: www.embl.org

w2 – Find out more about the plant science section of BASF here: www.basf.com/group/corporate/en/products-and-industries/biotechnology/plant-biotechnology

w3 – You can find more information on EMBL's international PhD programme here: www.embl.de/training/eipp

w4 – To learn more about *Jugend Forscht*, the German young scientist contest, see: www.jugend-forscht.de

The winners of *Jugend Forscht* participate in the European Union Contest for Young Scientists. See:

Rau M (2009) Discoveries in Paris: the European Union Contest for Young Scientists. *Science in School* **13**: 6-9. www.scienceinschool.org/2009/issue13/eucys09

Resources

To browse all the scientist profiles published in *Science in School*, see: www.scienceinschool.org/scientists

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Vienna Leigh studied linguistics at the University of York, UK, and has a master's degree in contemporary literature. As well as spending several years as a journalist in London, she has worked in travel and reference publishing as a writer, editor and designer. She's been widening her scientific horizons in recent years as the information and publications officer at the European Molecular Biology Laboratory and as editor of its newsletter, *EMBL&cetera.*

Why the Lion Grew its Mane: a Miscellany of Recent Scientific Discoveries from Astronomy to Zoology

By Lewis Smith

Reviewed by Michalis Hadjimarcou, Cyprus

- Biology
- Earth science
- Physics
- Ecology
- Astronomy

The scope of *Why the Lion Grew its Mane: A Miscellany of Recent Scientific Discoveries from Astronomy to Zoology*, as stated by the author, is to offer a "fascinating collection of recent discoveries that overturn popular conceptions, enter realms that were previously the preserve of science fiction, or simply add to the sum of human knowledge". Indeed, the book consists of a large number of articles covering a wide variety of science issues, some of which are well known and thoroughly investigated, while others bring forward new topics for inquiry. Whatever the case, every article provides new and often exciting, even unexpected, information.

The main source of information and inspiration for the articles are reports of scientific discoveries in peer-reviewed journals and specialist publications. Therefore, the reader knows that the material presented is the product of published scientific research and not the product of the author's imagination. The book is by no means aimed only at science-oriented people; even those with minimal science knowledge will be able to understand and enjoy most, if not all, of the topics presented.

No reader is likely to find the answers to all of his or her scientific questions; neither will (s)he be interested in every bit of information provided in the book. Nevertheless, with more than 120 topics from nine themes, the average reader should expect to enjoy reading enough articles to make having this book worthwhile. Biology lovers will probably indulge in the 'new species', 'animal behaviour' and the 'all in the genes' topic areas, whereas dinosaur fanatics will focus on the 'life gone by' section. Ecologists and environmentalists might prefer to start with the 'shaping the Earth' essays. Physicists and high-tech enthusiasts would enjoy the 'tomorrow's world' section. The last three thematic areas, 'stars, planets and space', 'what's in our heads' and 'ancient people', contain articles of more general interest.

All of the articles are very short, rarely exceeding a single page in length, making reading them very easy. Additionally, the articles are accompanied by large colourful pictures – a good reason to spend time flipping though the book.

Why the Lion Grew its Mane would be an excellent idea for a gift or a handy tool for the science teacher to use to give students a short break from a not-so-interesting science topic. Some of the articles would even make a good starting point for in-depth projects or investigations.

Details

Publisher: Papadakis Publisher
Publication year: 2008
ISBN: 9781901092837

Nanoscale: Visualizing an Invisible World

By Kenneth S Deffeyes (author) & Stephen E Deffeyes (illustrator)

Reviewed by Marie Walsh, Limerick Institute of Technology, Republic of Ireland

- Biology
- Chemistry
- Earth science

Nanoscale: Visualizing an Invisible World is a beautifully produced book, filled with engaging text and attractive illustrations, which provides a captivating tour of the 'invisible' world of the nanoscale.

Beginning with a short introduction in which the author tentatively suggests that he has attempted to update *The Architecture of Molecules*, published in 1964 by Linus Pauling and Roger Hayward (to whom the new book is dedicated), he cites advances in X-ray crystallography as being vital to our impressions of molecular and atomic structure. The book uses X-ray diffraction data to provide 50 colourfully illustrated short essays about atomic and molecular structures.

The essays start with familiar and relatively simple topics such as air, water, gold, diamonds and chemical bonds, moving on to haemoglobin, chlorophyll, viruses and nanotubes, and ending with more complex structures including superconductors, fuel cells and quasi-crystals. The subjects of each essay were chosen because they illustrate how different structures at the atomic and molecular levels create properties such as hardness, colour or even toxicity. However, others were chosen because they provide interesting stories, or simply for their beauty – as was the case with the fibrous virus sourced in bacteria of the species *Pseudomonas aeruginosa:* it resembles a sheaf of wheat when viewed side-on, but a fabulous floral asterisk from the end-on view.

The author answer questions such as how diamonds ride volcanoes to the Earth's surface (if they came up more slowly they would be graphite), how viruses reproduce, or how a fuel cell works, and provides links to everyday life wherever possible. There are also stories from the author's own experience, such as the day he was working with two rare earth magnets. He put one of the neodymium magnets on top of a bookcase, but when he picked up the other from his bench, the one on the bookcase flew off and trapped his finger in a 'magnet sandwich' – and needless to say the iron tools that were close by didn't help the situation.

Kenneth S Deffeyes, a professor emeritus of geology at Princeton University, USA, wrote the witty and informative essays. Stephen E Deffeyes is a freelance illustrator and designer who developed the illustrations for the essays from real X-ray diffraction data. Together they have produced a wonderful little book. Nanotechnology is here to stay, and promises to be the next trillion dollar industry – books like *Nanoscale*, which may be the stepping stone to studies in nanoscience, should be in every school library. They teach fundamental principles in a way that many textbooks cannot; for example, when was the last time you heard ionic bonding described as occurring where one of the parent atoms has custody of the bonding electrons? Or metallic bonding as 'some of the (outermost) electrons wandering around the street unsupervised'? This book may just capture the imagination of students, and in doing so attract them to science.

Details

Publisher: MIT Press
Publication year: 2009
ISBN: 9780262012836

The Periodic Table: its Story and Significance

By Eric R Scerri

Reviewed by Eric Demoncheaux, Battle Abbey School, UK

- Chemistry
- Physical chemistry
- History of science

Professor Eric Scerri is a leading philosopher of science who specialises in the history and philosophy of the periodic table. The periodic table is one of the most significant achievements in science, capturing the essence not only of chemistry but also of physics and biology. It is a unique tool, enabling scientists to predict the appearance and properties of matter on Earth and in the rest of the Universe. Scerri's book, *The Periodic Table: its Story and Significance*, is a fascinating and rich account of the history, development and current significance of the periodic table, not only containing a wealth of information on the periodic table but also invoking the principles of modern physics to explain the periodic system.

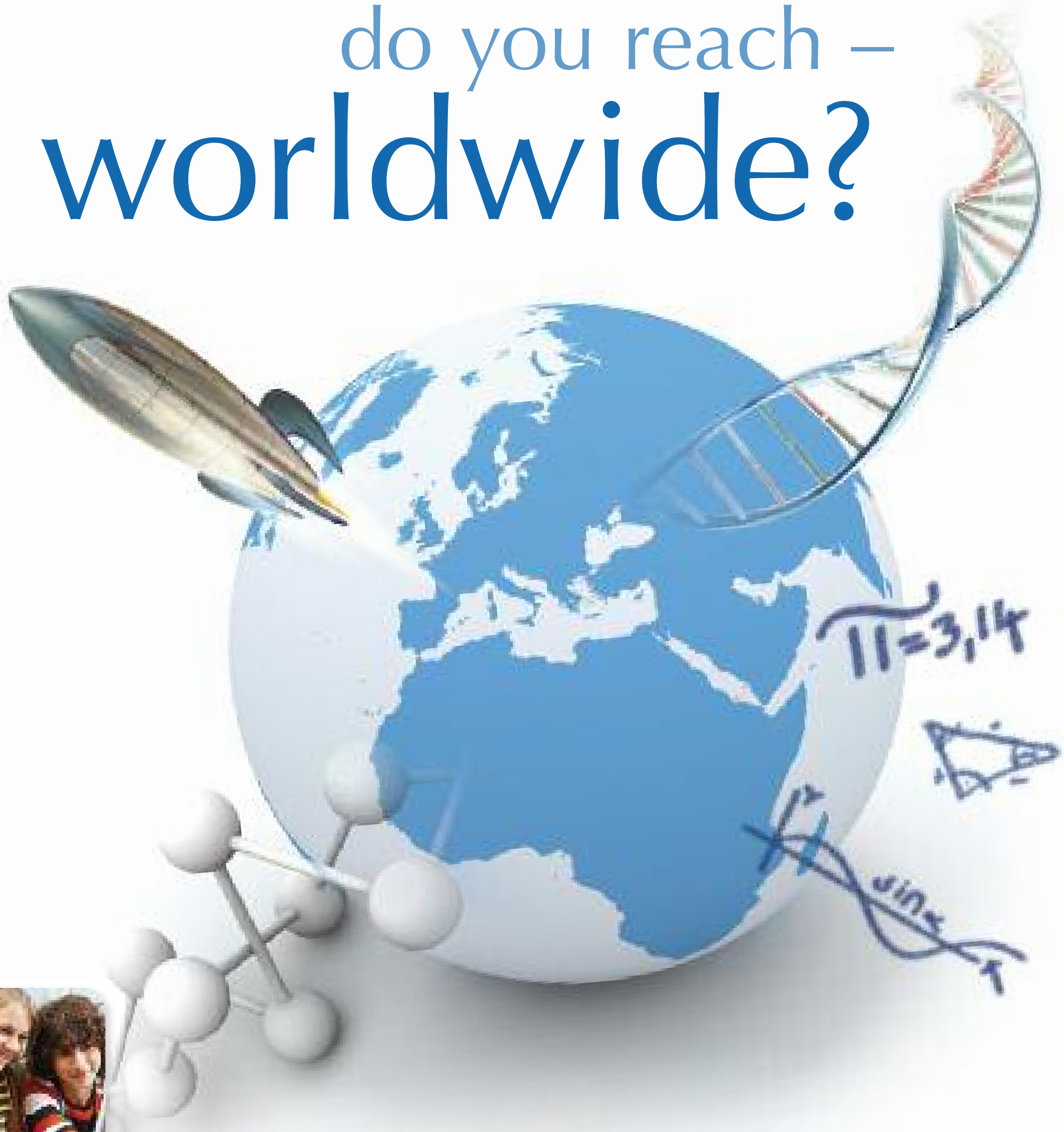
The Periodic Table begins with an overview of the importance of the periodic table and the elements. It gives a systematic account of the early developments that led to the classification of the elements. Two chapters are dedicated to Mendeleev's predictions and how already-known elements fitted in his table. Chapters 6 and 7 deal with the impact of physics, such as radioactivity, isotopes and Bohr's quantum model of the atom, on the periodic table, and Chapter 8 focuses on new physical theories by chemists to correct some of the early electronic configurations. Chapter 9 analyses the impact of modern quantum mechanics and how it might help to explain the periodic system from first principles. Chapter 10 deals with how the elements evolved following the Big Bang and in the interior of stars.

This book is a tour de force and a must-have for any true scholar with a passion for chemistry. Scerri's book presents an uninhibited 'warts and all' history of the periodic table. Most college or secondary-school textbooks give only a brief 'heroes only' account of the history of the periodic table, but Professor Scerri manages to give a well balanced story. This book would be helpful for any secondary-school science teachers specialising in chemistry who want to understand the far-reaching implications of the nature of the periodic law and the challenges that modern science still faces in fully explaining the classification of the elements. This book is a nice step out of the trees to see the wood for a while. I strongly recommend *The Periodic Table: its story and significance* to all secondary-school chemistry teachers.

Details

Publisher: Oxford University Press USA
Publication year: 2006
ISBN: 9780195305739

How many schools and teachers do you reach – worldwide?



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