Summer 2012 Issue 23

SCIENCE in SCHOOL

The European journal for science teachers

In this issue:

Build your own radio telescope

Also:

Intersex: falling outside the norm

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EIROforum

Editorial

What makes diamonds strong or a tiger stripy? Why is music uplifting or the Alhambra palace beautiful? The answer: mathematics. As mathematician Marcus du Sautoy explains in our feature article, mathematics is all around us – and this can be the key to exciting lessons.

X and Y – algebra or sex chromosomes? We used to think the 'equation' was simple – XX = female, XY = male – but then why do some people fall in between, exhibiting features of both sexes? As two scientists who work on the intersex condition explain, the answer involves anatomy, genetics and hormones (page 48). Genetics may also lie at the heart of another condition: cancer. As scientists at EMBL have discovered, some cancers may be triggered when one of our chromosomes explodes (page 12).

Damage on a much larger scale occurs when tectonic plates collide in an earthquake. Did you know that you can monitor earthquakes in your classroom, using a homemade seismograph (page 25)? And if you like making your own apparatus, you'll probably also enjoy building a radio telescope from a satellite dish, then using it to study the Sun and other radiating bodies (page 38).

In this, the international year of sustainable energy for all, we stay with the subject of solar radiation to learn what happens inside a solar panel when the Sun shines (page 43). The Sun often disappears behind the clouds, but – less frequently – it also disappears for another reason: a solar eclipse. On page 20, learn how to replicate both solar and lunar eclipses in the classroom.

Although more than 40 years have passed since the first human landed on the Moon, more distant space travel still poses enormous challenges. To reach Mars, for example, astronauts would need to spend about a year and a half exposed to extreme conditions, far from help and packed together in cramped quarters. Spending the winter on the Concordia research station in Antarctica is similar in many ways: enduring eight months of cold and darkness, isolated from the outside world. For this reason, the European Space Agency sends a researcher to observe the overwintering crew, to help predict the effects of space travel on physical and mental health (page 53).

We all know that exercise is important for health, but did you know that regular exercise causes your body to build more mitochondria, the 'power plants' of the cell that transform digested food into usable energy (page 16)? Instead of using food as an energy source, primary-school teacher David Lewis has used it as a source of inspiration: he developed a series of bread-based activities, covering microbes, fermentation, migration, nutrition – and, of course, baking (page 33).

For older students, physics teacher Günter Bachmann produced teaching resources to communicate the joy and interest of particle physics, during an inspiring two-month visit to CERN. Adrian Mancuso, in contrast, spends every working day at the cutting edge of experimental physics – developing an X-ray instrument to help us understand the structure of biomolecules, viruses, small cells and other particulate material.

These last two articles can be read only on our website – where you can also browse the complete archive of articles, many of which are available in other European languages. And to keep up-to-date with *Science in School* and other great resources for science teachers, why not 'like' our newly launched Facebook page? See: www.facebook.com/scienceinschool

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About *Science in School*

The European journal for science teachers

Science in School is the **only** teaching journal to cover all sciences and target the whole of Europe and beyond. Contents include cutting-edge science, teaching materials and much more.

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Science in School is published and funded by EIROforum (www.eiroforum.org), a partnership between eight of Europe's largest intergovernmental scientific research organisations.

Inspiring science teachers worldwide

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Image courtesy of Toni Matás Urós; image source: Flickr

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To read the whole issue, see: **www.scienceinschool.org/2012/issue23**

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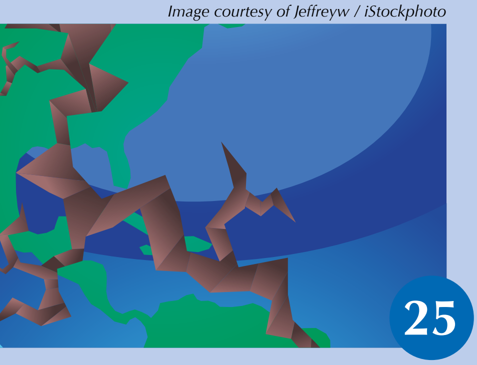

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A voyage through space, arts and the seven seas

Dust specialist Anna Widdowson and remote handling engineer Justin Thomas discuss the nitty-gritty of the virtual-reality vacuuming interface at the Joint European Torus

Image courtesy of EFDA-JET

CERN:
And the winner is… FameLab comes to CERN

On 4 February 2012, 22 young scientists aged 18 to 35 convened at CERN's Globe of Science and Innovation for the regional FameLab semi-finals of the French-speaking part of Switzerland. This UK-based international science communication competition has become a truly global event: in 2012, more than 20 countries are participating, among them for the first time Switzerland. However, FameLab is not just a competition. The idea is also to create a group of young scientists committed to their research and to science communication.

Five winners impressed a panel of experts with a three-minute presentation on a science topic of their choice. Among them is first-prize winner Boris Lemmer, a PhD student from the University of Göttingen, Germany, currently working at CERN, who acted out a conversation between his father and himself with a dry sense of humour that won over the judges and audience. As Boris explains, "It addressed the day that every student fears, when the parents want to know what you're actually doing."

On 30 March in Zürich, Swiss representative Bechara Saab, a postdoctoral student at the University of Zürich's Brain Research Institute, was chosen from among the five regional finalists to take part in the international FameLab event at Cheltenham Science Festival, UK, in June.

To find out more about the competition, all participants and winners, see http://famelab.org for the international competition and www.famelab.ch for the Swiss competition.

Based in Geneva, Switzerland, CERN is the world's largest particle physics laboratory. To learn more, see: www.cern.ch

For a list of CERN-related articles in *Science in School*, see: www.scienceinschool.org/cern

FameLab finalist Boris Lemmer with his proton prop

Image courtesy of CERN

EFDA-JET:
Robots do the dirty work

The Joint European Torus (JET) is a doughnut-shaped vessel, 6 metres from side to side, in which fusion experiments ten times hotter than the Sun are carried out. These experiments produce neutrons, which make the walls radioactive, making it unsafe for humans to carry out maintenance inside the vessel. Instead, a versatile pair of 6-metre-long robotic arms has been developed, which can perform all kinds of maintenance using a virtual-reality remote-handling interface. The system is so versatile that scientists have even got it doing the vacuuming.

Anna Widdowson is one of these scientists: she studies dust. But the dust she collects is not just last week's biscuit crumbs and dog hairs, it is residue left in JET by the fusion plasma pulses, formed from fuel combined with material burnt off the walls. "We need to balance the books to see where all the fuel has gone," she says. Every trace of fuel, which includes radioactive tritium, is accounted for, and if possible reused.

Anna thinks the multi-million euro investment in the system is worthwhile. "I hate vacuuming!" she laughs. "The robotic arm's total vacuuming time was over 24 hours in the last shutdown. Imagine that!"

To find out more about the JET vessel, see:

Rüth C (2012) Harnessing the power of the Sun: fusion reactors. *Science in School* **22**: 42-48. www.scienceinschool.org/2012/issue22/fusion

Situated in Culham, UK, JET is Europe's fusion device. Scientific exploitation of JET is undertaken through the European Fusion Development Agreement (EFDA). To learn more, see: www.efda.org

For a list of EFDA-JET-related articles in *Science in School*, see: www.scienceinschool.org/efdajet

Science in School is published by EIROforum, a collaboration between eight of Europe's largest inter-governmental scientific research organisations. This article reviews some of the latest news from the EIROforum members (EIROs).

EMBL:

All shipshape – TARA Oceans' successful return

After two and a half years of sailing the world's oceans, the schooner of the Tara Oceans expedition returned to its home port, Lorient in Brittany, France, on 31 March 2012. Co-directed by Eric Karsenti, senior scientist at CNRS and EMBL, and Etienne Bourgouis, president of the Tara Foundation, the vessel has sampled material for laboratory analysis at 150 sites worldwide, to study the effects of global warming on planktonic and coral reef ecosystems and their consequences on food webs and marine life.

The expedition's success was celebrated in Lorient by two full days of workshops, exhibitions, lectures and more, followed by a week of activities for local schools, during which students visited the boat, met the crew, and presented the work they had done throughout the school year on the subject of Tara.

And the project will continue – the first scientific results are about to be published, but the analysis of the samples will still take several years to complete, and the project will be presented throughout 2012, for example at the Earth Summit in Rio, Brazil.

For more information about the Tara Oceans expedition, including interviews, videos, films, blogs, DVDs, books and more, in English, French, Spanish and Portuguese, see: http://oceans.taraexpeditions.org

The Tara Junior website also offers a wealth of material for children and teachers, in English and French. See: http://tarajunior.org

To listen to a podcast about Tara Oceans, visit www.embl.de/taraoceans

EMBL is Europe's leading laboratory for basic research in molecular biology, with its headquarters in Heidelberg, Germany. To learn more, see: www.embl.org

For a list of EMBL-related articles in *Science in School*, see: www.scienceinschool.org/embl

The Tara Oceans schooner

Image courtesy of J Girardot / Tara Oceans

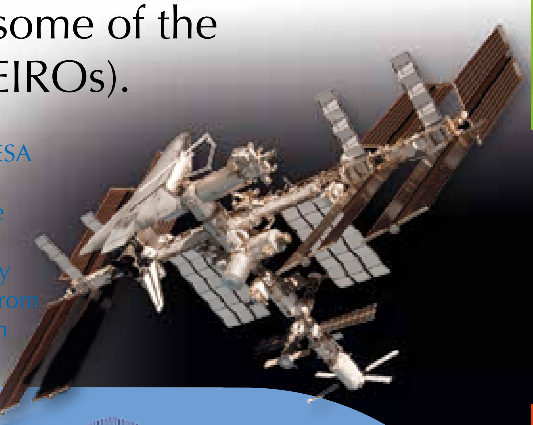


Photo taken by ESA astronaut Paolo Nespoli from the Russian Soyuz spacecraft shortly after its release from the Space Station

Image courtesy of ESA / NASA

ESA:

YouTube Space Lab – the Universe's largest science lesson

Having your science experiment performed on board the International Space Station (ISS) with the whole world watching via a YouTube live stream: this exciting experience awaits the two winning teams of YouTube Space Lab, a campaign co-sponsored by ESA and other space agencies.

Students aged 14 to 18 from around the world were challenged to design a science experiment to be performed in September 2012. Six finalist teams were selected from more than 2000 proposals, among them Laura Calvo and María Vilas from Spain who wanted to test the effect of microgravity on how different types of liquid interact when mixed with compounds that lower their surface tension.

The global winners, Dorothy Chen and Sara Ma from the USA, and Amr Mohammed from Egypt, will get to choose a unique space experience: either a trip to Japan to watch their experiment lift off in a rocket bound for the ISS, or, once they are 18 years old, a one-of-a-kind astronaut training experience in Star City, Russia, the training centre for Russian cosmonauts.

In addition, the regional winners from Europe, the Middle East and Africa will join a hands-on guided tour of ESA's European Astronaut Centre training facilities in Cologne, Germany.

To learn more about the YouTube Space Lab competition, meet the winners, and join the Universe's largest science lesson in September, see: www.youtube.com/SpaceLab

ESA is Europe's gateway to space, with its headquarters in Paris, France. For more information, see: www.esa.int

For a list of ESA-related articles in *Science in School*, see: www.scienceinschool.org/esa

ESO:
Carina unveiled by infrared imaging

ESO's Very Large Telescope (VLT) has delivered the most detailed infrared image of the Carina Nebula stellar nursery taken so far. Many previously hidden features, scattered across a spectacular celestial landscape of gas, dust and young stars, have emerged.

The Nebula is about 7500 light-years away in the constellation of Carina (The Keel) in the part of the Milky Way that is best seen from the southern hemisphere. This cloud of glowing gas and dust is one of the closest incubators of very massive stars to the Earth and includes several of the brightest and heaviest stars known. One of them, the mysterious and highly unstable star Eta Carinae, was the second brightest star in the entire night sky for several years in the 1840s and is likely to explode as a supernova in the near future by astronomical standards (the next million years). The Carina Nebula is a perfect laboratory for astronomers studying the violent births and early lives of stars.

For more information, see the press release: www.eso.org/public/news/eso1208

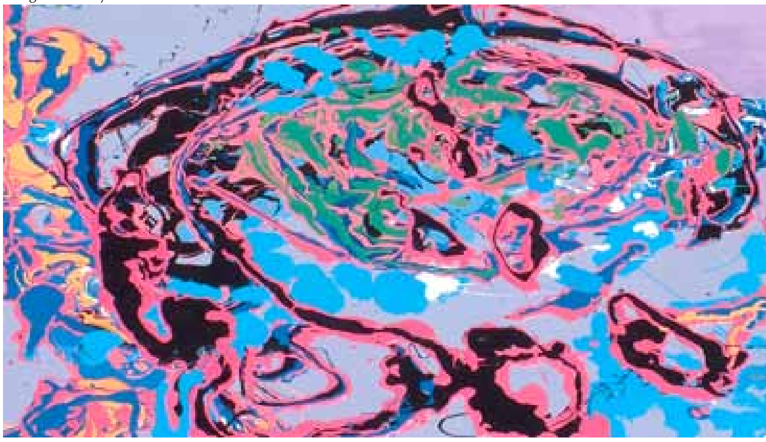
ESO is the world's most productive astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. For more information, see: www.eso.org

For a list of ESO-related articles in *Science in School*, see: www.scienceinschool.org/eso

This broad panorama of the Carina Nebula, a region of massive star formation in the southern skies, was taken in infrared light using the HAWK-I camera on ESO's VLT

Image courtes of ESO / T Preibisch

Image courtesy of ESRF / I Petmezakis



Artist Nina Grúňová's painting was inspired by a 3D model of a fossil wasp. The 16 layers of enamel represent the 720 layers that comprise the original 3D model

ESRF:
Picasso meets Einstein – a contest for young people

Three-dimensional X-ray images turned into an oil painting, molecules inspiring the shape of a sculpture, a time-lapse mosaic of what scientists see at work – ESRF and the European Commission have joined forces with 15 other partners under the co-ordination of the Marche Polytechnic University in Ancona, Italy, to shed light on the common roots of creativity in science and the arts.

In July 2011, four young artists visited ESRF during one week, and their creations are on display at an exhibition that began travelling across Europe in February 2012. This is one of the showcasing events of Immersion into the Science Worlds through Arts (ISWA), a project with the objective to inspire young people across Europe to create works of art about science.

ISWA is organised in five artistic areas: modern dance, cinema, contemporary art, imaging and literature. Students aged 15 to 19 were invited to take part in a pan-European competition by developing their own creations in these categories to win one of 35 attractive prizes. The final event for all winners will take place at ESRF in February 2013.

For more information, see: www.iswaproject.eu

Situated in Grenoble, France, ESRF operates the most powerful synchrotron radiation source in Europe. To learn more, see: www.esrf.eu

For a list of ESRF-related articles in *Science in School*, see: www.scienceinschool.org/esrf

European XFEL:
The data challenge

The X-ray laser facility European XFEL will produce an incredible amount of data – all of which needs to be stored and made available for analysis. Its instruments will generate 10 million gigabytes of data per year for the first few years, increasing to more than 50 million gigabytes per year as a result of detector upgrades. To picture the storage of 50 million gigabytes of data, imagine 10 million DVDs stacked on top of one another – they would reach 12 kilometres high.

"The extremely large data volumes generated at X-ray free-electron lasers require a new way of thinking about how data is managed and analysed," says Christopher Youngman, leader of the European XFEL group 'Data Acquisition and Controls'. At the European XFEL, data will be stored securely in a large disk system, exploiting technologies similar to those used by companies such as Google. To provide enough computer power when the X-ray laser facility becomes operational, the group has begun to look into capabilities of processors used in graphic cards to do calculations.

To find out more, see: www.xfel.eu/news/2012/the_data_challenge

European XFEL is a research facility currently under construction in the Hamburg area in Germany. It will generate extremely intense X-ray flashes for use by researchers from all over the world. To learn more, see: www.xfel.eu

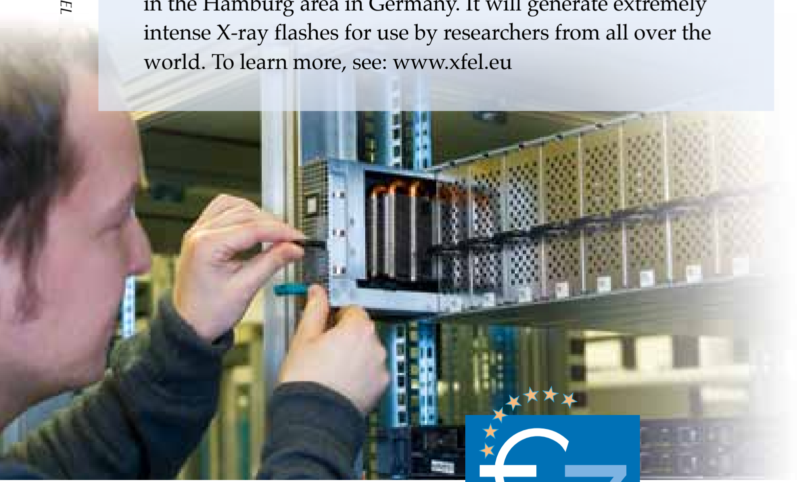


Image courtesy of European XFEL

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EIROforum combines the resources, facilities and expertise of its member organisations to support European science in reaching its full potential. To learn more, see: www.eiroforum.org

For a list of EIROforum-related articles in *Science in School*, see: www.scienceinschool.org/eiroforum

To browse the other EIRO news articles, see: www.scienceinschool.org/eironews

Image courtesy of Benjaminet / Fotolia.com

ILL:
DNA is as stretchy as nylon

Neutron scientists at ILL have measured how fast sound travels along DNA to determine its structural elasticity or 'stiffness', and account for the wide variety of values obtained from previous measurements.

The double-helix structure of DNA is constantly being mechanically twisted, bent and stretched inside the cell through interactions with proteins. "Quantifying the molecular elasticity of DNA is fundamental to our understanding of its biological functions," says Mark Johnson, a physicist at ILL.

The team used the brand new IN5 spectrometer at ILL – and its exceptionally high neutron flux – to measure the structural flexibility of the molecule. On DNA samples placed inside the instrument, the team measured how sound waves travel along the double-helix structure. By measuring frequencies and force constants, they were able to determine the DNA's stiffness as being 83 N/m, which is stiffer than predicted by classical measurements. This value is roughly equivalent to that of nylon, commonly used in textiles.

For more information, see the press release on the ILL website (www.ill.eu) or using the direct link (http://tinyurl.com/7wo5sjn), or the research paper:

Van Eijck L et al. (2011) Direct determination of the base-pair force constant of DNA from the acoustic phonon dispersion of the double helix. *Physical Review Letters* **107, 8:** 1-5. doi: 10.1103/PhysRevLett.107.088102

ILL is an international research centre at the leading edge of neutron science and technology, based in Grenoble, France. To learn more, see: www.ill.eu

For a list of ILL-related articles in *Science in School*, see: www.scienceinschool.org/ill

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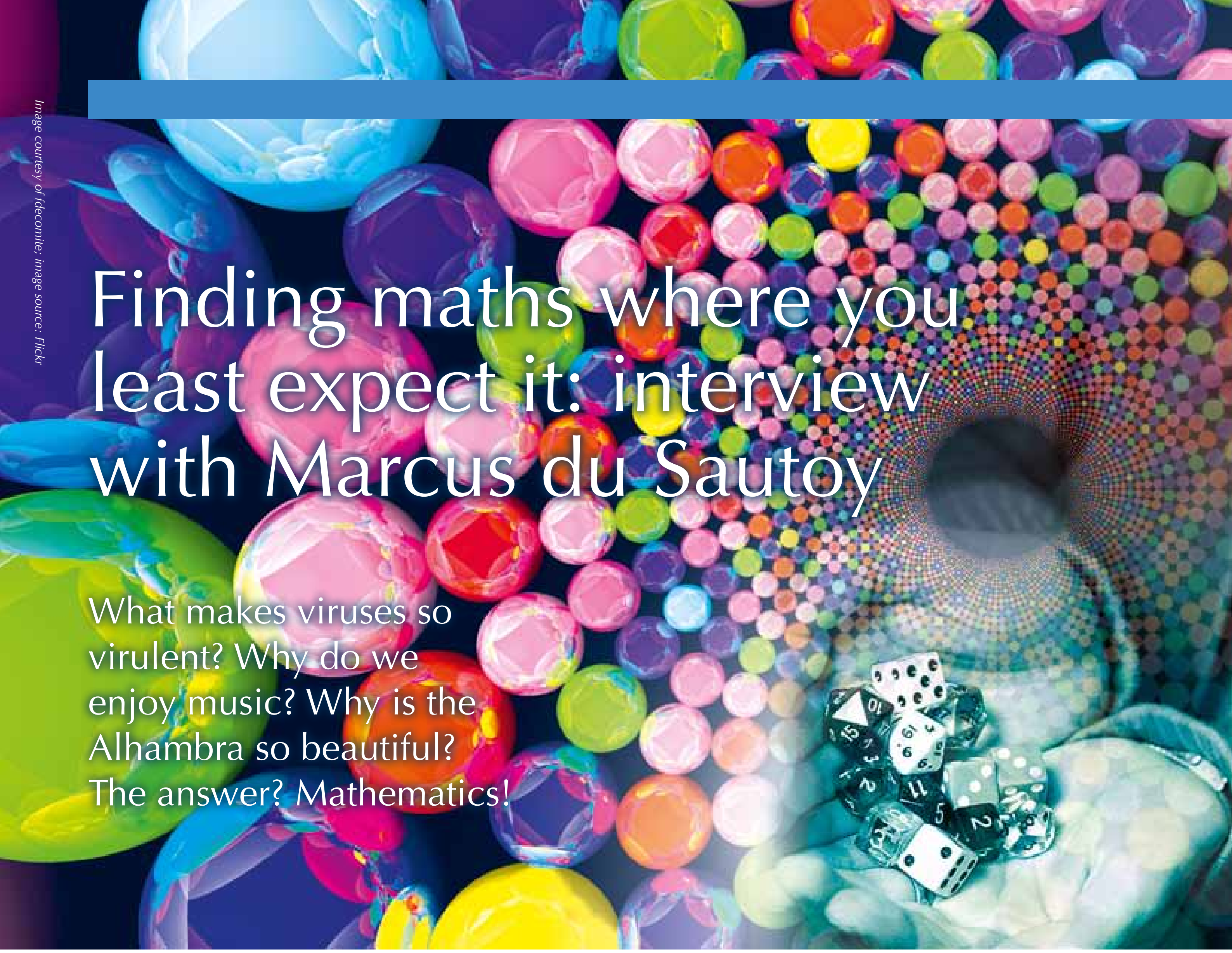

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Finding maths where you least expect it: interview with Marcus du Sautoy

What makes viruses so virulent? Why do we enjoy music? Why is the Alhambra so beautiful? The answer? Mathematics!

By Eleanor Hayes

"I've got very sore feet this morning from walking the tightwire." Somehow, that doesn't fit my stereotype of a mathematician – but then I am talking to Professor Marcus du Sautoy. As he says, "I'm keen to break down the stereotype of a mathematician: a social recluse hiding behind a beard. I haven't got a beard, or glasses, and I'm keen to get out there and show people that mathematicians aren't weird."

And he certainly does get out there – I feel honoured that Marcus found time for *Science in School*. While we're on the phone, he's being driven from the BBC World Service offices in London, where he's been discussing CERN's Large Hadron Collider, to a planning meeting for the Wiltshire Music Festival. And yesterday he was at a circus school, filming a programme about artificial intelligence and how the human brain learns new skills. Hence the sore feet.

Marcus clearly relishes being the professor for the public understanding of science at Oxford University, UK. "It's a hugely varied job – making television programmes, doing radio interviews, giving lectures – and that's what I find so exciting about it. Another thing I enjoy is working with a team, because mathematics can be quite a lonely pursuit: you spend a lot of it on your own at your desk in your own little mathematical world."

Isn't a mathematician an odd choice for the job, though? After all, maths isn't always even considered a science.

"There are definitely differences between maths and the other sciences," agrees Marcus. "In mathematics, you can prove things with 100 % certainty. The ancient Greeks proved that there are infinitely many prime numbers, and that's as true today as it was 2000 years ago. Personally, I've discovered new symmetrical objects that I know won't be overturned by future discoveries. So mathematics can give you a little bit of immortality.

"In the other sciences, in contrast, a new theory emerges which knocks the old theory off the pedestal. Newton's physics had to give way to relativity, and perhaps relativity will give way to a new theory. So the other sciences are a much more evolutionary process – only the fittest theories survive.

"However, the other sciences often rely on mathematics to articulate their discoveries and predictions. As we speak, everyone's getting excited about the announcement of poten-

Image courtesy of Richard Marshall

Marcus du Sautoy

Detail of the bombe, a device used by British cryptologists to decipher encrypted signals during the Second World War. It was designed by mathematician Alan Turing

Image courtesy of Leo Reynolds; image source: Flickr

tial evidence for the Higgs boson at CERN, but the Higgs boson couldn't have been predicted without mathematics. Maths is the language of science, so in some ways having a mathematician as the professor for the public understanding for science is the best of all possible worlds." He then adds, "but I would say that, wouldn't I?"

His predecessor in the post, Richard Dawkins, edited *The Oxford Book of Modern Science Writing*, selecting pieces by scientists Stephen Jay Gould, JBS Haldane, Rachel Carson, Stephen Hawking and Primo Levi. If

Image courtesy of Chris Ruggles; image source: Flickr

How the tiger got its stripes: the patterns of some animals can be explained by equations

REVIEW

- Mathematics
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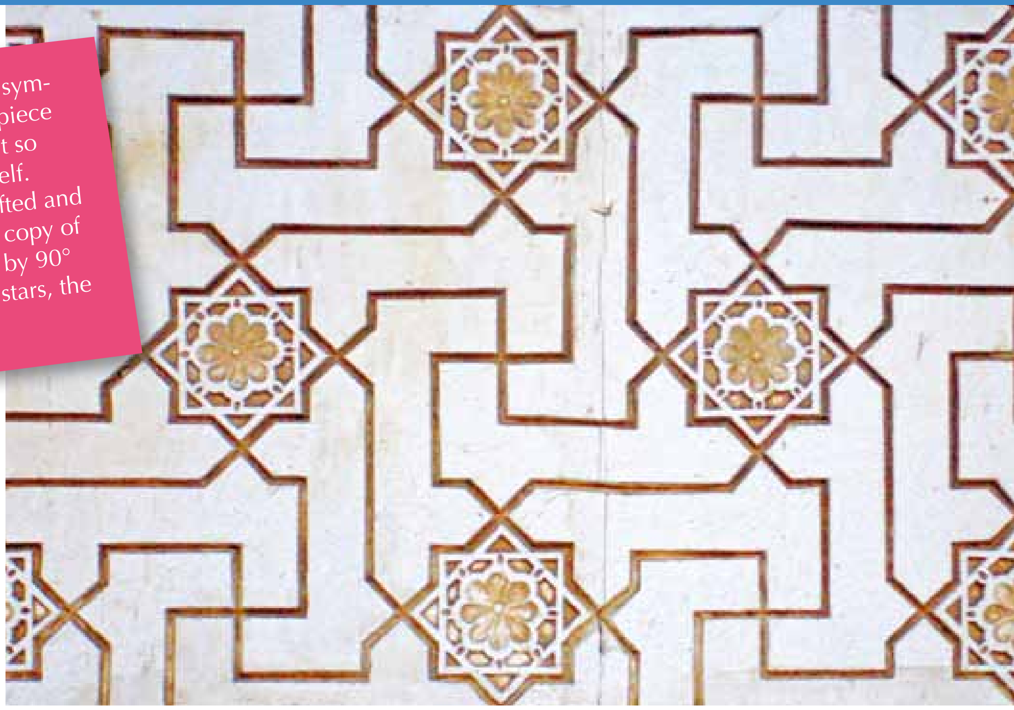
Marcus du Sautoy's enthusiasm for mathematics is infectious as he describes the multifaceted dimensions of his subject. Teachers and students alike will be inspired to look beyond the equations, entering a world of patterns that help to make sense of the living and man-made world. Du Sautoy is keen to improve pedagogical practices in mathematics, by encouraging teachers to contextualise their lessons and to teach through games.

The interview reveals a mathematician who is clearly managing to break free from the stereotype that confines him to the solitary world of the Nobel laureate John Nash, as depicted in the brilliant 2001 film *A Beautiful Mind*. Du Sautoy constantly switches references from learner to teacher, showing that the learning of mathematics in schools should be an exciting discovery in which teacher and student are partners in their quest for answers to scientific questions. Marcus du Sautoy would certainly be a welcome speaker at any school, acting as a bridge between everyday life and the too-often unreachable mountain called mathematics.

Angela Charles, Malta

General science

Image courtesy of Teacher Traveler; image source: Flickr



A decorative carved wall at the Alhambra. The symmetry of the design is very special. First, each piece can be lifted and moved up, down, left or right so that it eventually fits perfectly on a copy of itself. Second, a copy of the whole design can be lifted and moved horizontally or vertically to lie over a copy of itself. Third, if a copy of the design is rotated by 90° about the centre of one of the eight-pointed stars, the design fits perfectly over the original

Marcus were to make a similar collection, whom would he include?

"Obviously, I would probably include more mathematicians than Richard did. Bernhard Riemann, for example, who really changed the way we look at geometry. It's thanks to him that we can talk about relativity – without Riemann's world, we wouldn't have Einstein. I would love to take several scientific topics and show that at their hearts are great pieces of mathematics. For example, Alan Turing, who is famous for cracking German codes at Bletchley Park, UK, during the Second World War, also made extraordinary contributions to the theory of artificial intelligence, to computing, and even to biology. The equations that he was studying towards the end of his life explain why animals have certain patterns; it's mathematics that controls why a leopard has spots and a tiger has stripes."

Marcus believes that maths even affects how we perceive the world. "Most people think that maths is about long division to lots of decimal places. Really, though, a mathematician is someone who looks at structure and pattern – and in a sense that's how everyone reads the world: we're all mathematicians at heart. Part of my mission is to reveal to people that if, for example, they love listening to music, they are probably listening to it in a very mathematical way, spotting patterns and structures, bits that are similar but changed – perhaps in a symmetrical way, having been turned upside down."

In his book about symmetry, *Finding Moonshine*, Marcus includes a chapter about the Alhambra in Spain[w1].

Image courtesy of Caroline Ingram; image source: Flickr

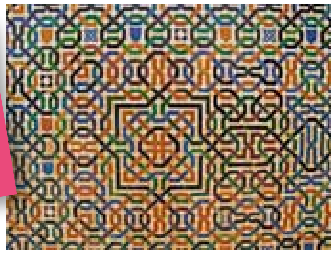


Image courtesy of Teacher Traveler; image source: Flickr

Can you spot the different types of symmetry in these tiles at the Alhambra palace?

Patio de los Arrayanes: one of the highly decorated courtyards at the Alhambra in Granada, Spain

Image courtesy of magro_kr; image source: Flickr

"The palace is full of symmetry, for example in the tiles on the walls; most people appreciate the Alhambra but haven't got the language to articulate what makes it so special. Lots of people have told me, 'I've always loved the Alhambra, but after I read your chapter I saw it in a completely different way'."

The hero of *Finding Moonshine* is the 19th century mathematician Évariste Galois[w2]. "He died in a duel at the age of 20, perhaps over a lover," says Marcus, "but he'd already discovered so many extraordinary things, including a way of looking at symmetry very algebraically and linguistically. I'd love to go back in time and warn him not to fight that morning, and then spend that time with him discussing how he came to create the language we use to understand symmetry – a language that I use every day as a practicing scientist."

Unsurprisingly, perhaps, symmetry is the focus of Marcus du Sautoy's research. "Basically, I'm trying to understand what symmetrical objects exist in mathematics and in nature – not just in three dimensions but in

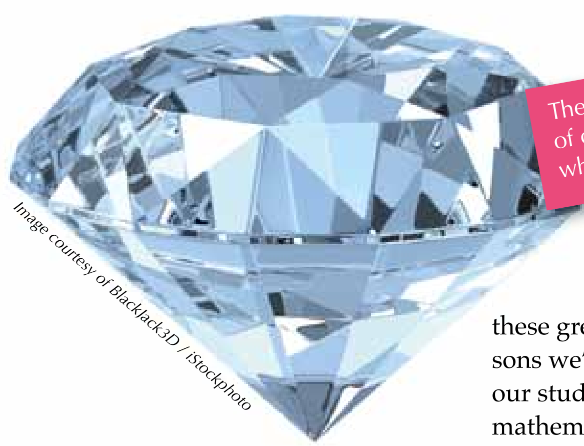
Public domain image; image source: Wikimedia Commons

Mathematician Évariste Galois, killed in a duel at the age of 20

higher dimensions as well. Symmetry is incredibly important across all of the sciences. Crystal structures, for example, are all to do with symmetry; the reason that diamond is so strong is because of its underlying symmetry – the way that the carbon atoms are bound together. Symmetry is very important in biology too – viruses are very often symmetrical in shape and that's key to why they're virulent and so strong. In physics, understanding the fundamental particles depends on symmetry."

Symmetry is important in modern technology, too. "For example, your mobile phone changes your voice into a series of 0s and 1s which then

Image courtesy of BlackJack3D / iStockphoto



The symmetrical arrangement of carbon atoms in diamond is what makes it so strong

get beamed around the world. Often, there's a lot of corruption on the line, which changes some 0s to 1s and some 1s to 0s. Using symmetry, we encode your voice before it is sent. Any corruption destroys that symmetry, but by using symmetry at the other end, you can often recover what the original message was."

This is all very different from the maths I learned at school. Marcus explains: "It's because the maths taught at school is like the grammar and vocabulary of the language, rather than the stories or the great literature. Children leave school not realising that there are fantastic stories about prime numbers[w3], about topology, geometry, and symmetry – they just know about sines and cosines and percentages. In English lessons, my son is reading *Othello* and *Animal Farm*. He doesn't understand the full complexity of these great works, but in language lessons we're not frightened of exposing our students to difficult things – in mathematics, I sometimes think we're a bit timid."

Marcus continues: "I don't blame teachers for the state of our science and maths education, because they are very constrained by the curriculum. But I think any opportunity to give the story behind the maths, to put things in context, can really help to motivate a student. For example, the volume of a pyramid: you can teach the formula as a third of the height times the area of the base – and that's quite boring. Or you can put it in context, explaining that it was discovered in ancient Egypt and showing them a copy of the Rhind Papyrus, which includes the formula. Why were the Egyptians interested? They wanted to know what volume of the stones they needed for their pyramids. Behind the formula is a beautiful story[w4]."

There's also a touching story behind how Marcus became interested in maths. "When I was 13, I went to the

Image courtesy of William Hook; image source: Flickr

Symmetry can help sort out signal from noise during mobile phone transmission

Image courtesy of JanetandPhil; image source: Flickr

What have cicadas got to do with prime numbers? Some species of these insects have life cycles lasting 13 or 17 years, with the adults almost absent in the intervening years. The long life cycles, synchronous emergence and the fact that 13 and 17 are prime numbers all help the adult cicadas to escape parasites and predators. If the cicada has a life cycle of 17 years and its parasite has a life cycle of five years, how frequently will the two coincide?

General science

Royal Institution Christmas lecture series[w5], when they were given by Christopher Zeeman. I was thrilled to see one of the best mathematicians in the world trying to communicate to kids the excitement of maths. I thought 'I'd love to be him when I grow up'. When I got the chance to give the Christmas lectures in 2006, it was a wonderful way to pay back that inspiration. In the last of the lectures, I told the audience 'I was sitting in your place in 1978, and it was watching these lectures that inspired me to become a mathematician. I hope that one day, one of you will stand up here saying the same thing'. It was an extraordinarily emotional moment – some of the production team got quite tearful too."

The Giant's Causeway in Northern Ireland. Many of the basalt columns from which this geological structure is made are hexagonal and reflect the symmetrical structure of honeycomb

Image courtesy of Überraschungsbilder; image source: Flickr

Inspiring school students is important to Marcus, but he receives many more invitations than he has time to accept. His public communication work also limits the amount of university teaching he can do – disappointing for those students who chose Oxford for his sake. In an attempt to do justice to both groups, he trained a team of enthusiastic students to give some of his public presentations[w6]. "It's a win-win situation," he enthuses. "I get the material into schools, and the students get to do some outreach, go to science festivals – some of them have even worked with me on television projects."

In his continuing quest to bring maths to life for young people, Marcus and a friend also dreamed up an ambitious project: to take the entire maths curriculum and turn it into online games[w7]. "It was an interesting challenge," he laughs. "How do you turn quadratic equations into a game? We're really pleased with the result, though. Kids love playing these games, which the teachers say actually deliver the curriculum. They can set particular games as homework and know that the children can't score the necessary points without having understood the maths."

Research, university teaching, public lectures, broadcasting, popular science writing…. With such a multitude of activities, it can't be an easy question, but when he looks back in 30 years, what would Marcus du Sautoy like to feel he has achieved? "When someone tells me that one of my lectures inspired them to study maths, it's a great feeling. But it's my mathematical work that I'm most proud of – forging into the unknown and discovering something new and useful. And there are still a few more conjectures I'd like to prove, to look back on and think 'wow, I contributed to that extraordinary edifice we call mathematics'."

The story behind the maths. Why did the ancient Egyptians need to know how to calculate the volume of a pyramid?

Image courtesy of Dennis Jarvis; image source: Flickr

Reference

Du Sautoy M (2008) *Finding Moonshine: A Mathematician's Journey Through Symmetry*. New York, NY, USA: Harper Collins. ISBN: 9780007214617

Web references

w1 – On the Page 69 blog, Marcus du Sautoy discusses page 69 of his book *Finding Moonshine* – about rotational symmetry in the Alhambra palace. See http://page69test.blogspot.de or use the direct link: http://tinyurl.com/ctejj2r

w2 – In his TED lecture, Marcus du Sautoy tells the story of Évariste Galois and demonstrates why symmetry is so important – such as in sexual attraction, in disease and in beauty. See: www.youtube.com/watch?v=415VX3QX4cU

w3 – Why did footballer David Beckham choose the number 23 shirt? How is 17 the key to the evolutionary survival of a strange species of cicada? In this video, Marcus du Sautoy discusses the mystery of prime numbers, the history behind the Riemann hypothesis and the ongoing quest to solve it. See: www.youtube.com/watch?v=PgqEaUT8Qo0

w4 – To help you fill in the story behind the maths, NRICH offers stimulating and relevant resources

Image courtesy of Toni Matés Urtós; image source: Flickr

Image courtesy of Lisa Sorensen; image source: Flickr

Starfish, sea urchins and their relatives have five-fold symmetry

One of nature's most beautiful symmetrical creations: the honeycomb

Image courtesy of justus.thane; image source: Flickr

to explore the ways in which mathematics, science and technology are linked, roughly aimed at 11- to 16-year-old students and their teachers. See: http://nrich.maths.org/stemnrich

w5 – Started by Michael Faraday in 1825, the Christmas lectures at the UK's Royal Institution are demonstration-packed, fun-filled science events for young people. Many of them are available online. Visit: http://richannel.org/christmas-lectures

w6 – A group of maths students trained by Marcus du Sautoy, Marcus' Marvellous Mathematicians, offers workshops, activities and talks about maths to a wide range of audiences. To find out more, visit www.maths.ox.ac.uk or use the direct link: http://tinyurl.com/7ybv99m

w7 – The Manga High website offers free, short versions of maths games for different ages and topics. To access the full-length games, you need to subscribe. See: www.mangahigh.com

Cut open an apple and admire the five-fold symmetry

Image courtesy of Rasbak; image source: Wikimedia Commons

Resources

In the Brief History of Mathematics podcasts, Marcus du Sautoy introduces the mathematicians behind the calculations – from Newton to the present day. See: www.bbc.co.uk/podcasts/series/maths

Du Sautoy M (2004) *The Music of the Primes: Why an Unsolved Problem in Mathematics Matters*. New York, NY, USA: Harper Collins. ISBN: 9781841155807

Du Sautoy M (2011) *The Number Mysteries: A Mathematical Odyssey through Everyday Life*. London, UK: Harper Collins. ISBN: 9780007309863

The German research centre Matheon offers school visits, lectures, teacher training and other up-to-date and fun maths activities. See: www.matheon.de

To find out more about CERN's Large Hadron Collider, see:

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

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

If you enjoyed this article, why not browse the other feature articles in *Science in School*? See: www.scienceinschool.org/features

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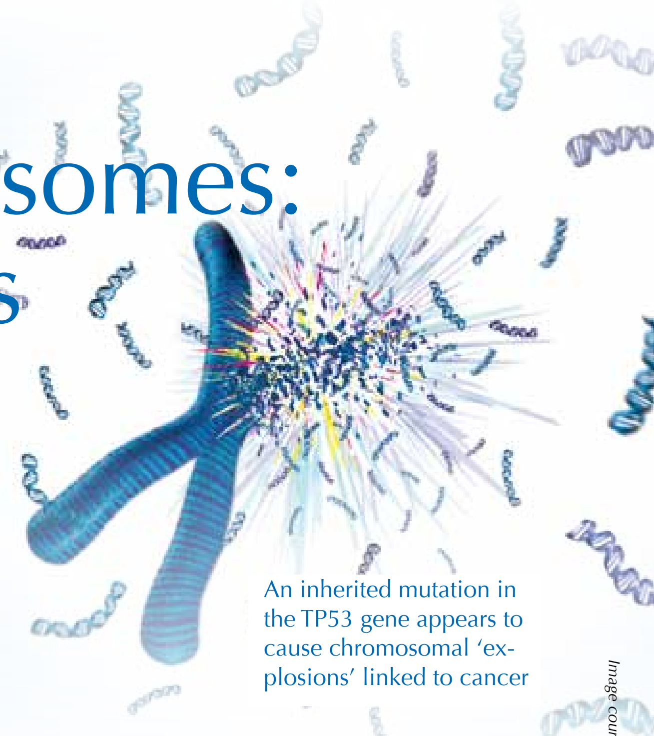
Dr Eleanor Hayes is the editor-in-chief of *Science in School*. She studied zoology at the University of Oxford, UK, and completed a PhD in insect ecology. She then spent some time working in university administration before moving to Germany and into science publishing in 2001. In 2005, she moved to the European Molecular Biology Laboratory to launch *Science in School*.

To learn how to use this code, see page 65.

General science

Exploding chromosomes: how cancer begins

Brain tumours are one of the most common causes of death in children – and may begin when chromosomes are torn apart during cell division.



An inherited mutation in the TP53 gene appears to cause chromosomal 'explosions' linked to cancer

Image courtesy of EMBL / P Riedinger

By Sonia Furtado Neves, EMBL

It's a scene that has played out in many a household: the whole family on hands and knees, chasing coloured beads, as a distraught child stands wide-eyed, holding the remnants of a favourite necklace. Once most of the beads have been collected, a kind adult threads them onto a new cord, and the crisis is over. Unless, of course, the child won't be satisfied with anything less than an exact replica of the original necklace: finding all the beads – including the ones that rolled under the sofa or behind the cupboard – and threading them back in the right order can be a tricky business.

At Heidelberg University Hospital, Germany, Andreas Kulozik encountered a family with a much more serious problem: a little girl and her brother had developed highly aggressive tumours. In initial genetic tests,

REVIEW

- **Medicine**
- **Biology**
- **Genetics**
- **Mutation**
- **Inheritance**
- **Cancer**
- **Ages 16+**

The article is written in a clear and concise manner with an interesting hook to set the scenario. The analogy of exploding chromosomes and broken necklaces is very apt; it can help students understand the difficult job of putting an exploded chromosome back together again in its original form. It is feasible to carry out a demonstration of this at school, since beads are fairly standard pieces found in a school biology laboratory.

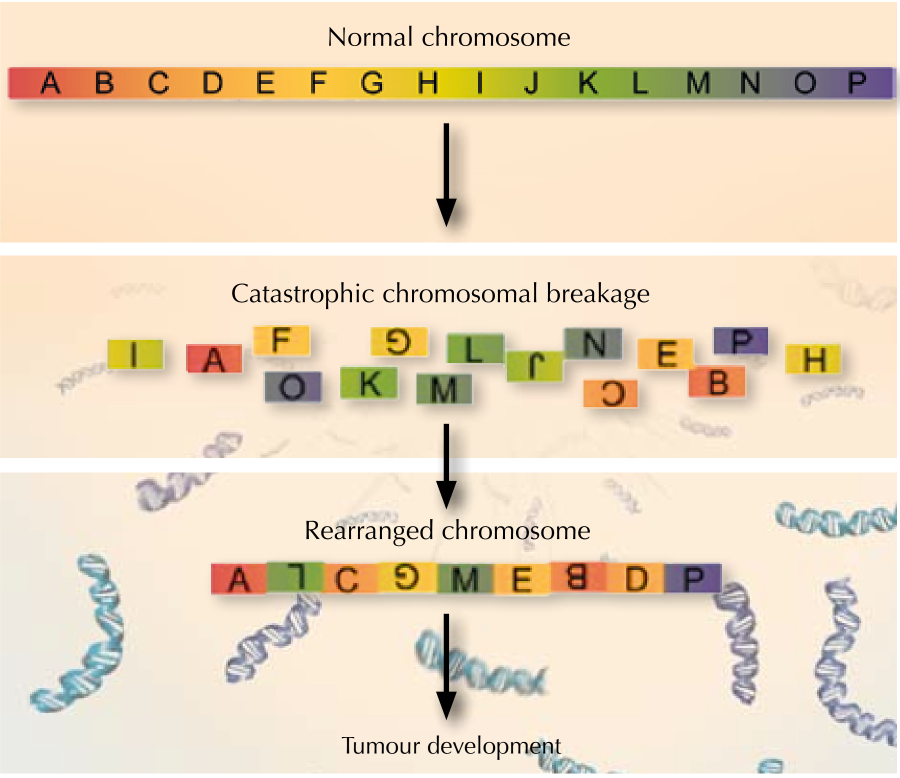
This article can be used as an extension activity to the teaching of genetic mutations or to extend discussion of the role of genes in cancer. It can also be used as a basis for further research into TP53 mutations, or the role of genes in cancer and childhood medullablastomas for students who are interested in becoming medics. Used in conjunction with appropriate questions, this article can be used as a comprehension exercise with plenty of opportunity for further web-based investigations into mutations, oncogenes, types of cancers, cancer treatments and telomeres.

Suitable comprehension questions include:

1. If a mutation is found in all cells, is it more likely to be a random mutation or one inherited from parents? Explain your answer.
2. What is a medulloblastoma? Explain why it is so malignant.
3. Draw a series of diagrams to show what chromothripsis is.
4. What are two roles of the TP53 gene?
5. What are two possible mechanisms by which a TP53 mutation causes cancer?
6. What are oncogenes?
7. How does the TP53 mutation affect cancer treatments?
8. What is the role of telomeres in chromosomes?

Students could also use the article to construct a glossary of uncommon words and concepts.

Shaista Shirazi, UK



Reproduced and simplified from Rausch T et al. (2012), with permission from Elsevier

Andreas found that the siblings had the same mutation in the gene TP53. They had this mutation in all their cells, not just the cancerous ones, which meant it was inherited from their parents, rather than acquired later by the cells that formed the tumour. When Jan Korbel from the European Molecular Biology Laboratory[w1] teamed up with Stefan Pfister and Peter Lichter from the German Cancer Research Center[w2] to look at the genetics of childhood brain tumours, this family connection seemed a good place to start. As part of the International Cancer Genome Consortium, Jan, Stefan and Peter were sequencing the whole genome of cells from a childhood tumour for the first time. Called medulloblastoma, it is the most common of all malignant paediatric brain cancers, which are the most fatal cancers in children and the second most common cause of childhood deaths in developed countries after car accidents.

"When we got the DNA sequence data back, we saw a chaos in the girl's genome that we couldn't really explain at first," says Tobias Rausch, from Jan's research group, who led the data analysis. "Then we saw a paper by another group, describing a newly discovered phenomenon they called *chromothripsis*, and it clicked," adds fellow group member Adrian Stütz.

The scientists realised they too were seeing chromothripsis, the cellular equivalent of the broken necklace scenario: a chromosome (sometimes two) had somehow exploded into countless small pieces, and had then been put back together with some pieces missing and others in the wrong order. As they analysed more samples, the scientists realised that this happened in the cancerous tissues of all medulloblastoma patients who carried any inherited TP53 mutation, but in none of the patients with normal TP53 or in the healthy tissue of the medulloblastoma patients. "This makes us suspect that these three events are connected," says Jan. "We believe that a TP53 mutation may cause chromosomes to explode, or possibly prevent the cell from reacting properly when they do. This somehow then leads to highly aggressive forms of cancer."

So how could a mutation in TP53 cause chromosomes to explode, and how would that lead to cancer? Scientists know that TP53 helps prevent chromosomes from fraying at the ends, by protecting telomeres – the caps that keep the ends of chromosomes together. If TP53 is faulty, Jan and colleagues speculate, telomeres could be compromised, and chro-

More about EMBL

EIROforum

EMBL

The European Molecular Biology Laboratory (EMBL)[w1] is one of the world's top research institutions, dedicated to basic research in the life sciences. EMBL is international, innovative and interdisciplinary. Its employees from 60 nations have backgrounds including biology, physics, chemistry and computer science, and collaborate on research that covers the full spectrum of molecular biology.

EMBL is a member of EIROforum[w3], the publisher of *Science in School*.

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

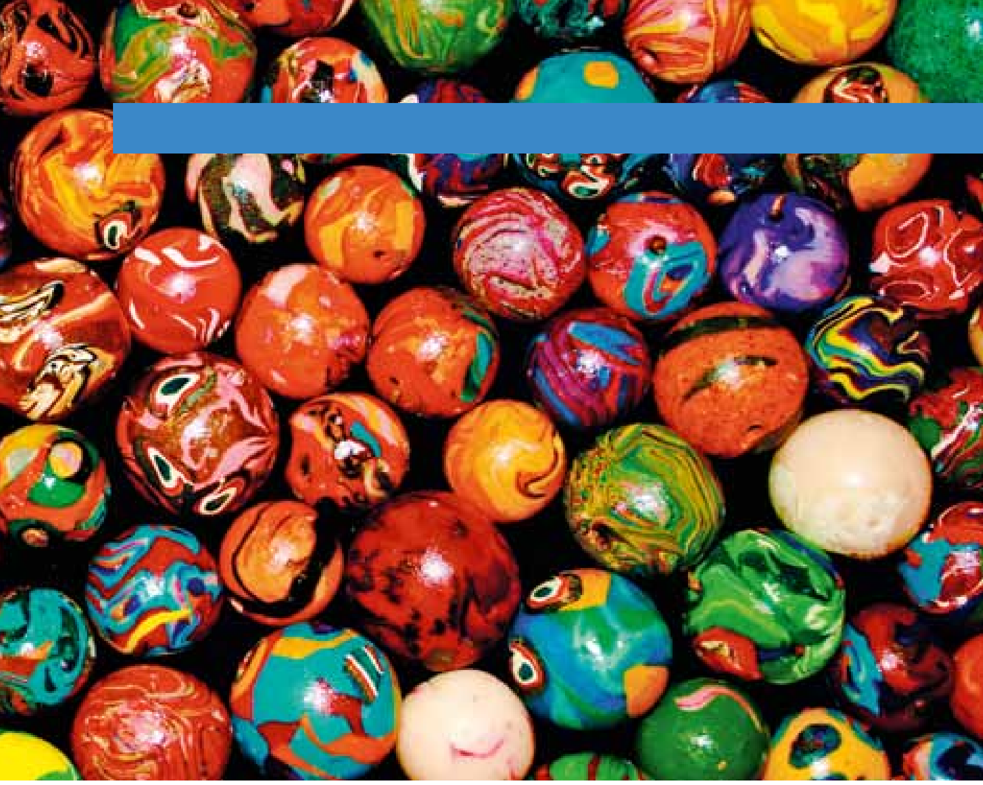


Image courtesy of faith goble; image source: Flickr

mosomes could stick to each other. In such a scenario, when that cell came to divide, chromosomes that were stuck together could run into problems. They would be pulled in opposite directions. At some point the strain would be too much, and, like the bead necklace that's pulled too hard, one or both of the chromosomes would shatter, sending fragments of DNA flying. As the cell's machinery raced to put the chromosome(s) back together, bits of genetic material might be left out and others re-assembled in the wrong order – or even from the wrong chromosome.

On the other hand, TP53 also plays a key role in inspecting our DNA for damage. If this guardian of the genome finds too many mistakes, it can push the cell into a programmed suicide (apoptosis) or into the cellular equivalent of old age (senescence), to prevent the cell from dividing and passing on those genetic defects. But if TP53 is mutated, extensive damage to DNA could go unnoticed – damage such as a badly reassembled chromosome after chromothripsis, regardless of whether TP53 was involved in causing the chromosome explosion or not. As a result, oncogenes – genes that lead to cancer – could be activated, and the cell could start dividing and dividing, unchecked, thereby creating a tumour. Jan, Stefan and Peter speculate that these effects of a faulty TP53 may combine to lead to cancer in these patients, and would now like to investigate exactly how this is happening at each step.

In the meantime, their findings already have immediate repercussions for clinicians like Andreas and Stefan, and for their patients. "If a patient's tumour cells show signs of chromothripsis, we now know that we should look for an inherited TP53 mutation," Stefan says. And this is important, because having an inherited TP53 mutation could make the most commonly used cancer treatments backfire. Many chemo- and radiotherapy treatments kill cancer cells by damaging their DNA, but they also affect other cells in the body. In most patients, although this can lead to painful side effects, it does little long-term harm. Not so for someone with an inherited TP53 mutation. Because of that mutation, all of that person's cells, including the healthy ones, will have trouble reacting to DNA damage. So treatments that target DNA could actually make healthy cells turn cancerous, causing so-called secondary and tertiary tumours – "something we often see in patients with inherited TP53 mutations", says Stefan. For such patients, it may be preferable to prescribe less intensive treatments using agents that do less damage to DNA. And, if a patient has an inherited TP53 mutation, this tells the doctor that that person's immediate family should be tested, too. If any healthy family members carry the mutation, it should be seen as a signal for regular screening, as they are very likely to develop tumours at some point in their lives. "And the best chances of fighting cancer – especially the aggressive, early-onset types of cancer that seem to be associated with chromothripsis – are if it is diagnosed early," Jan points out.

In fact, scientists think that 2-3 % of all cancers are probably caused by chromothripsis, so Jan's group are now investigating whether TP53 mutations play a role in similar chromosome explosions in other tumours besides medulloblastoma. They have already found evidence for the same link between chromothripsis and inherited TP53 mutations in acute myeloid leukaemia. In this aggressive type of blood cancer in adults, Jan and colleagues discovered that patients with both a non-inherited TP53 mutation (i.e. a TP53 mutation only in their tumour cells) *and* evidence of chromothripsis tended to be elderly. The scientists point out that this makes sense in light of TP53's role in telomere integrity. Our chromosome caps naturally get shorter as we age, making chromosome ends even more likely to get stuck to each other if TP53 goes awry. This in turn makes chromothripsis – and the ensuing cancer – more likely, the scientists suspect.

Jan's group is continuing to explore these issues in brain, blood and other cancers, to unravel how faulty versions of TP53 are linked to chromosomes exploding like broken

Image courtesy of Evan-Amos; image source: Wikimedia Commons

Image courtesy of francisblack / iStockphoto

necklaces, as well as what other aspects of cells' housekeeping efforts are involved in cancer.

Reference

The research results were published in:

Rausch T et al. (2012) Genome sequencing of pediatric medulloblastoma links catastrophic DNA rearrangements with TP53 mutations in cancer. *Cell* **148(1-2)**: 59-71. doi: 10.1016/j.cell.2011.12.013

Web references

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

w2 – The German Cancer Research Center (*Deutsches Krebsforschungszentrum*) is the largest biomedical research institute in Germany, where over 1000 scientists investigate the mechanisms of cancer, identify cancer risk factors and try to find strategies to prevent people from getting cancer. To learn more, visit: www.dkfz.de

w3 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

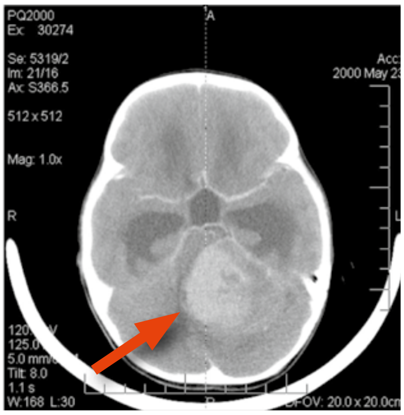


Image courtesy of Reylan; image source: Wikimedia Commons

CT (computed tomography) scan showing a medulloblastoma (see arrow) in the brain of a six-year-old girl

Resources

For a teaching activity about how geneticists identify cancerous cells, see:

Communication and Public Engagement Team (2010) Can you spot a cancer mutation? *Science in School* **16**: 39-44. www.scienceinschool.org/2010/issue16/cancer

To learn how cancer stem cells may revolutionise the treatment of cancer, see:

Mazza M (2011) Cancer stem cells – hope for the future? *Science in School* **21**: 18-22. www.scienceinschool.org/2011/issue21/cscs

For more information on how genetic mutations cause diseases, see:

Patterson L (2009) Getting a grip on genetic diseases. *Science in School* **13**: 53-58. www.scienceinschool.org/2009/issue13/insight

For a classroom activity about knowing what your genes have in store for you, including the possibility of cancer, see:

Strieth L et al. (2008) Meet the Gene Machine: stimulating bioethical discussions at school. *Science in School* **9**: 34-38. www.scienceinschool.org/2008/issue9/genemachine

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For other medicine-related articles, see: www.scienceinschool.org/medicine

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Sonia Furtado Neves 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 what she really enjoys is telling people about science. She went on to do a master's degree in science communication at Imperial College London, and is now the press officer at the European Molecular Biology Laboratory in Heidelberg, Germany.

To learn how to use this code, see page 65.

On your bike: how muscles respond to exercise

Image courtesy of Let Ideas Compete; image source: Flickr

We all know that exercise makes us fitter and healthier – but what changes take place in our cells to make this happen?

By Maléne Lindholm and Susanna Wallman Appel

Next time you are working out in the gym, or pounding the streets running or jogging, ponder this: the idea of 'muscle memory' – that today's exercise has effects on our muscles years from now – has never been demonstrated scientifically. Does it really exist, and if so, how does it work? These are some of the questions we hope to answer in our on-going research, which aims to pin down the changes that occur in muscles when we exercise, and how our muscles 'know' to respond differently to, say, endurance training as opposed to strength training.

Helping us to investigate these questions is a large team of volunteers. Not only must they cycle to exhaustion in our gym, but before and after a strenuous exercise regime lasting several weeks, we take a tiny sample of their leg muscle under local anaesthetic (figure 1). The aim of our research is to help people optimise their training programmes for maximal fitness, and potentially to help develop new treatments for people who cannot exercise because they are paralysed or have joint diseases.

We assess the fitness of our volunteers before and after participation in the studies by measuring their maximal oxygen uptake. They cycle on an exercise bike against increasing resistance until exhausted, while wearing a

Image courtesy of Maléne Lindholm and Susanna Wallman Appel

Figure 1: A biopsy needle is used to take a fragment of muscle from the leg of a study participant. This tissue can reveal what changes occur in muscle fibres in response to different types of exercise

Image courtesy of Maléne Lindholm and Susanna Wallman Appel

Figure 2: Prior to the exercise studies, participants perform a test in which all their exhaled air is collected and the amount of oxygen taken up by the body is measured. This provides information on the fitness level of each participant's heart and working muscles

Image courtesy of Maléne Lindholm and Susanna Wallman Appel

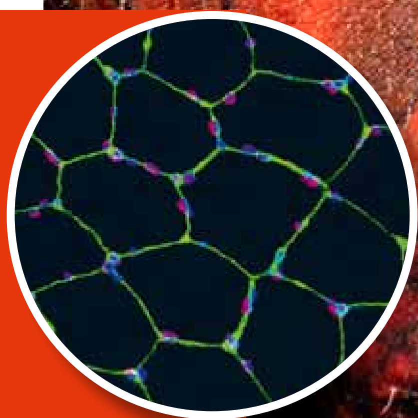

Figure 3: A microscope is used to visualise changes that occur within the muscle fibres in response to exercise. Different types of staining can reveal different structures within the cell. Here, one specific histone modification is stained in red, with the nuclei in blue and the cell membrane in green. To find out if a change has occurred, we would compare it with an image taken before training

Image courtesy of Mariana Ruiz Villarreal; image source: Wikimedia Commons

Artist's impression of a cross-section of a mitochondrion, showing its inner folded membrane structure

mask to analyse their oxygen consumption (figure 2). This gives us information about the pumping capacity of the heart and metabolism of the working muscles – both factors associated with a person's fitness level.

Then we study the muscle tissue from the biopsies either by slicing and staining the tissue, then viewing it under a microscope (figure 3), or by breaking up the tissue and measuring the levels of particular molecules.

Of course, we already know that regular exercise produces health benefits. Physically active individuals have a lower risk of developing cardiovascular diseases, type II diabetes and certain types of cancer. Even a moderate amount of daily physical activity, for example 30 minutes of brisk walking, is enough to confer many of the benefits. And the more exercise we take, the greater the benefits. It's not just a question of how much exercise we take, though, but also what sort and how intense it is: different types of exercise produce different effects on the body. Heavy resistance training, such as weight lifting, causes skeletal muscles to grow, providing enhanced strength, whereas regular endurance exercise, for example long-distance running, cycling or aerobics, improves fitness and reduces fatigue.

How does regular endurance exercise lead to these effects? Over time, the heart gains the ability to pump larger strokes and after a couple of months of training, new tiny blood vessels (capillaries) form around muscle cells to ensure a good oxygen supply. Also, the number of mitochondria – the cell's 'power plants' – increases. Inside the mitochondria, enzymes use oxygen to turn digested sugar and fat into usable energy. The more mitochondria the muscles have, the more fat and sugar they can metabolise and the more energy they can release.

But what we don't yet understand is exactly how exercise causes such changes. We are pursuing this question along two lines: first, how does exercise lead to more mitochondria in skeletal muscle cells? And second, how does exercise change the way in which the cell's DNA is used?

REVIEW

- ✔ **Biology**
- ✔ **Genetics**
- ✔ **Ages 16+**

Exercising is an activity that relates (or should relate) to every human on the planet; as such, it has received a lot of attention for decades. Although the potential benefits of exercise are well known, the cause of these benefits is largely unknown. This article gives an overview of some of the genetic factors that might be involved in the positive outcomes observed in the physical state of an individual who exercises.

Biologists and other persons with at least a modest understanding of genetics, including advanced secondary-school biology students, will probably find the information provided in this article highly interesting. They might even be motivated to think of alternative ways in which exercising can lead to health benefits.

Michalis Hadjimarcou, Cyprus

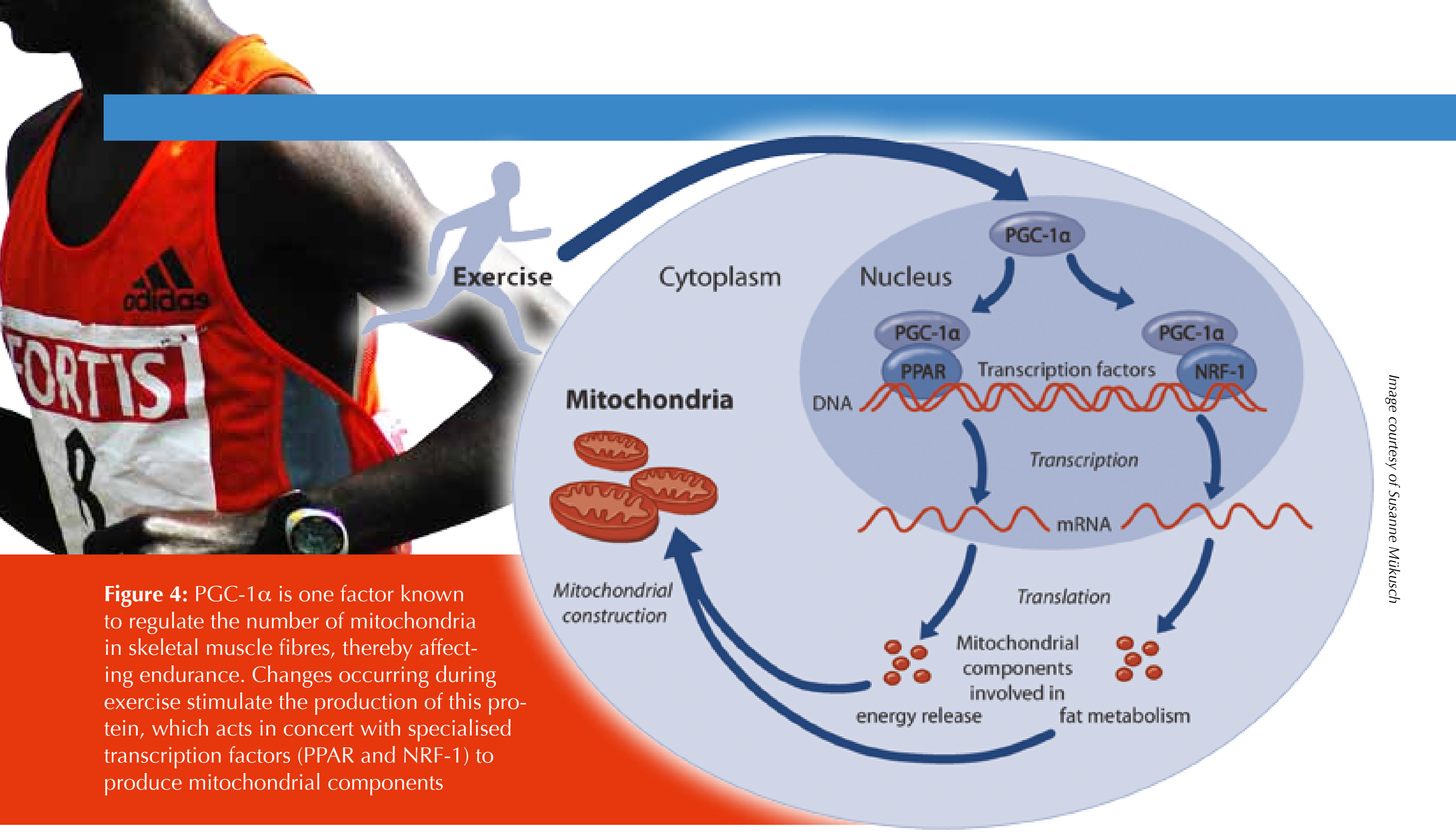

Image courtesy of Susanne Mikusch

Figure 4: PGC-1α is one factor known to regulate the number of mitochondria in skeletal muscle fibres, thereby affecting endurance. Changes occurring during exercise stimulate the production of this protein, which acts in concert with specialised transcription factors (PPAR and NRF-1) to produce mitochondrial components

Building mitochondria

Mitochondria are constructed from protein molecules, so factors that boost the production of mitochondrial proteins can increase the number of mitochondria in a cell. One factor that acts as a key regulator of the production of mitochondrial proteins is a molecule called PGC-1α (figure 4).

For a gene to be *expressed* – that is, used to make a protein – the DNA information held in the nucleus must first be copied, or *transcribed*, onto an mRNA molecule. The mRNA molecules then move out of the nucleus to sites in the cell where protein molecules are constructed.

The transcription process is controlled by DNA-binding molecules called transcription factors. These attach to the DNA strand at very specific points, either blocking or promoting the transcription process. PGC-1α acts in concert with transcription factors to promote the expression of many genes coding for mitochondrial proteins.

We have recently discovered that one variant of PGC-1α is not present at all before exercise, but high levels of it can be found after only one hour of cycling. This suggests that certain genes are turned on exclusively by exercise, and this may be a clue to the effects of exercise training on health. We are now investigating possible protein modulators of PGC-1α, which may attach to this protein to increase or decrease its activity in boosting mitochondrial protein production.

Epigenetic factors

We are also exploring the possible impact of exercise on *epigenetics*. Epigenetic changes affect how the DNA is used, without affecting the genetic information encoded within it. In our cells, DNA is wrapped around coin-shaped proteins called histones. Attaching small chemical molecules to the DNA strand or to histones affects the ability of transcription factors to reach their target genes. For example, adding a methyl (CH_3) molecule to DNA generally makes the adjacent genes less accessible and thus less active, whereas attaching an acetyl ($COCH_3$) group to histones usually relaxes that part of the DNA strand, making it more accessible for transcription (figure 5).

Using the biopsy material from our volunteers, we aim to see if such epigenetic effects remain after a prolonged period without physical training, and whether they influence how an individual responds to a later period of training. Based on the results of these experiments, we will be able to investigate whether 'muscle memory' truly exists and, if so, how it works.

Resources

To learn more about the role of exercise in the prevention and treatment of different diseases, see:

Henriksson J, Sundberg CJ (2008) General effects of physical activity. In Ståhle A (ed) *Physical Activity in the Prevention and Treatment of Disease* pp 11-37. Stockholm, Sweden: Professional Associations for Physical Activity. ISBN: 9789172577152. www.fyss.se/wp-content/uploads/2011/02/fyss_2010_english.pdf

WHO (2010) Global recommendations on physical activity for health. ISBN: 9789241599979. www.who.int/dietphysicalactivity/factsheet_recommendations

The publication is currently available in English, Chinese, French, Russian and Spanish.

For more information about the physiological effects of exercise, see:

Wilmore JH, Costill DL, Kenney WL (2007) *Physiology of Sport and*

Image adapted with permission from the NIH Common Fund (for original, see: http://commonfund.nih.gov/Epigenomics/epigeneticmechanisms.aspx)

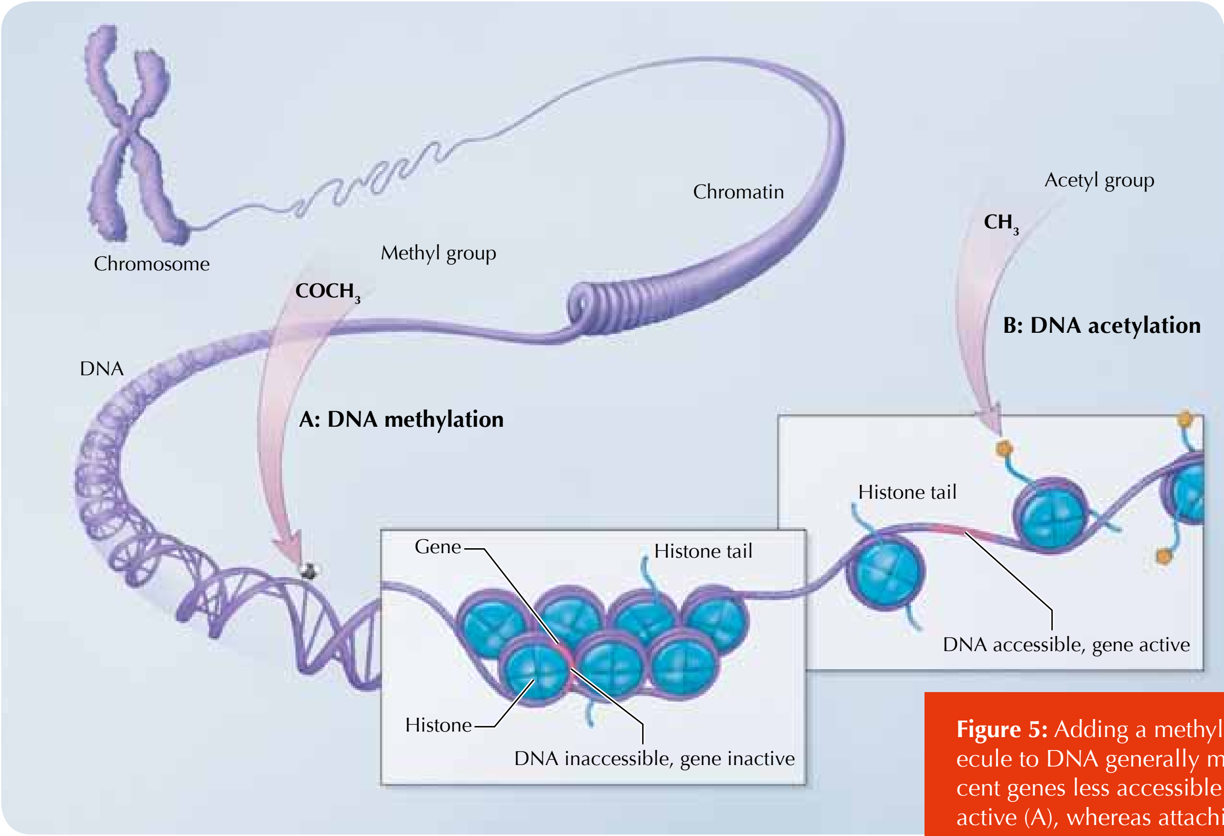

Figure 5: Adding a methyl (CH_3) molecule to DNA generally makes the adjacent genes less accessible and thus less active (A), whereas attaching an acetyl ($COCH_3$) group to histones usually relaxes that part of the DNA strand, making it more accessible for transcription (B)

Exercise 4th edition. Champaign, IL, USA: Human Kinetics. ISBN: 9780736055833

Information aimed at 14- to 16-year-old school students, with an online activity. See the BBC's GCSE Bitesize website (www.bbc.co.uk/schools/gcsebitesize; search for 'effects of training and exercise') or use the direct link: http://tinyurl.com/8xfksl6

'How the body responds to exercise' video on the US Teachers' Domain website (www.teachersdomain.org) or via the direct link: http://tinyurl.com/chvndus

'Where do you get your energy' video on the US Teachers' Domain website (www.teachersdomain.org) or via the direct link: http://tinyurl.com/cfwct6g

The following research articles provide more information about the scientific details:

Booth FW, Gordon SE, Carlson CJ, Hamilton MT (2000) Waging war on modern chronic diseases: primary prevention through exercise biology. *Journal of Applied Physiology* **88(2)**: 774-787

Gollnick PD et al. (1973) Effect of training on enzyme activity and fiber composition of human skeletal muscle. *Journal of Applied Physiology* **34(1)**: 107-111

Norrbom J et al. (2011) Alternative splice variant PGC-1α-b is strongly induced by exercise in human skeletal muscle. *American Journal of Physiology – Endocrinology and Metabolism* **301(6)**: E1092-1098. doi: 10.1152/ajpendo.00119.2011

Norrbom J et al. (2010) Training response of mitochondrial transcription factors in human skeletal muscle. *Acta Physiologica* **198(1)**: 71-79. doi: 10.1111/j.1748-1716.2009.02030.x

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Image courtesy of cszar; image source: Flickr

Acknowledgement

The authors would like to thank Associate Professor Carl Johan Sundberg for providing us with the opportunity to work in his lab and for valuable input on this article.

Maléne Lindholm and Susanna Wallman Appel are carrying out doctoral research on the effects of exercise on human skeletal muscle function and the concurrent health benefits. They both hold masters degrees in biomedicine from the Karolinska Institutet in Stockholm, Sweden, where they also teach physiology.

To learn how to use this code, see page 65.

Creating eclipses in the classroom

During an eclipse, the Sun or the Moon seems to disappear. What is happening? Why not explore this fascinating phenomenon in the classroom, with an easy to build model?

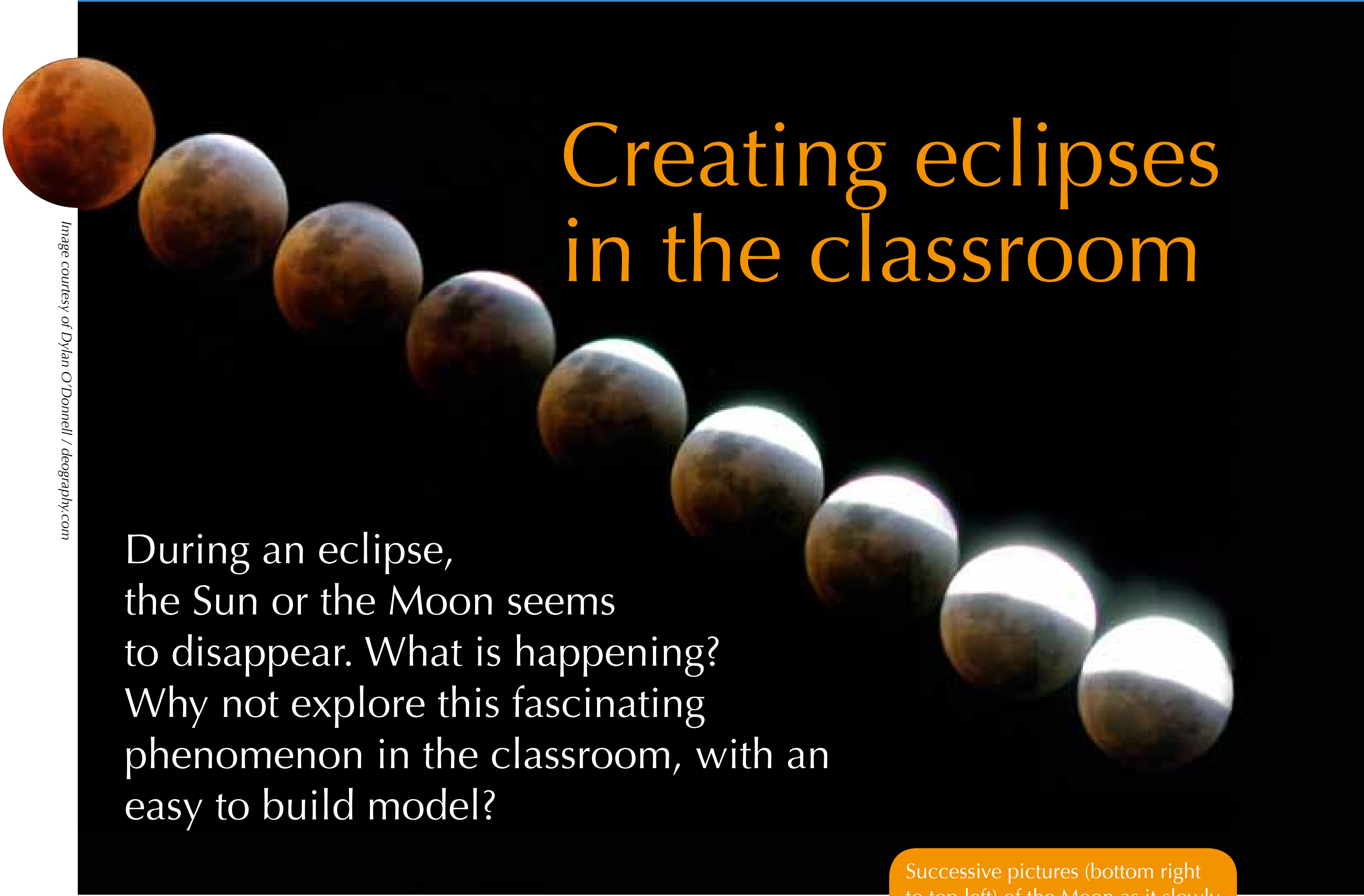


Image courtesy of Dylan O'Donnell / deography.com

Successive pictures (bottom right to top left) of the Moon as it slowly crosses into the shadow of Earth

By Marissa Rosenberg from EU Universe Awareness

Solar and lunar eclipses are astronomical phenomena that have been shrouded in myth and legend throughout history. The ancient Chinese, for example, believed that solar eclipses occurred when a celestial dragon devoured the Sun. The Chinese word for an eclipse, 'chih', even means 'to eat'.

Because eclipses are frequent and can be observed without a telescope, they are an excellent topic for introducing astronomy at school. This article describes a simple activity to help students aged 6-14 to understand eclipses, our Solar System and the motion of Earth and the Moon within it. The students begin by building and using their own model of the Sun, Moon and Earth. To consolidate and expand on what they have learned, the UNAWE project[w1] – an astronomy programme that fosters universe awareness – then enables the students to work with other schoolchildren around the globe. What time of day is it for them? What season? What can they see in the sky at a particular moment?

Lunar eclipses

Although the Moon appears brightly in the night sky, it does not in fact shine but simply reflects the light from the Sun. The shape of the Moon that you see depends on both where you are on Earth and where the Moon is in its orbit around Earth. Every month the Moon completes a cycle, starting as a complete circle (at full moon), shrinking to become almost invisible (at new moon), then swelling to a full circle again; these stages are called the phases of the Moon (figure 1). To learn more, see Mitchell et al., 2008.

Usually, when the Moon is on the far side of Earth from the Sun (figure 1B), the three bodies do not lie in a straight line; instead, the Moon is slightly above Earth and is still illuminated, so we see a full moon. Occasionally, however, Earth passes directly between the Sun and Moon, and the Moon is completely in the Earth's shadow – we call this a lunar eclipse. You can see it with the naked eye, as the Moon enters the Earth's shadow (the *umbra*) and travels across it, taking on a beautiful dim red glow[w2]. As the Moon crosses in or out of the umbra, you can even see the curve of Earth partially shadowing the Moon (see image above). This partial shadow is called the *penumbra*.

REVIEW

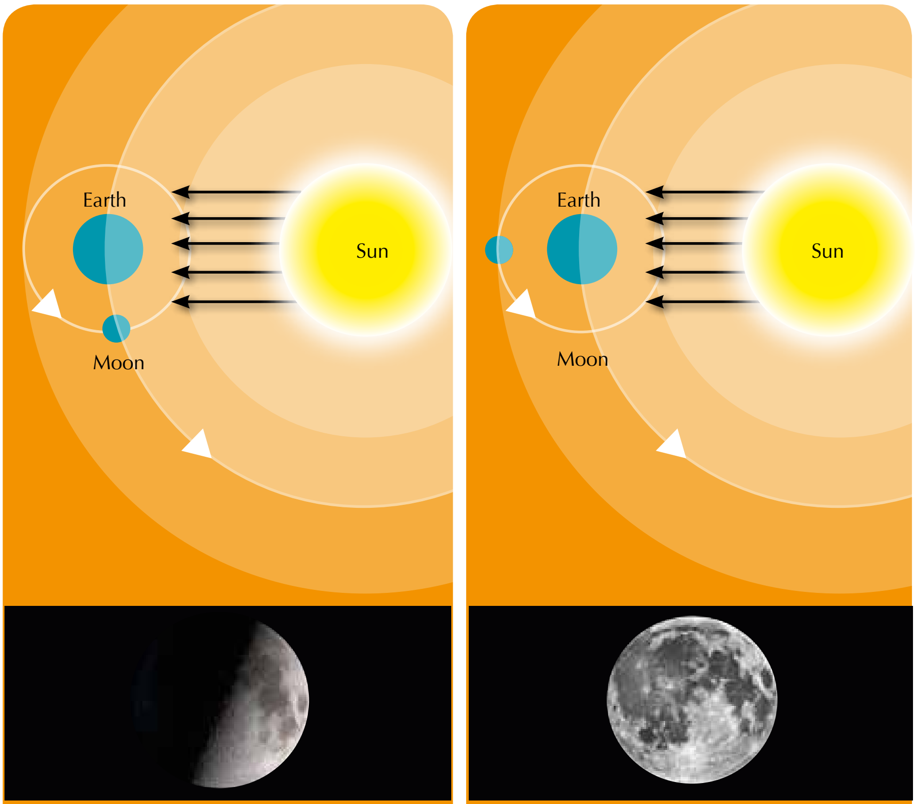
- Physics
- Astronomy
- Earth and space
- Art
- Languages
- Ages 8-14

Eclipses provide an excellent opportunity for students to understand how day, night and the seasons are affected by our position on Earth relative to the positions of the Sun and Moon. This article describes hands-on activities in which the students build a model of Earth, the Moon and the Sun to show lunar and solar eclipses. Models of heavenly objects serve to bring fascinating phenomena closer to the learner and enable students to make sense of an otherwise mysterious sky.

The article also raises the possibility for students in different countries to link via video conferencing with other classes around the world and thus better understand how what we see in the sky at any one point is affected by where we are on Earth. Students learn best when they feel that they own the experience. In this way both the receiver and transmitter experience the learning in context.

Angela Charles, Malta

Images courtesy of Marissa Rosenberg (diagrams) and NASA (Moon images)



A: At this stage of the Moon's orbit around Earth, if it is night-time for you on Earth, you can see only half of the illuminated (day) side of the Moon. Thus the Moon appears as a semi-circle

B: At this stage of the Moon's orbit around Earth, if it is night-time for you on Earth, you can see the whole of the illuminated (day) side of the Moon. Thus the Moon appears as a complete circle (full moon)

Figure 1: The phases of the Moon. The circles represent the orbits of Earth around the Sun and the Moon around Earth. The shaded areas represent darkness: at any one time, one-half of Earth and one-half of the Moon are illuminated by the Sun

Solar eclipses

Unlike lunar eclipses, solar eclipses are very rare. Most people will never see one because solar eclipses are only visible from relatively small areas of Earth at any one time. Solar and lunar eclipses have somewhat different causes: during a solar eclipse, *we* are in shadow. When the Moon passes exactly in front of the Sun, it casts a shadow on Earth. Because the apparent size of the Moon is so much less than that of the Sun, this shadow will only be seen in a small area of Earth. To understand this, hold your thumb in front of the Sun so that it is completely covered. Your eyes are in the shadow of your thumb, but it does not affect the person standing next to you, as they are not in the same shadow. They see the Sun as normal. Once the Moon moves directly between Earth and the Sun[w3], the sky takes on a spooky twilight, which causes animals to become confused. The air cools and, during a total eclipse, the Moon appears as a black disk in the sky surrounded by a crown of fire. That fire is actually the Sun behind the Moon; as the Moon passes, the full burning light of the Sun returns.

Eclipses in the classroom

Building the Sun-Earth-Moon system described below will allow your class to discover how and why eclipses happen. They will be able to understand exactly what they are seeing if ever they see a real eclipse. Building the model, which is not to scale, takes about 45 minutes.

Materials

For each model, you will need:

- Adhesive tape
- Glue
- Two cardboard tubes (e.g. empty toilet rolls)
- Torch
- Scissors (suitable for cutting cardboard)
- Aluminium foil
- Sturdy but bendable wire (35-50 cm long)
- Styrofoam ball the size of a large orange
- Ping pong ball (or a Styrofoam ball of a similar size)
- Large strip of cardboard (about 60 cm in length and no less than 20 cm in width)
- Stack of books or magazines

Image courtesy of Marissa Rosenberg

Step 3: making the base to support Earth

Image courtesy of Marissa Rosenberg

Step 5: Placing Earth on its base

Image courtesy of Bill Livingston, NSO / AURA / NSF

Three-quarter solar eclipse observed at the Kitt Peak Vacuum Telescope on 10 June 2002

Image courtesy of Bill Livingston, NSO / AURA / NSF

The 'diamond ring' effect occurs when only a tiny sliver of the Sun is visible around the Moon during a total solar eclipse

Method

1. Divide the class into groups of three or four. Give each group their own materials to make the model.
2. Take one cardboard tube and make a series of small (2 cm) even, vertical cuts around the circumference of each end.
3. At each end, bend the cut pieces out, then stand the tube upright. At the top, the cut edges should fan out like a flower (see image).
4. Using adhesive tape, fasten one end of the cardboard tube to the strip of cardboard; this is the base of the model. The tube should be at least 30 cm from one end of the cardboard strip.
5. Using tape or glue, attach the larger ball to the open flower of the tube. This ball is Earth.
6. Cover the smaller ball with aluminium foil, shiny side out. This is the Moon.
7. Insert one end of the wire into the top of Earth, so that the wire is vertical.
8. Measure a finger's length along the wire. Bend the wire at a right angle to give a horizontal arm.
9. Insert the other end of the wire into the Moon.
10. About halfway between Earth and the far end of the cardboard strip, measure a finger's length along the wire and bend it downwards at a right angle, toward the cardboard base. The Moon's equator should be at the same height as Earth's equator.
11. Balance the torch on a stack of books or magazines at the other end of the cardboard strip from Earth. Make sure the height is correct: the middle of the torch beam should hit Earth's equator. If the beam is too diffuse, attach the second cardboard tube to the end of the torch to direct the light

Images courtesy of Marissa Rosenberg

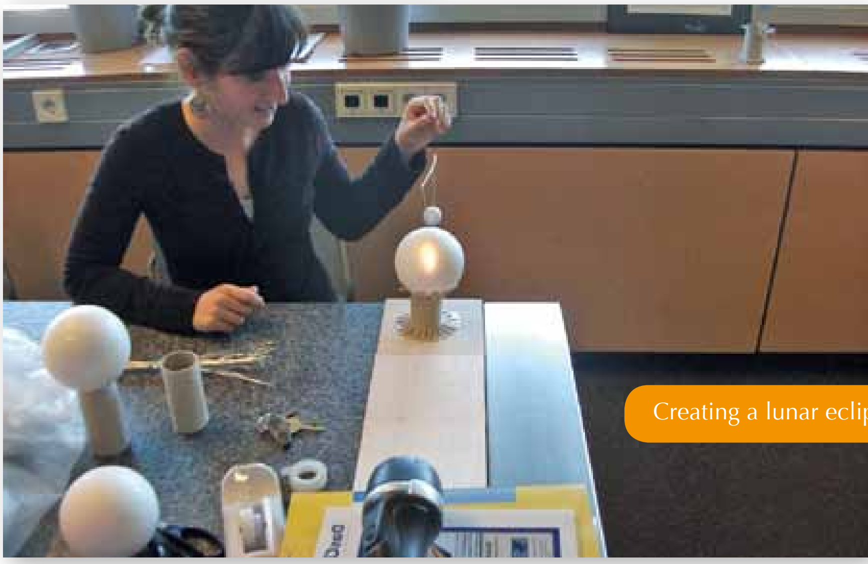
Step 10: Bending the wire so that the equators of the Moon and Earth are at the same height

Step 11: Adjusting the Moon and Sun so that the light from the Sun hits Earth's equator and the Moon can directly block the Sun's rays from reaching Earth

Creating a solar eclipse

Image courtesy of NSO / AURA / NSF

The delicately structured glow of the solar corona, as seen during the total eclipse of the Sun on 7 March 1970. The corona is visible to the naked eye only during an eclipse



Creating a lunar eclipse

horizontally. Ensure the beam hits the nearest half of Earth and the Moon directly. If the beam is not bright enough, move the stack of books closer.

Using the model

Duration: 30-45 minutes.

1. Ask your students if they have ever seen an eclipse. Was it a solar or a lunar eclipse[w4]? Explain that solar eclipses are much rarer but today they will be lucky enough to see both.
2. Create a solar eclipse. Stand facing the torch and swing the wire around until the Moon casts a shadow on Earth; if necessary, dim the lights. The Moon is now between Earth and the Sun and is blocking the sunshine for some people on Earth. Point out that only people directly in the shadow see a complete eclipse of the Sun.

   You can show how the shadow moves by slowly rotating the wire.
3. Now create a lunar eclipse. Stand facing the torch and swing the wire so that the Moon is behind Earth. No light should be hitting the Moon: Earth is between the Sun and the Moon, casting a shadow over the entire Moon. Explain that unlike during the solar eclipse, the entire 'night side' of Earth can see the lunar eclipse.

International collaboration

Collaborating with other schools worldwide can help your students to understand the subject even better.

1. Contact UNAWE[w1] to facilitate a Skype session with a school class in another part of the world. UNAWE will strive to connect schools that speak the same language.
2. Put the students in your class in pairs; they will speak to a pair of students from the partner class.
3. Ask each pair of students to make a list of five relevant questions to ask their international partners. The first two questions could be:

   Ages 6-10:
   - What does the sky look like to you right now? What time is it?
   - Do you know any stories or legends about why eclipses happen?

   Ages 10-14:
   - Are there any superstitions in your culture about eclipses?
   - If there was a lunar eclipse, could we both see it at the same time? What about a solar eclipse? [The answers will depend on the location of the two countries involved.]
4. During the Skype session, the pairs of students can take turns to ask each other their questions and record the answers.
5. After the Skype session, your students can present their international partners and their answers to the rest of the class.

Discussion

Ages 6-10:

During a lunar eclipse:

- Which bright object is in shadow? Which object is casting the shadow?
- Does everyone in the world see it? Who can't see a lunar eclipse?

During a solar eclipse:

- Which bright object is covered up? Which object is blocking the sunlight?
- Does everyone in the world see it? Who can't see a solar eclipse?
- Draw a picture showing the positions of the Moon, Earth and Sun during a lunar and a solar eclipse. (Use the model to help.)
- Do you see lunar eclipses at night or during the day? What about solar eclipses?
- Why are solar eclipses so much rarer than lunar eclipses?

Ages 10-14:

- During a solar eclipse, what would you see if you stood on the Moon and looked at Earth?
- What is the phase of the moon during a solar eclipse? And during a lunar eclipse?
- Why don't we see a lunar eclipse during every full moon?
- Do other planets have eclipses?

Reference

Mitchell WA et al. (2008) Science for the Next Generation: activities for primary school. *Science in School* **10**: 64-69. www.scienceinschool.org/2008/issue10/nextgeneration

Web references

w1 – UNAWE is an astronomy programme to educate and inspire young children around the world. To learn more and get in touch, visit: www.unawe.org

w2 – For a video explanation of why the Moon looks red during a lunar eclipse, see www.bbc.co.uk/news/science-environment-13787011 or use the shorter link: http://tinyurl.com/7v6vxxy

w3 – For more information about how solar eclipses occur, see: www.mreclipse.com/Special/SEprimer.html

w4 – For a comparison of lunar and solar eclipses, see: www.moonconnection.com/lunar_vs_solar.phtml

Resources

For another classroom activity to model an eclipse, using fruit, see the website of the Lunar and Planetary Institute (www.lpi.usra.edu; search for 'fruit loops') or use the direct link: http://tinyurl.com/cz8xxmu

Lunar Eclipse 2105 is a fun, scientifically accurate story of an eclipse being viewed from our Moon by a young boy. It could be a good starting point for other lunar eclipse activities. See the website of NASA Science (www.science.nasa.gov) or use the direct link: http://tinyurl.com/2ctfkct

For photographs and information about the lunar eclipse of 15 June 2011, which could be seen all over Europe, see: http://eaae-astronomy.org/blog/?cat=38

To find out how two school students investigated and observed an eclipse in a prize-winning project, see:

Pathmanathan P (2007) Students Catch a Star: researching and observing a solar eclipse. *Science in School* **7**: 39-44. www.scienceinschool.org/2007/issue7/catchastar

If you found this article useful, you may like to browse the other astronomy articles in *Science in School*. See: www.scienceinschool.org/astronomy

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Marissa Rosenberg graduated in astrophysics from the University of California, Los Angeles (UCLA), USA, then completed a master's degree at the International Space University in Strasbourg, France. She is currently working on her PhD in astrophysics at Leiden Observatory in the Netherlands.

Marissa is involved with EU Universe Awareness, writing astronomy articles for children. She has also completed three years of science teacher training through the California Teach programme at UCLA.

To learn how to use this code, see page 65.

Building a seismograph from scrap

Did you know that you can use old hi-fi speakers to detect earthquakes? And also carry out some simple earthquake experiments in the classroom? Here's how.

By Panteleimon Bazanos

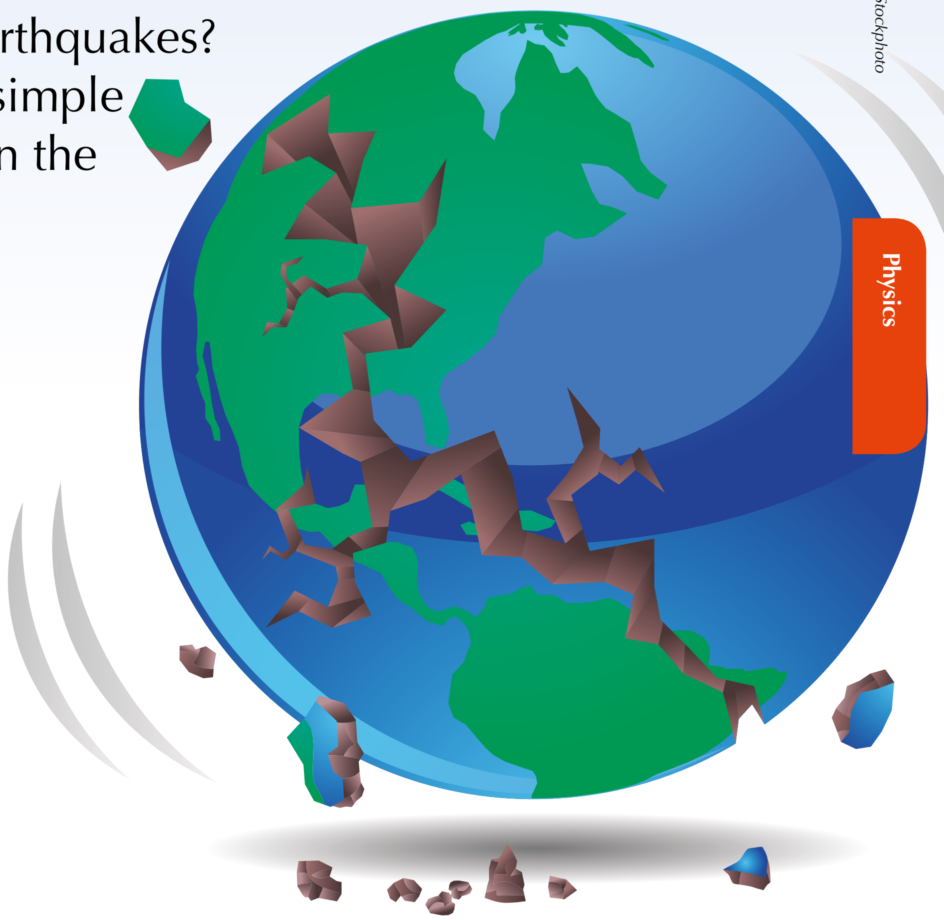


Image courtesy of jeffreyw / iStockphoto

Physics

Earthquakes occur around the world all the time. In 2011, the earthquakes that caused the Fukushima disaster in Japan, killed thousands in Turkey and devastated New Zealand's capital city made the headlines. But did you know that 2011 also saw earthquakes in Finland, Belgium and the Czech Republic?

Some earthquakes may be so slight as to be practically unnoticeable, but they can still be recorded. Each tremor produces different types of vibration, or seismic waves, which travel through Earth's interior with different velocities. These waves can be detected and recorded by instruments called seismographs, which are often sited at great distances from the earthquake. By measuring the time that the seismic waves take to arrive at seismographs, as well as recording the amplitude and duration of the waves, we can calculate the magnitude of the earthquake and determine its epicentre.

Monitoring local earthquakes

Earthquakes are a daily occurrence in Greece (figure 1), sitting as it does at the boundary of two tectonic plates. The district of Messinia, where our school is located, has a history of major earthquakes. In 1886, a severe earthquake of

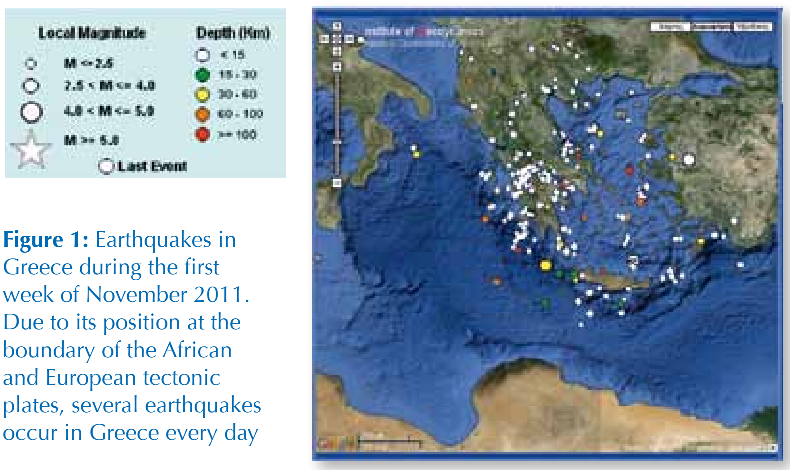


Figure 1: Earthquakes in Greece during the first week of November 2011. Due to its position at the boundary of the African and European tectonic plates, several earthquakes occur in Greece every day

Image courtesy of Panteleimon Bazanos; data source: the automated alert system of the Institute of Geodynamics at the National Observatory of Athens

Image courtesy of Panteleimon Bazanos; data source: the automated alert system of the Institute of Geodynamics at the National Observatory of Athens

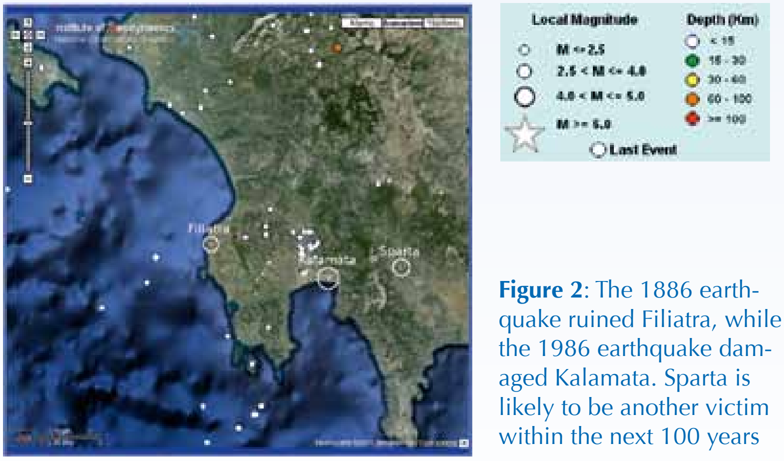


Figure 2: The 1886 earthquake ruined Filiatra, while the 1986 earthquake damaged Kalamata. Sparta is likely to be another victim within the next 100 years

Image courtesy of Nicola Graf

magnitude 7.5 on the Richter scale struck Filiatra[w1] (figure 2). A century later, Kalamata was hit by another strong earthquake[w2], this time of magnitude 6.0. Within the next 100 years, it is predicted that Sparta will be struck by an earthquake[w3] of at least magnitude 7.0.

To encourage my students to learn about earthquakes, I acquired and set up a commercial, educational seismograph in our school (figures 3 and 4), the General Lyceum of Filiatra. The seismograph is based on an array of three geophones – devices that respond to the seismic waves and convert them to electrical signals. Each of the three geophones monitors waves

REVIEW

- Earth science
- Physics
- IT
- Electrical engineering
- Acoustics
- Seismology
- Ages 16-19

In 2011, an earthquake caused an environmental disaster by damaging the nuclear power plants in Fukushima, Japan. This article briefly describes the mechanism of earthquakes and especially the propagation of the different waves running through Earth. These waves can be measured with seismographs.

The author describes how you and your students can build your own seismograph using an adapted loudspeaker and audio software. This would be an interesting project in physics (acoustics, acoustic-converter, induction, the mechanical properties of springs), earth science (earthquakes and their classification), or electrical engineering (practical work) lessons. It could also be used in IT lessons (analysing the audio signal and how audio software works; using database software to build a earthquake database).

If you have too little seismic activity in your region to make it worth building your own seismograph, you could visit the suggested websites to download earthquake data to analyse with your students. And of course you could still carry out the earthquake-simulation experiments that the author describes.

The article stimulates questions like:

- What is an earthquake? What can you find out about severe earthquakes in your area?
- How do earthquake waves travel through Earth?
- What is a seismograph and how does it work?
- How do loudspeakers work, and why and how can they be used for earthquake detection?
- What are the basic electrical laws to consider when using a loudspeaker as a microphone or geophone? How do you get a voltage out of them?

Gerd Vogt, Higher Secondary School for Environment and Economics, Yspertal, Austria

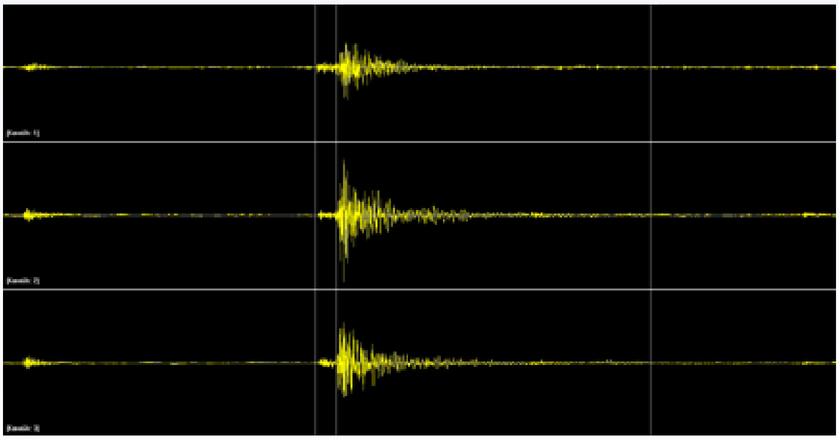


Image courtesy of Panteleimon Bazanos; image source: Seismic Logger, Helicorder and Dataviewer software, Seismology Laboratory of the University of Patras

Figure 3: A three-channel seismogram from our commercial seismograph, showing the start times of the primary (P) and secondary (S) waves and the vibration end time (C).

Primary waves are compressional longitudinal waves[w4] that are the first to arrive at the seismograph. They can travel through solids or fluids – in air they take the form of sound waves, travelling therefore at the speed of sound (340 m/s). In water they travel at about 1450 m/s and in granite at about 5000 m/s. Secondary waves are shear transverse waves, arriving at the seismograph after the primary waves and displacing the ground in a direction perpendicular to the direction of propagation. They do not travel through liquids or gases, travelling through solids at speeds of about 60% of those of primary waves.

The epicentre distance (in km) and the earthquake magnitude (measured on the Richter scale) are calculated according to the formulae

$$\text{distance} = p_1 \cdot (t_s - t_p)$$

and

$$\text{magnitude} = p_2 \cdot \log_{10}(t_c - t_p) + p_3 \cdot \text{distance} - p_4$$

where p_1, p_2, p_3, p_4 are constants that depend on the types of rock that the earthquake passed through. Default values are $p_1 = 7.6$, $p_2 = 2.31$, $p_3 = 0.0012$, $p_4 = 1.0$. Three time measurements (in seconds) are needed: the time that P waves arrive (t_p), the time that S waves arrive (t_s) and the time that vibrations end (t_c)

in the up-down, east-west or north-south directions. The three signals are then processed by computer, allowing the magnitude of the earthquake and the distance from the epicentre to be calculated (figure 3).

Building a seismograph

I also wanted to encourage the students to think about the technology that is used to detect and measure earthquakes and to understand what each component does, rather than viewing a seismograph as a 'black box'. To this end, we build our own seismograph, with which we can detect local earthquakes – up to 100-200 km away, depending on their magnitude.

At the heart of any seismograph are the geophones. They convert the ground vibrations into electrical signals using a coil that moves relative to a magnet, producing an electrical voltage at the end of the coil (Faraday's law; figure 4). To build our seismograph, we used everyday technology as the geophone: a loudspeaker. Normally, loudspeakers operate by converting an electrical signal into the relative movement of a coil and a magnet, which causes the cone to move in and out, thus generating vibrations: sound waves (figure 5). By making them operate the other way round – turning vibrations into electrical signals – they can be made to function as geophones.

To make our geophone, we used a 'woofer' – a speaker for low-pitched sounds – because woofers are designed to work well for low frequencies, and seismic waves are of course low-frequency vibrations. To minimise interference from sound vibrations, we removed the cone of the loudspeaker.

To complete our geophone (figure 6), we also used a weight, a spring and the lid of a spray can. The weight serves to increase the inertia, as the loudspeaker coil itself is very light. Placing a weight directly onto the coil would damage it, so we used the

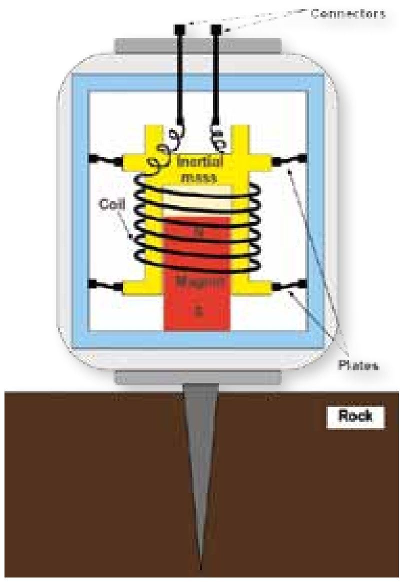


Image courtesy of Panteleimon Bazanos

Figure 4: How a geophone works. When the ground vibrates, the mass with the coil attached to it moves relative to the magnet. The potential difference produced in the connectors depends on the way the ground vibrates

Image courtesy of Iain Fergusson; image source: Wikimedia Commons

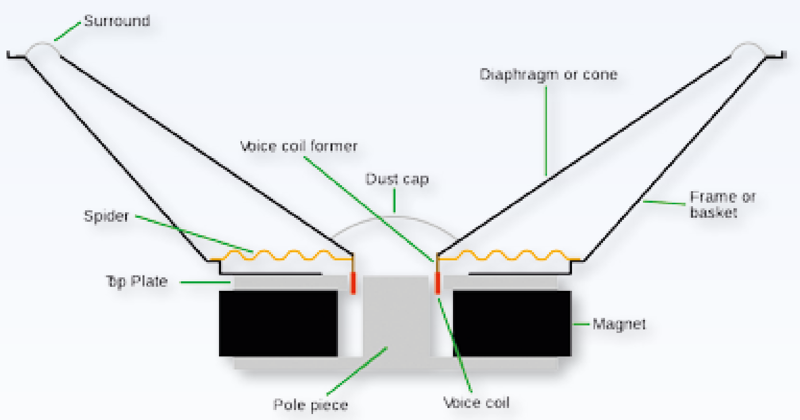


Figure 5: How a loudspeaker works. As the function of loudspeakers is based on the relative movement of coil and magnet, we can use them to detect ground vibrations. These vibrations move the coil relative to the magnet, producing a potential difference between the coil's connectors. This electrical signal is recorded by the computer via the sound card, in the same way as input from a microphone would be[w5]

Image courtesy of Panteleimon Bazanos

Figure 6: Our homemade geophone

spring to hold the weight over the coil, allowing it to oscillate. The lid protected the coil. We then plugged our woofer geophone into the sound-card port of a computer, and recorded the signals using sound-editing software, creating a working seismograph.

Detailed instructions for building our seismograph can be downloaded from the *Science in School* website[w6].

Now it's your turn

If you are interested in monitoring and investigating seismic activity in the classroom, you could:

1. Monitor and analyse data from existing seismographic stations[w7,w8].
2. Use a commercial, educational seismograph.
3. Construct your own seismograph, using the downloadable instructions on the *Science in School* website[w6].
4. Carry out some simple experiments to simulate and investigate the physics of earthquakes (see below).

To record earthquakes with either a commercial or a homemade seismograph, you will need to be relatively close to their epicentres. Our homemade seismograph detected earthquakes up to 100-200 km away[w9], depending on magnitude. With our commercial seismograph[w10], we detected earthquakes of 4.0 on the Richter scale from 500 km away.

Options 1 and 4 have the advantage of being feasible even in regions with very little seismic activity.

Looking for earthquakes

The coil of the homemade seismograph is very sensitive, so the geophone must be handled with great care. For the best measurements, set up the seismograph somewhere quiet and free from vibrations, perhaps in the school cellar. However, to encourage student participation, I set mine up in the classroom.

Once you have set up your seismograph, let it record continuously for one or two days, then save the data in a file. Before you can search for earthquakes in the data, you will need to do some processing. The exact details of the processing will depend on the software you use, but it should be fairly straightforward.

1. Remove any *DC offset*, to remove the contribution of any DC current to the signal.
2. Amplify the low frequencies (below 100 Hz). This is the range in which you will detect earthquakes.
3. Remove background 'noise' (thermal noise, electronic noise, etc.) to make the signal clearer.
4. After that, you can search the data for patterns that indicate an earthquake.

Not all signals recorded by seismographs are earthquakes. Other, more local sources, including traffic, wind, explosions and opening and closing doors, can cause confusion. Earthquakes often have a characteristic pattern: a small waveform followed by a large one (see figure 3). Because this is not always the case, however, you and your students may sometimes be unsure if what you have detected really is an earthquake. The only way to be certain is to do what professional seismologists do and compare your data with the recordings made at other seismographic stations[w7,w8].

When you are confident that you have detected an earthquake, you can calculate its magnitude (on the Richter scale) and your distance (in km) from the epicentre (figure 7). For that, you need only three measurements: the arrival time (in seconds) of the P and S waves, and the time at which the vibrations stop (see figure 3). For more details, download the instructions from the *Science in School* website[w6].

Image courtesy of Panteleimon Bazanos

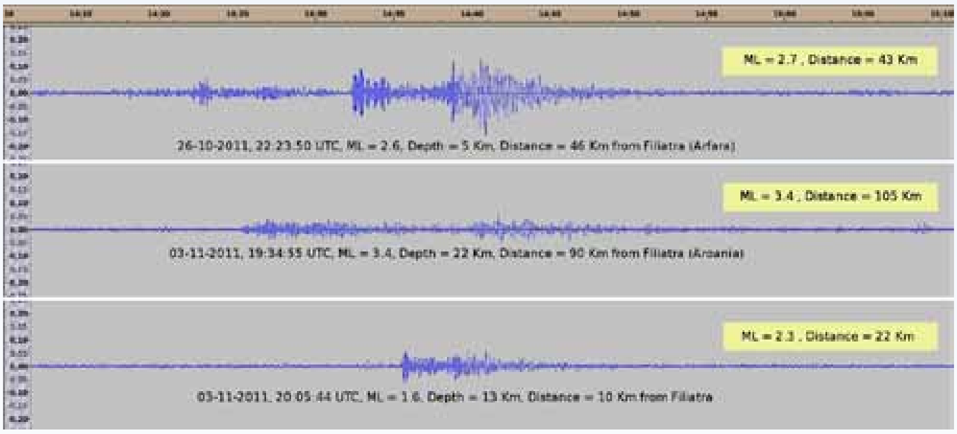


Figure 7: Earthquake signals recorded with our homemade seismograph. The values in the yellow boxes were calculated from the homemade seismograph data, while the values under the signals are from the reports of the Institute of Geodynamics of National Observatory of Athens. ML stands for local magnitude (ML) on the Richter scale

Vibration experiments using computer speakers

I also devised some experiments to simulate some aspects of earthquakes and the signals they produce – for example, how the energy of the earthquake decreases as it passes through different materials.

To do this, we used speakers and a computer equipped with a sound card and audio processing software, as before. But in place of geophones you can use old computer speakers (again with the cone removed), which can be moved around as needed in the experiments (figure 8). You can use 100W / 8Ω woofers, as in the construction of our seismograph, or 3W / 8Ω computer speakers, plus the sound-editing software Audacity[w11]. For more details, see steps 1, 8 and 9 in the downloadable instructions[w6].

The experiments involved dropping balls from different heights (representing different energies) at different distances from the detectors (the speakers), onto surfaces made from various solid materials. When the ball strikes the hard surface, it produces vibrations that travel through the solid – just as an earthquake produces waves that travel through Earth.

Experiment 1: The power of a shake

This activity demonstrates the relationship between earthquake power and ground movement. We caused vibrations on a piece of marble (or wood, plastic or even the ground) by dropping a mouse ball (from a computer mouse) from different heights, producing different ground-shaking powers. The amplitude of the signal depends on the power of the shake.

Image courtesy of |Chris|; image source: Flickr

1. Set up the equipment as shown in figure 9A.
2. Drop the ball from different heights, recording the signal amplitude (figure 10) in table 1. It is not important exactly what distance from the speaker you drop the ball, but make sure you drop it onto the same spot each time.
3. Plot a graph of amplitude against height.
4. Discuss the graph. Your students should conclude that the more energy is released, the more the ground vibrates.

Experiment 2: Energy attenuation

This activity demonstrates the energy attenuation (decrease) as seismic waves travel through Earth's crust. We produced vibrations by dropping a 4 kg shot put (metal ball) on the ground from the same height but at different distances from the woofer geophone or loudspeaker. As the waves travel, they lose energy and the ground vibrates less. This is reflected in the amplitude of the signals.

Image courtesy of Panteleimon Bazanos

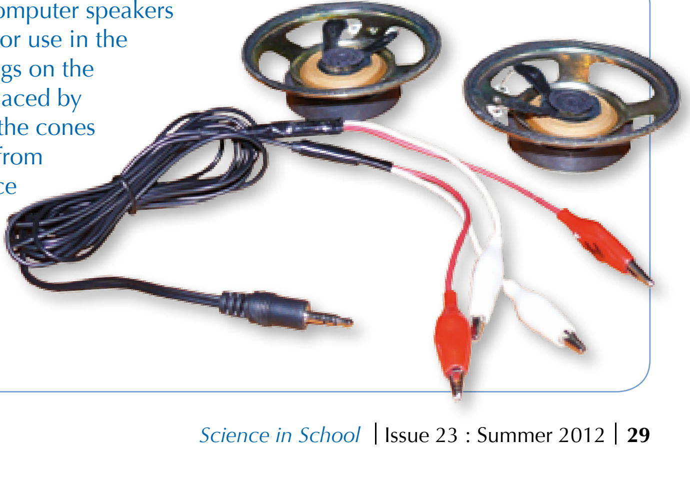


Figure 8: A pair of computer speakers and cable modified for use in the experiments. The plugs on the cable have been replaced by crocodile clips, and the cones have been removed from the speakers to reduce interference from sounds travelling through the air

Physics

Image courtesy of Panteleimon Bazanos

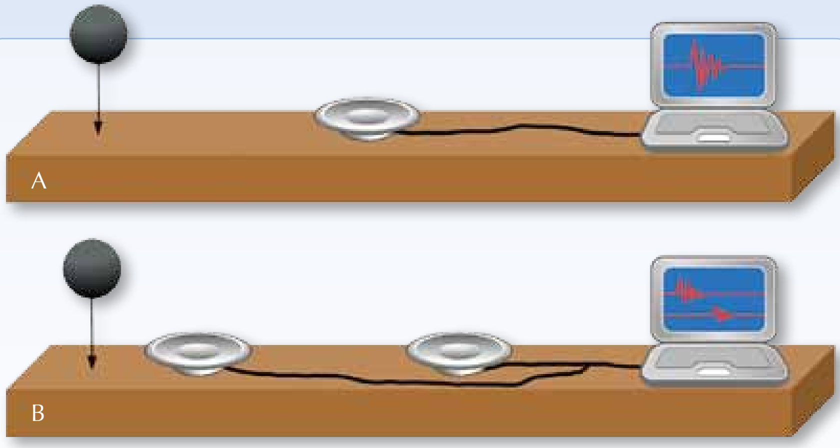


Figure 9: Two set-ups for the experiments, using one (A) or two (B) speakers

Image courtesy of Panteleimon Bazanos

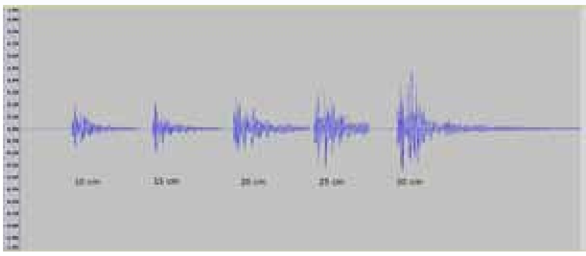


Figure 10: The signals recorded in experiment 1. The signals were amplified by a factor of 10

Table 1: Enter your results for experiment 1

Height (cm)	10	15	20	25	30
Signal amplitude					

Image courtesy of Panteleimon Bazanos

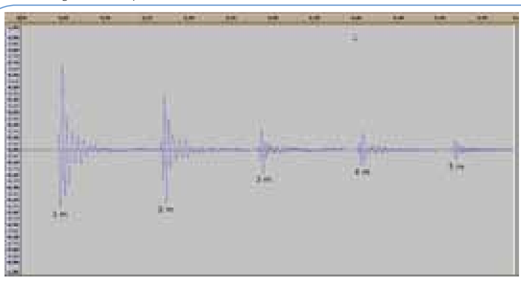


Figure 11: The signals recorded in experiment 2. The signals were amplified by a factor of 4

Table 2: Enter your results for experiment 2

Distance from geophone (m)	1	2	3	4	5
Signal amplitude					

1. Set up the equipment as shown in figure 9A.
2. Mark 5 distances of 1 m intervals from the woofer geophone or loudspeaker along the ground.
3. Let the ball fall from the same height (e.g. 1 m) onto the ground at each marked distance, recording the results (figure 11) in table 2.
4. Plot a graph of amplitude against distance.
5. Discuss the graph. Your students should conclude that the farther away the 'earthquake' is, the less the ground vibrates.

Experiment 3: Wave velocity in different media

In this activity, we investigate wave velocities in different media. As seismic waves travel through Earth, their velocity differs depending on the composition of the rocks they are travelling through. This gives seismologists and geologists important information about Earth's interior. Here, we investigate how fast vibrations travel through different solid materials.

We used wood, iron and marble as the materials, but any hard solid can be used. Just make sure you have the various materials available in a size suitable for the activity.

1. Set up the equipment as shown in figure 9B. We used a distance (x) of 80 cm between the speakers.
2. Drop a mouse ball (or other suitable object) onto the first solid material, close to one speaker, but not between the speakers. Record the times for the signal to reach each speaker (t_1, t_2).
3. Repeat with the other materials, entering each result in table 3. Work out the wave velocities using the formula: $v = x / (t_2 - t_1)$
4. Discuss the results. In which material do the waves travel fastest?

Web references

w1 – To learn more about the 1886 earthquake in Filiatra, see: www.

Table 3: Enter your results for experiment 3

Material	t_1	t_2	t_2-t_1	x	$v = x / (t_2 - t_1)$
Wood					
Iron					
Marble					

oasp.gr/node/666 (in Greek, with automated translation into English)

w2 – For more information about the 1986 earthquake in Kalamata, see: www.oasp.gr/node/672 (in Greek, with automated translation into English)

w3 – For an interview (in Greek) with Professor Dimitrios Papanikolaou of the University of Athens, in which he discusses the expected earthquake in Sparta, see: www.youtube.com/watch?v=ukP4KKiblhA

w4 – For an interactive 3D seismic wave simulation, showing primary, secondary and surface waves, see the ForgeFX website: www.forgefx.com (select 'showcase') or use the direct link: http://tinyurl.com/6l6n3gm

w5 – To learn how loudspeakers can act as microphones, see: http://en.wikipedia.org/wiki/Microphone

w6 – Detailed instructions for building your own seismograph can be downloaded from the *Science in School* website: www.scienceinschool.org/2012/issue23/earthquakes#resources

w7 – To monitor the current seismic activity in Greece, see the website of the Institute of Geodynamics: http://bbnet.gein.noa.gr/NOA_HL

w8 – The Seismographs in Schools programme aims to create an international educational seismic network; already nearly 400 schools have joined. From the website, you can view and (if you have .sac file-viewing software) download seismographic data collected by other schools around the world, searching for specific earthquakes, or for schools or data in particular countries or regions. The website also includes tools to share your own seismic data in real-time, classroom activities. See: www.iris.edu/hq/sis

w9 – For local earthquakes (within 0-100 km), the vast majority of the energy will be in the frequency band 1-50 Hz, but there should still be enough energy to detect vibrations of 50-100 Hz. For more distant earthquakes, the energy content will be much lower: the energy from earthquakes originating in the Pacific rim will be in the frequency range 0.05-1 Hz by the time it reaches Europe. Unfortunately, computer soundcards have filters that limit the frequencies detected to above 40-60 Hz, thus limiting the ability of your homemade seismograph to detect distant earthquakes.

One alternative is to construct a simple mechanical seismometer and then interface it with a specially designed (but relatively affordable) seismic digitiser. For more details, see: www.bgs.ac.uk/schoolSeismology/seismometers.html

w10 – Our commercial seismograph, model GES-24A from the Industrial Systems Institute (ISI), cost around 1000 €; ISI will shortly launch a newer model costing around 600 €. ISI also has a website where schools can exchange their data. See: www.isi.gr/modseism

The Seismographs in Schools website has a useful list of other educational seismographs. See: www.iris.edu/hq/sis

Physics

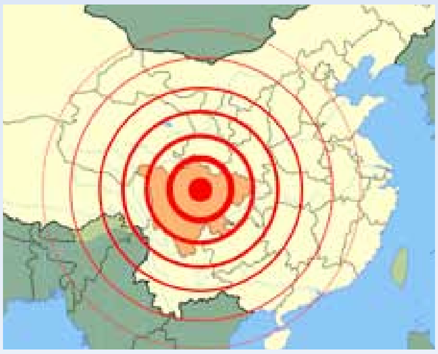
Fires and destruction caused by the 1906 San Francisco earthquake. It is estimated that this famous earthquake killed more than 3000 people

Image courtesy of Durova; image source: Wikimedia Commons

Image courtesy of Shazster; image source: Flickr

Damage caused by the 2011 earthquake in Christchurch, New Zealand

Image courtesy of Mistman123; image source: Wikimedia Commons



Map showing the epicentre of the 2008 earthquake in China's Sichuan province. The earthquake killed an estimated 68 000 people

Image courtesy of Tubbi; image source: Wikimedia Commons

Earthquake damage to a pavement

w11 – To download Audacity and learn the basics of digital processing, see: http://audacity.sourceforge.net

Resources

On the website of Natural Resources Canada, there is a brief introduction to seismographs and how they function. See: http://earthquakescanada.nrcan.gc.ca/info-gen/smeters-smetres/seismograph-eng.php or use the shorter link http://tinyurl.com/74ql2f7

To learn about earthquake-measuring scales, see About.com (www.about.com; search for 'earthquake magnitudes') or use the direct link http://tinyurl.com/cvwpj9q

For a compact and comprehensive guide for budding seismologists, see the website of Michigan Technological University: www.geo.mtu.edu/UPSeis

For a visual representation of recent earthquakes, see the world seismic monitor: www.iris.edu/seismon/

For another seismograph to build at school, this one based on an ancient Chinese design, see:

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

For a collection of teaching ideas for seismology, see the website of the UK's National STEM Centre (www.nationalstemcentre.org.uk) or use the direct link: http://tinyurl.com/ccbbnvm

The materials are free but you need to register on the website to download them.

To learn how to use geographical information systems to analyse earthquakes, see:

Kerski J (2010) GIS: analysing the world in 3D. *Science in School* **15**: 34-38. www.scienceinschool.org/2010/issue15/gis

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

For more teaching ideas about earthquakes, see the education web pages of the Incorporated Research Institutes for Seismology (www.iris.washington.edu; search for 'education outreach') or use the direct link: http://tinyurl.com/y6lq9s4

For further ideas, see 'How to teach natural hazards in school: raising awareness on earthquake hazard' from the EU-funded Eduseis project. The PDF can be downloaded from the European Commission website (http://ec.europa.eu/research/environment/pdf/how_natural_hazards.pdf) or via the shorter link http://tinyurl.com/bqvkpnz

Increasing numbers of schools are becoming involved in recording seismic data themselves. To strengthen the links between such schools in Europe, teachers are invited to apply for the second European summer school in school seismology. To be held in Summer 2013 in France, it is funded by EU Comenius grants to teachers. To find out more, visit www.bgs.ac.uk/schoolseismology/EUworkshop.html

If you found this article inspiring, why not browse all the science education projects in *Science in School*. See: www.scienceinschool.org/projects

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Panteleimon Bazanos has a degree in chemistry and has taught secondary-school science in the private and public education sectors in Greece for around 25 years. For the past five years, he has taught chemistry and physics at the General Lyceum of Filiatra. He has been involved in many school projects on environmental education.

To learn how to use this code, see page 65.

Image courtesy of madlyinlovewithlife; image source: Flickr

A block of fresh yeast

Image courtesy of Hellahulla; image source: Wikimedia Commons

Colonies of yeast growing on agar

Image courtesy of Lilly_M; image source: Wikimedia Commons

General science

Primary

REVIEW

- Chemistry
- Domestic science
- History
- Ages 10-15*

This article proposes interesting and novel activities for primary school, combining chemistry, history and cooking – teaching about microbes within the framework of bread-making. Although the author recommends the activity for 9- to 11-year-olds, I am sure that younger secondary-school students would also love to play the game, experiment with yeast and go one step further to prepare their own bread.

Christiana Nicolaou, Cyprus

*Note that the author suggested carrying out the project with students aged 9-11

Bread-making: teaching science in primary school

Something as everyday as bread can offer a surprising spectrum of interdisciplinary teaching opportunities.

By David Lewis

Millennia ago, humans mixed flour and water together to make bread. At some point, a bread-maker was distracted, possibly by a passing sabre-toothed tiger, and returning to the dough hours later, found it was strangely lighter and fluffier. Thus the foundations of leavened bread – bread raised using yeast, a widespread, naturally occurring microbe – were laid[w1].

Image courtesy of seniwati; image source: Flickr

A mouldy orange

In this series of activities for children aged 9-11, we look at the science of bread making and at the helpful microbes involved. Activities 1-4 can be squeezed into an hour but bread-making needs at least half a day, built around activities whilst the bread is proving.

Activity 1: looking at natural microbes

There are many microbes in the world around us, invisible to the naked eye. Like us, they are programmed to survive and reproduce; to do so they feed off natural sugars and proteins wherever they find them and, in the process, cause them to decay. Have you ever reached for an orange and found a ring of white mould with blue-green mould in the centre, or taken cheese out of the fridge to find that a greenish-black mould got there first?

It's easy to go 'fishing for microbes' almost anywhere and you can take your class on a 'fishing trip' by getting them to leave plates of bread, cheese or fruit exposed to the air, in a safe place, and waiting for a few days or weeks. What the students will see is the result of the microbes in the air settling on the food and feeding off sugars and proteins in it, eventually developing fruiting bodies that we call mould.

Safety note: Make sure none of the children has allergies to mould, and remind them not to eat the food or to get too close to the moulds in case they breathe in the spores.

We can watch a faster example of microbes feeding, using baker's yeast – a cluster of yeast microbes that can be seen, smelled and felt. Ask the class to mix a teaspoon of fresh or dried baker's yeast with about 100 ml warm water and sugar and leave it somewhere warm but ventilated. After a short time, the children should be able to observe froth forming on the mixture and to detect a pungent smell. These effects are caused by the production of carbon dioxide and alcohol in a process known as fermentation.

Many children will know that yeast is used to make bread, but how is fermentation involved?

Cut open a loaf of bread or a roll and ask the children to describe what they see. Hopefully they'll say that they see bubbles and that the bread looks like a sponge. Ask them if they can make a link between the bubbles they saw on the fermenting yeast and those in the bread.

Ask the children some more questions:

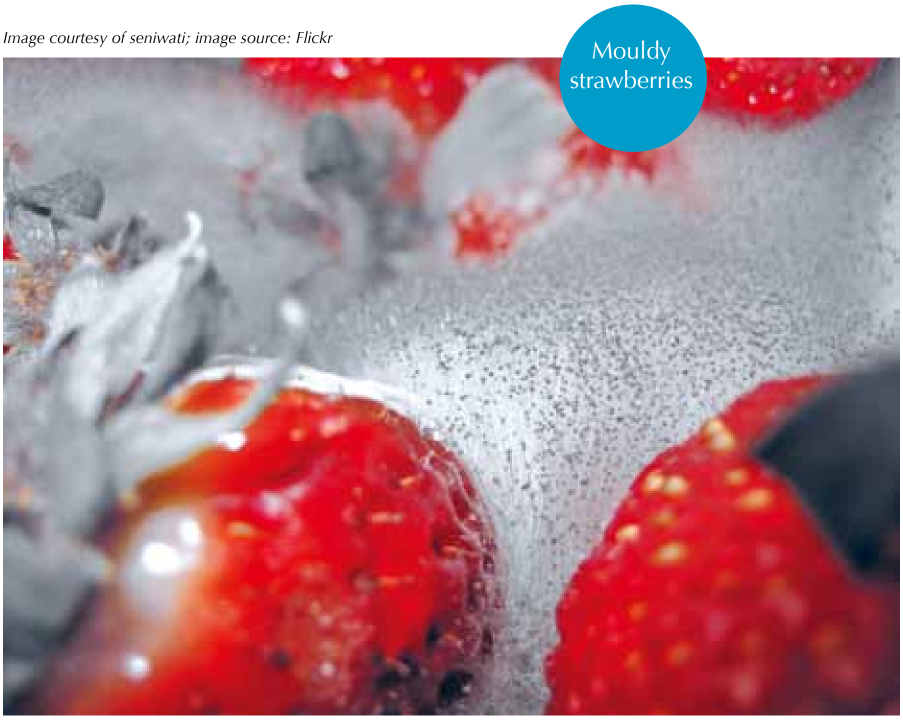
- What happens to the bubbles on the fermenting yeast? (They eventually pop.)
- Why doesn't that happen to the bubbles in the bread? (Because they're 'inside' the bread.)
- What is it about the bread that keeps the bubbles in? (Flour mixed with water.)

Now for a little activity. Ask the children to imagine they are the yeast, blowing carbon dioxide into the air. Where does it go? Next, give them balloons and ask them to blow into them. What is the difference in terms of where the air goes? (It's held within the balloons.) Help the children to understand the difference by putting all the inflated balloons in a box to simulate the carbon dioxide in a loaf of bread, held in place by tiny 'balloons' of dough.

Activity 2: the story of bread-making

In activity 1, the children will have learned that yeast, sugar and water

Image courtesy of seniwati; image source: Flickr



Mouldy strawberries

produce the trapped gas that makes the bread rise. They'll also have learned that flour, when mixed with yeast and water, forms a 'balloon' to hold the gas bubbles in a loaf. As an introduction to the wider aspects of bread-making, you can read the story of *The Little Red Hen*. If you don't have a copy, use the online Project Gutenberg version[w2]. The story illustrates clearly the main aspects of the bread-making process from field to plate. After reading the story, ask the class to illustrate and label each stage of the process and display it around the classroom. Can the students use the ideas from the book together with what they learned in activity 1 to write instructions for bread-making? There may be gaps but they can fill them in later after completing the rest of the activities.

Activity 3: invaders and settlers

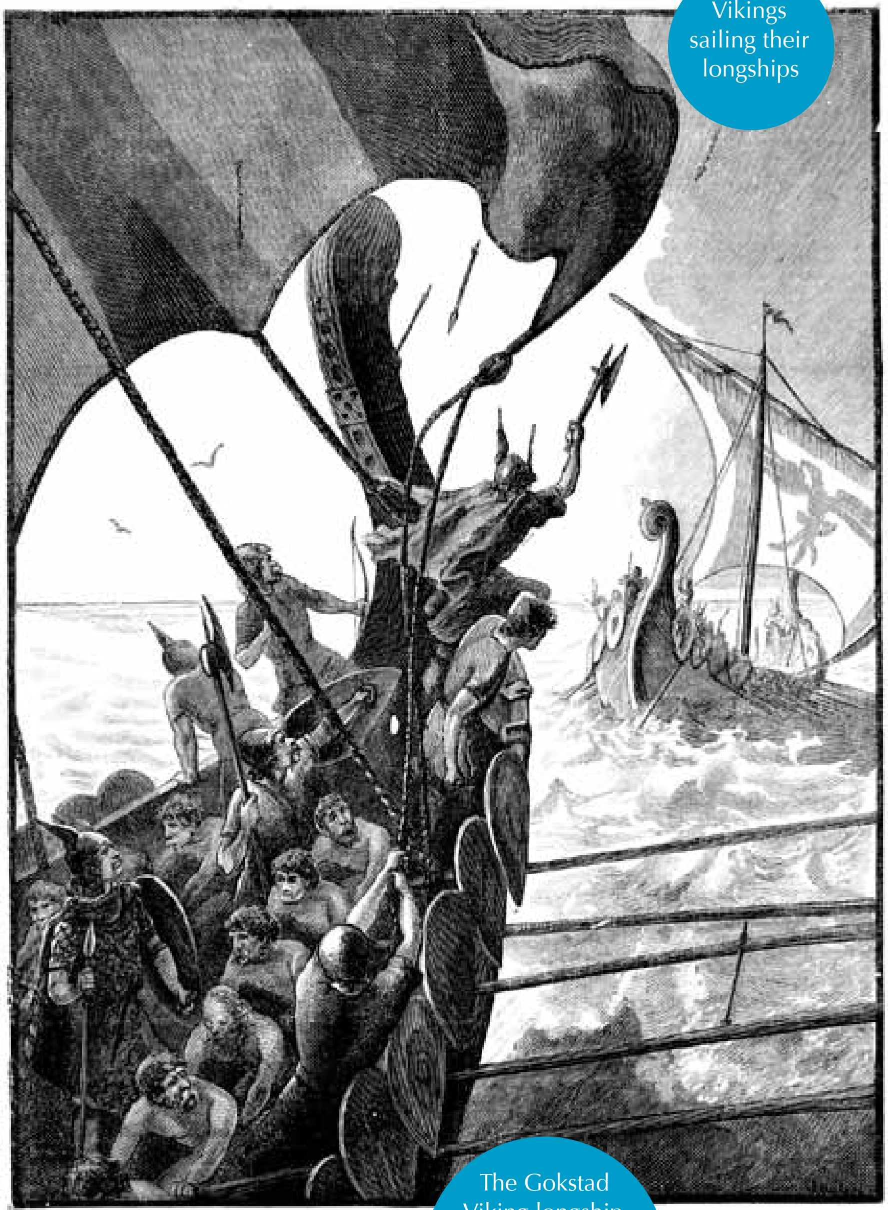
Like many other regions, the British Isles have a history of invasion and of settlement: the Romans, Angles, Saxons, Jutes and Vikings all came to the British Isles as invaders and eventually settled. Similarly, mainland Europe has seen waves of invaders and settlers over the centuries. The newcomers brought some food with them but would soon have needed to eat local food. You can integrate the subjects of bread-making and bread consumption into history lessons using the topic of invaders and settlers. We'll begin with a role-play.

In an area in the school hall or playground, label cones or chairs with signs listing individual food types such as berries, fruit, wheat, meat, dairy products and vegetables. Ask the children to sit down in the area as if they were settlers, look at the named foodstuffs around them, and decide which they would be likely to eat as settlers. You may need to remind them of the times of year that the different food types are available and also the time taken to grow them or process them into edible food.

Now repeat the role-play by asking the children to enter the area at different seasons of the year as invaders who won't be there for long. Which foods can they eat and which will be unavailable to them? Can they suggest why? What would the invaders do if they decided to settle there?

The activity should teach the children that some foodstuffs such as bread or vegetables have to be cultivated and processed using tools, so are appropriate foods for a settler, whereas others such as meat or berries can be taken straight away and processed easily, and are thus suitable foods for an invader.

Image courtesy of duncan1890 / iStockphoto



Vikings sailing their longships

The Gokstad Viking longship was excavated from a Norwegian burial mound in 1880

Image courtesy of Karamell; image source: Wikimedia Commons

General science

Primary

Activity 4: different types of bread

For this activity, ask the children to bring in different types of bread. Amongst others, you may get wholemeal, granary (with added bran and wheatgerm), oatmeal, rye, soda and flat breads. Set up an observation and taste test. Ask the children to suggest features for comparison such as what the bread looks like, its texture, the size of its holes / bubbles, its taste and whether they like or dislike it.

Safety note: before starting, make sure none of the children suffers from coeliac disease, an autoimmune disease triggered by the wheat protein gluten.

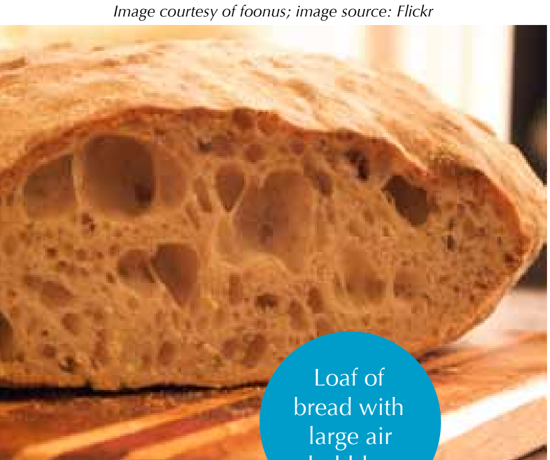
Image courtesy of Anonymous friend of ElinorD; image source: Wikimedia Commons

Kneading the dough

Image courtesy of Dawn Endico; image source: Flickr

French bread dough after proving. The air bubbles are formed from the carbon dioxide produced by the yeast during fermentation

Image courtesy of foonus; image source: Flickr



Loaf of bread with large air bubbles

If the bread is pre-packed, you can check the bag for information on its ingredients and how it was baked. Otherwise, you can find nutritional information about different types of bread on the Internet[w3]. If you've already covered the topic of healthy eating, the children will understand the basics of the nutritional information chart on the bag. If the children haven't covered the topic yet, a quick online investigation of the categories in a nutritional information chart will soon tell them what is healthy and what is not[w4]. You could then discuss healthiness by looking at the nutritional information on each bag and ranking the breads in order of healthiness, deciding what it is about each type of bread that makes it healthy or unhealthy. Which has the highest amount of fibre, for example, or the lowest salt level?

Activity 5: making your own bread

Now for making the bread! Children love this and it's easy and almost always successful. Take it right back to the basics and get some whole wheat grains for them to 'mill' using a mortar and pestle. The children will see the flour appear from the crushed grains and can sieve it to get pure flour. I wouldn't recommend making all your flour this way as it will take forever. Instead, mix your product with commercial bread flour to make up the required quantity. As a simultaneous activity, you could sow some wheat seeds and watch them grow – perhaps producing the wheat for next year's class! This links neatly to the story of *The Little Red Hen*.

Remember those helpful microbes in the first activity? Begin with some of the yeast mixture that the children made in activity 1. As soon as it froths, mix it with the flour and salt and stir vigorously – you can download the recipe from the *Science in School* website[w5]. You'll need to add more warm water until the dough becomes one ball that leaves the sides of the bowl cleanly, at which point the children should begin kneading it on a clean, floured desktop. What do they notice happening to the dough as they knead it? The gluten in the flour is being released and making the dough stretchy. Once the dough is smooth, you'll need to leave it in a warm place to prove ('ripen').

An hour later, ask the children what they observe and what they think has happened to the dough to make it rise. Carefully cut a piece off using a sharp knife and show the children the bubbles in the dough. Remind them of the balloon experiment to reinforce why the air stays in the dough. The bread dough requires a second kneading before it is left to prove again; this helps to spread the yeast and the air throughout the dough. Finally it'll be ready for baking. Make a loaf of your own and you can use it as an example, cutting it open once baked to smell the yeast and see the bubbles.

Image courtesy of djwtwo; image source: Flickr

Acknowledgement

This activity was first published on Freedom to Teach, the Collins Education blog[w6].

Web references

w1 – For more information about the history of bread, see: www.breadinfo.com/history.shtml

w2 – The complete illustrated story of *The Little Red Hen* is freely available online on the Gutenberg Project website (www.gutenberg.org) or via the direct link: http://tinyurl.com/727ukyv

w3 – For basic nutritional information about different types of bread, see: www.dailymail.co.uk/health/article-104785/How-good-loaf.html or use the shorter link: http://tinyurl.com/c2vpmzc

w4 – To learn about food labels, see:

The Teens Health website (www.kidshealth.org/teen; search for 'food labels') or use the direct link: http://tinyurl.com/cpn4xbf

w5 – A simple recipe for baking bread can be downloaded from the *Science in School* website: www.scienceinschool.org/2012/issue23/bread#resources

w6 – Collins Education publishes teaching and learning resources for children of all ages. Supported by Collins Education, the Freedom to Teach blog offers articles and information for teachers by teachers. See: http://freedomtoteach.blogspot.com

To read the original version of the bread-making activity, search the blog or use the direct link: http://tinyurl.com/7qf2zp5

Resources

Norwegian chemist Erik Fooladi offers a set of experiments comparing the chemistry of baking soda, horn salts and baking powder in Christmas cakes on his website of gastronomic science activities (in Norwegian). See www.naturfag.no or follow the direct link: http://tinyurl.com/3spkkwm

If you found this article inspiring, you might enjoy the other primary-school articles in *Science in School*. See www.scienceinschool.org/primary

With a teaching degree specialising in science, David Lewis has been a primary-school teacher for 20 years in the UK and now teaches at an international school in Cyprus. In 2006, David and his pupils made it to the finals of the Rolls Royce Science Prize, awarded for innovative approaches to science in the curriculum. He has been involved in teacher training and curriculum development, and in his spare time, he writes for Teach Primary magazine, Collins Education and an education blog in Cyprus.

To learn how to use this code, see page 65.

General science

Primary

Image courtesy of Claudio.Ar; image source: Flickr

Build your own radio telescope

Astronomers use giant radio telescopes to observe black holes and distant galaxies. Why not build your own small-scale radio telescope and observe objects closer to home?

By Bogusław Malański and Szymon Malański

When astronomers study the sky, they don't just look at starlight. Stars, planets and nebulae shine across the whole electromagnetic spectrum, and the light that human eyes can see is only a narrow part of it.

Radio telescopes observe the sky for radiation at wavelengths that are thousands to millions of times longer than visible light. The huge antennas that scientists have built to observe these wavelengths have become icons of modern technology. Arecibo Observatory, so big it was built into a bowl-shaped valley in Puerto Rico, is instantly recognisable from the James Bond movie *GoldenEye*, while Jodrell Bank has dominated the skyline of Manchester, UK, for half a century.

The resolution of a telescope's images depends both on the wavelength at which it operates and on the diameter of its dish. The longer the wavelength, the worse the resolution; and the larger the diameter, the better the

Detecting radio waves – one of the giant antennas of ALMA, the largest ground-based astronomy project in existence

Image courtesy of Izok Bončina / ALMA (ESO / NAOJ / NRAO)

REVIEW

- **Physics**
- **Biology**
- **Astronomy**
- **Ages 11-19**

If you would like your students to discover that the Sun or a hotplate emits a lot more than just visible light, that visible light is blocked by the clouds but radio waves are not, or that the electromagnetic spectrum consists of a variety of very interesting radiation; if you want your students to be able to find the position of the Sun on a cloudy day or to locate geostationary satellites; if you would like them to distinguish polarised radiation from non-polarised radiation; if you want to use a radio telescope in your lessons, constructed by your students and capable of helping you to teach all these topics and much more, then you will definitely be interested in the ideas presented in this article.

Using cheap materials and easy-to-follow instructions, you can build a simple but functional small-scale radio telescope. The activities suggested in this article are both interesting and applicable to a range of scientific topics (e.g. orbits, light, radiation and its effects on the body, and the electromagnetic spectrum), which can be covered in physics, astronomy and biology lessons.

Vangelis Koltsakis, Greece

resolution. Radio waves have a much longer wavelength than visible light, which is one reason why professional radio telescopes are enormous. Their huge size also helps them to capture the faint radiation from dim and distant objects. Nonetheless, the basic technology behind radio telescopes is quite simple and with some cheap equipment and simple tools, it's quite easy to build a simple but functional one of your own.

I called my radio telescope design RYSIA (a girl's name), or *RadiowyY Śliczny Instrument Astronomiczny* – Polish for 'beautiful radio astronomy device'. With RYSIA, you can carry out simple observations of objects that radiate brightly in the radio spectrum. This includes the Sun, our own planet, and man-made communications satellites such as Hot Bird, Astra and Sirius.

Materials

Local scrapyards, shops selling second-hand TV equipment and online auction sites such as eBay are good places to buy the parts you need.

- A satellite receiver dish

  When you watch TV, the satellite dish focuses the transmissions from the satellite onto the receiver. In your radio telescope, the dish will serve a similar purpose: it will reflect the relatively faint radio waves onto the receiver. I recommend one with a diameter of at least 1 m. The dish can be of offset or parabolic type. A new dish costs approximately 100 zł (€24). A used dish should cost no more than 12-20 zł (€3-5). You can also search at scrap metal yards – this is where I found mine.

  If the satellite dish has a mount, remove it (figure 1), as it just adds weight and makes it harder to move. The employee at the shop or scrap yard will probably be happy to remove it for you. Leave the arm attached, though.

Figure 1: Remove the mount (A) at the back of the satellite dish

Image courtesy of Szymon Malański

- A low noise block downconverter, or LNB

  LNBs are an essential part of satellite TV receivers, and sit at the point where the dish focuses incoming rays. When we watch TV, the LNB receives and amplifies the signal, strips out unwanted frequencies and then converts the signal to a lower frequency. In your radio telescope, the LNB will be the receiver that detects the radio waves reflected by the dish. Any brand or model will work fine, even the cheapest. The price of a new downconverter is approximately 40 zł (€10), but they can be bought second-hand for a fraction of the price.
- Satellite signal meter (figure 2)

  This tells us whether the LNB is receiving a signal, and if so, how strong it is. Be sure to get one that emits a sound when the antenna receives a strong signal; this makes it easier to demonstrate the device to large groups of students since everyone will be able to hear the signal. Additionally, the meter needs to be equipped with a dial or display that will allow you to measure the strength of the signal, so that you can make more precise measurements and compare different observations. Apart from these considerations, get the simplest

Images courtesy of Szymon Malański

Figure 2: A satellite signal meter

Figure 3: A power source for your radio telescope

Physics

Figure 4: Attaching the LNB to the antenna arm

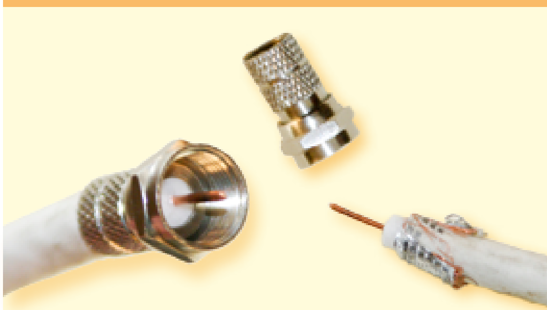


Figure 5: Attaching the BNC connectors to the coaxial cable

Images courtesy of Szymon Malański

Figure 6: Attaching the LNB to the satellite signal meter

Figure 7: The woven shield can be seen folded back along the cable. The metal core projects from the cable

Figure 8: Powering the satellite meter and receiving the signal from the LNB

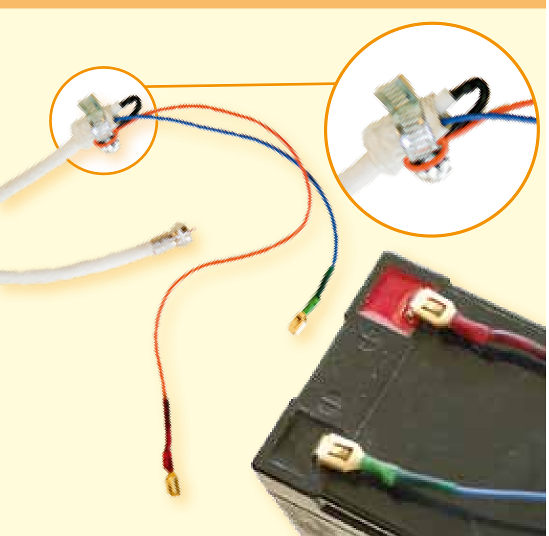


Figure 9: Connecting the power source

and cheapest one you can find – the cost of this part is approximately 20 zł (€5).

- 3 m of coaxial cable – 5-10 zł (€1-2)
- 3 BNC (Bayonet Neill-Concelman) connectors for the coaxial cable – 60-120 gr (15-30 ¢) each. If possible, choose 'twist-off' connectors, as they do not need soldering.
- A power source that provides 12 V to 18 V DC
  I used a 12V lead-acid car battery (figure 3). You can also use standard AA batteries connected in series.

Building your radio telescope

Once you have your materials, it is mostly a matter of fitting or plugging them together.

1. Mount the low noise block downconverter on the arm of the antenna, using the attachments provided (figure 4).
2. Cut the coaxial cable in half. Attach a BNC connector to each end of one piece of cable, and to one end of the other (figure 5).
3. Take the coaxial cable that has two connectors and plug one end into the LNB and the other into the socket labelled 'LNB' or 'satellite' on the satellite signal meter (figure 6).
4. Take the coaxial cable with only one connector, and strip the other end of the cable to reveal the metal core and the woven copper shield (figure 7).
5. Plug the connector on that coaxial cable into the satellite meter's second socket (labelled 'power' or 'receiver'; figure 8).
6. The other end of the cable now needs to be connected to your power source. Connect the woven copper shield to the battery's negative terminal and the core to the battery's positive terminal (figure 9).

You have now built a basic, mobile radio telescope that is light and manoeuvrable enough to transport and point at different objects by hand.

If you wish to build a mounted device, you will need to attach it to an object (such as a heavy tripod) that allows you to adjust both the azimuth (the horizontal direction that the telescope is pointing in) and the altitude (how high or low it is angled).

Activities using your radio telescope

You now have a radio telescope that works on some of the same principles as the gigantic radio telescopes that are used to investigate the earliest days of the Universe, capturing radiation from very distant galaxies (see Mignone & Pierce-Price, 2010). Although your much smaller telescope cannot detect distant stars, you can use it to demonstrate to your students that the Sun and other objects radiate not only visible light but also radio waves. Furthermore, you can find the position of the Sun on a cloudy day, demonstrate that the surface of Earth emits radio waves, and locate satellites.

If you used a parabolic antenna to build your radio telescope, you will need to point its axis directly at the object you are observing. If you used an offset antenna, however, you must take into account the angle by which it is offset. Most manufacturers do not provide this parameter but it can easily be calculated (this can be an additional task for the students). In practice, the arm of the satellite dish on which the LNB is mounted indicates the direction from which the signal is received (figure 10).

Observing the Sun

The Sun emits radiation across much of the electromagnetic spectrum. On a clear day, try pointing your radio telescope at the Sun and at a patch of empty sky. Compare the readings. Repeat the experiment on a cloudy day; the Sun's location can easily be determined, despite the clouds. Ask your students why they think that visible light is blocked by the

Image courtesy of Szymon Malański

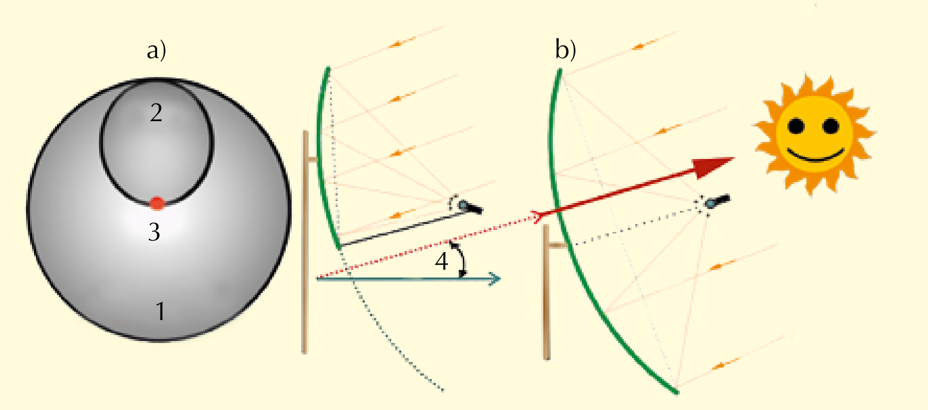


Figure 10:
a) A front view of the two types of satellite dish: parabolic (1) and offset (2) dishes, showing the position of the LNB (3)

b) Cross-sections of an offset satellite dish (left) and a parabolic satellite dish (right), showing the angle of elevation (4)

clouds but radio waves can penetrate.

You could also ask your students how they can distinguish the Sun's radiation from a satellite signal, particularly as they sometimes appear close together in the sky. The answer: the satellite signal is polarised (horizontally or vertically) whereas radiation from the Sun is not. So if you rotate the radio telescope dish and the signal strength is unchanged, the signal is coming from the Sun.

Observing Earth

Objects around us, including buildings, plants, people and even the ground under our feet, emit radio waves, reflected from the Sun or Earth. Try comparing readings for different objects. Thanks to the auditory signal from the satellite signal meter, you should be able to detect the location of buildings and trees around you easily, even when blindfolded. To make sure that the signal does not come from the Sun itself, make sure you carry out these experiments by pointing the dish away from the Sun.

Detecting heat

Most astronomical phenomena produce electromagnetic radiation because they are hot. The higher their temperature, the shorter the wavelength they can produce. At around 5500 °C, the Sun produces plenty of visible light as well as infrared and radio waves. Colder objects have to be detected using infrared or radio telescopes. You can demonstrate this by pointing your radio telescope at a hotplate as it heats up. It will only begin to emit visible light at around 700 °C, but your telescope will detect the radio waves emitted well before that.

Satellites

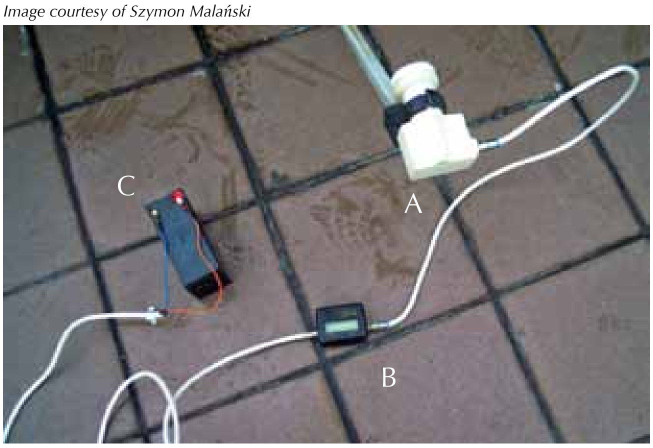
We have built this simple radio telescope using satellite TV technology, which allows it to detect spacecraft too. Professional radio telescopes do this too sometimes – Australia's Parkes Telescope was used to communicate with Apollo 11 during its mission to the Moon[w1].

The best-known communications satellites (e.g. Hot Bird, Astra and Sirius) are in geosynchronous orbits around Earth, which means they do not move in the sky, and orbit above the equator. This makes them easy to find. The Wolfram Alpha[w2] database provides the location of many satellites.

Be aware that during the spring and autumn equinoxes, the Sun shines above the equator and can interfere with satellite reception when the Sun and the satellite are in the same area

Physics

Image courtesy of Szymon Malański



Connecting your radio telescope. A: the LNB, on which the radio waves will be focused; B: the satellite signal meter; C: the power supply

Image courtesy of Szymon Malański

Using RYSIA on a cloudy day to locate the Sun

Image courtesy of Szymon Malański

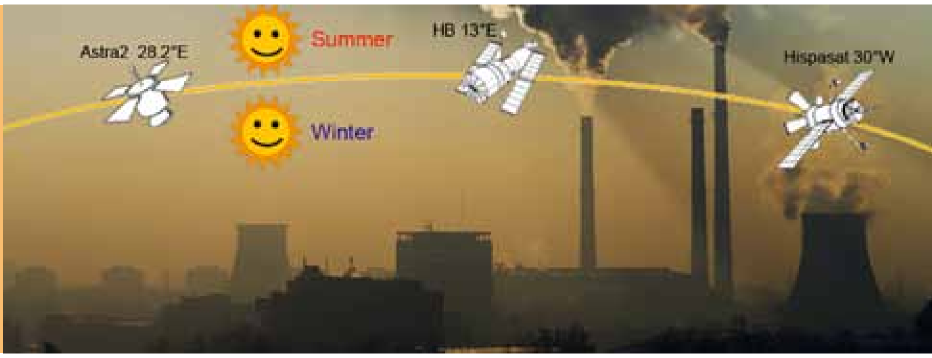


Figure 11:
In summer, the Sun is above the line representing the location of geostationary satellites. In winter, it is below this line

of sky (figure 11). Wolfram Alpha has a map of the Sun's location relative to a satellite, so this is easy to avoid.

Feedback

If you have suggestions for improving the telescope or for further activities, please leave a comment at the end of the online article[w3].

Acknowledgement

Our radio telescope was inspired by a working model built by Peter Kalberla, an astronomer at the University of Bonn, Germany, and demonstrated at his 2011 course 'Hands-On Universe: Connecting classrooms to the Milky Way'[w4] in nearby Bad Münstereifel.

Reference

Mignone C, Pierce-Price D (2010) The ALMA Observatory: the sky is only one step away. *Science in School* **15**: 44-49. www.scienceinschool.org/2010/issue15/alma

Web references

w1 – To learn more about how the Parkes Observatory supported the Apollo 11 mission, see the Parkes Observatory website (www.parkes.atnf.csiro.au) or use the direct link: http://tinyurl.com/d7lmjau

w2 – To locate satellites in the sky, search the Wolfram Alpha database: www.wolframalpha.com

w3 – Leave your suggestions for improvement and activities on the *Science in School* website: www.scienceinschool.org/2012/issue23/telescope

w4 – To find out more about the course that inspired this article, see: http://ec.europa.eu/education/trainingdatabase/index.cfm?fuseaction=DisplayCourse&cid=29914 or use the shorter link: http://tinyurl.com/blekkgk

w5 – To learn more about Boguslaw's planetarium (in Polish), see: www.mnc.pl/~malanski/lab/start.htm

Resources

For an activity to investigate radio transmission and the propagation of electromagnetic waves in air, see:

Iscra A, Quaglini MT, Rossi G (2006) Introducing radio transmission with a simple experiment. *Science in School* **3**: 39-42. www.scienceinschool.org/2006/issue3/radio

To find out more about electromagnetic radiation and how it is used in astronomy, see:

Mignone C, Barnes R (2011) More than meets the eye: the electromagnetic spectrum. *Science in School* **20**: 51-59. www.scienceinschool.org/2011/issue20/em

The European Southern Observatory (ESO) is one of the partners in the radio observatory ALMA, the Atacama Large Millimeter/submillimeter Array, an ensemble of huge, high-precision antennas on the Chajnantor plateau in Chile's Atacama region. Also on Chajnantor plateau is ESO's radio telescope APEX. To find out more about ALMA and APEX, visit the ESO website: www.eso.org

ESO is a member of EIROforum, the publisher of *Science in School*. See: www.eiroforum.org

If you enjoyed this article, you might like to browse the other *Science in School* articles about astronomy and space science. See www.scienceinschool.org/astronomy and www.scienceinschool.org/space

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Boguslaw Malański is a physics and astronomy teacher. He gained a physics degree and a PhD from the University of Łódź, Poland, after which he spent nine years as a physics lecturer at the University of the North-West in South Africa. He was also involved there in performing science experiments for local schools together with Pastor Bernd-Peter Jensen. Boguslaw is currently employed at the local planetarium and astronomical observatory in Łódź, where he teaches astronomy and physics. He also runs a small, non-profit experimentarium for local schools[w5].

Szymon Malański, Boguslaw's son, is a 5^{th}-year student studying telecommunications and computer science at the Technical University of Łódź, Poland. He enjoys experimenting and is keen on classical-analogue photography.

To learn how to use this code, see page 65.

Solar energy: silicon solar cells

With oil reserves running out, silicon solar cells offer an alternative source of energy. How do they work and how can we exploit their full potential?

Chemistry

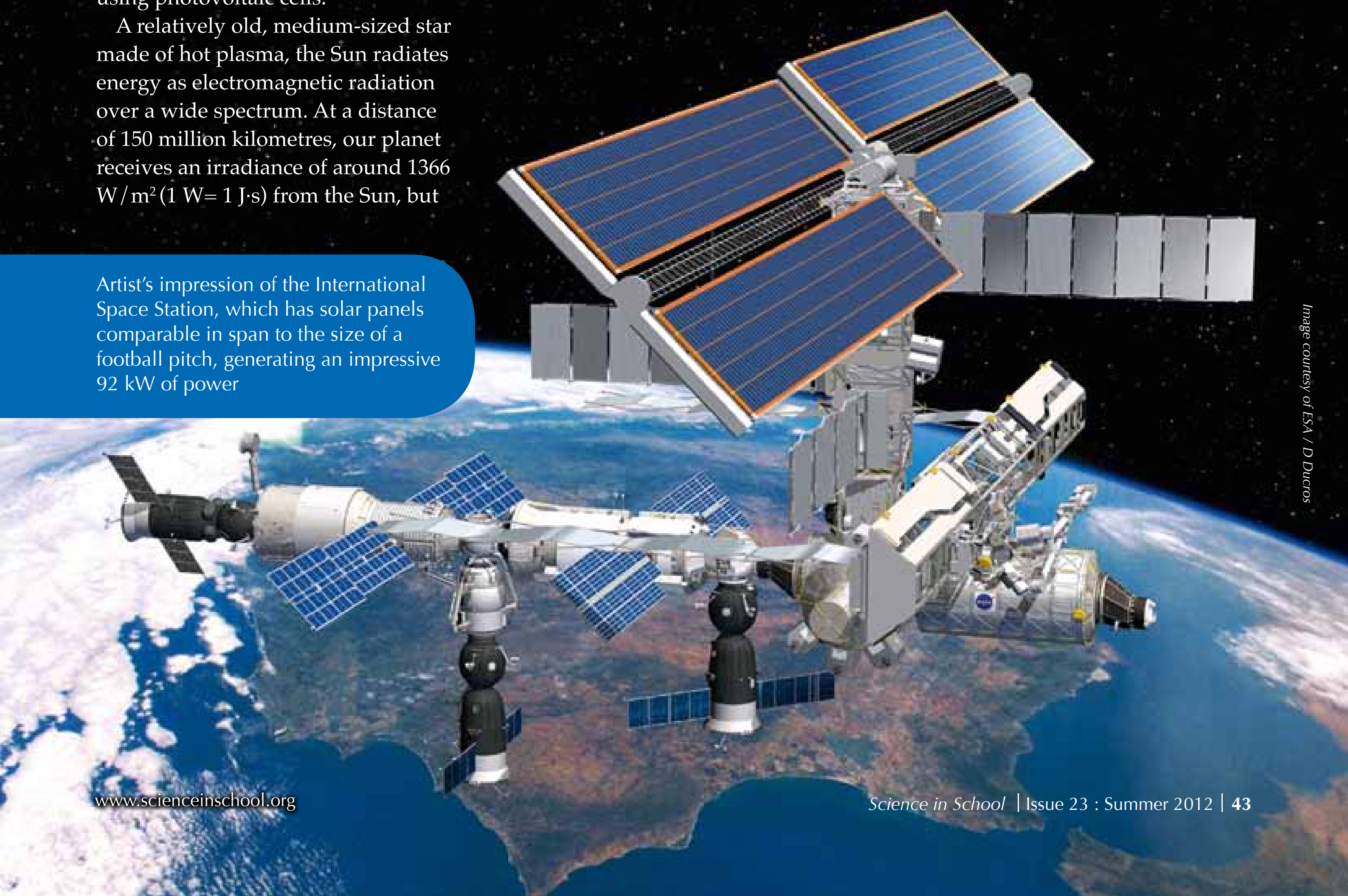
Physics

By Enrique García-García, Yahya Moubarak Meziani, Jesús Enrique Velázquez-Pérez and Jaime Calvo-Gallego

Indirectly, the Sun is the source of most of the energy we use on Earth: not only of fossil fuels and biomass, but also wind and tidal energy, to mention just a few. Increasingly, there is interest in capturing the energy from the Sun more directly, using photovoltaic cells.

A relatively old, medium-sized star made of hot plasma, the Sun radiates energy as electromagnetic radiation over a wide spectrum. At a distance of 150 million kilometres, our planet receives an irradiance of around 1366 W/m^2 (1 W= 1 J·s) from the Sun, but not all of this actually reaches us because Earth's atmosphere reflects and absorbs about 30 % of this energy. Nonetheless, every square metre of Earth's surface receives an average of nearly 1000 Joules per second from the Sun.

To put this into perspective, the total energy consumed globally in 2010 was around 5×10^{20} J. If we assume that our planet is a perfect sphere with a radius of 6370 km, Earth receives 1.8×10^{17} J/s, of which about 1.3×10^{17} J/s



Artist's impression of the International Space Station, which has solar panels comparable in span to the size of a football pitch, generating an impressive 92 kW of power

Image courtesy of ESA / D Ducros

REVIEW

- Chemistry
- Physics
- Solar energy
- Photovoltaic cells
- Semiconductors
- Conductivity
- Renewable energy sources
- Environmental science
- Ages 13+

The harnessing of solar energy is a topic that is currently widespread amongst various countries worldwide, especially in view of the rising awareness of climate change and the depletion of non-renewable sources of energy. Countries are becoming more conscious of the need to reduce their reliance on non-renewable sources of energy and, at the same time, to adopt policies favouring renewable sources of energy.

This article provides a very good example of how semiconductors are used in photovoltaic cells and gives a general idea of the energy radiated by the Sun and how much of it is actually collected through solar devices. The article's main concepts can be included as part of broader topics such as photoelectric effect, conductors, insulators, intrinsic and extrinsic semiconductors, energy band theory and electric current.

Comprehension and extension questions could include:

1. The Sun is a very powerful source of renewable energy. Why is it then that the energy generated from solar energy is just a small percentage of what we actually consume annually?
2. Explain why semiconductors such as silicon are used in photovoltaic cells.
3. The conductivity of a semiconductor can be increased by doping the material. Explain how this process produces p-type and n-type semiconductors.
4. How are these doped semiconductors used in photovoltaic cells to capture solar energy?
5. How efficient are these photovoltaic cells and in practice, how much of Europe's energy is obtained using photovoltaic technology?
6. What are the factors that limit the efficiency of solar energy collection?

This article is ideal for linking the topics of renewable energy (such as solar) to environmental issues. The positive impact of using solar photovoltaic cells or solar heaters to generate energy has been amply documented. However, we could also prompt our students to research and reflect on the impact that these devices will have on our planet in future years. Which materials are used to construct solar heaters, solar panels and photovoltaic cells? Is the manufacturing process harmful to the environment in any way? What is the lifespan of this equipment, and how is it disposed of upon reaching its end of life? Are these materials manufactured from non-renewable materials? If yes, how long will the materials last? In view of the efficiency of these devices, are they economically viable to produce and maintain?

Catherine Cutajar, Malta

reaches Earth's surface. Thus in one hour, the Sun provides Earth with all the energy we need for a whole year.

It isn't quite that simple, however. Due to meteorological factors, the Sun's declination and Earth's rotation, the irradiance is actually closer to 230 W/m^2. If we repeat the last calculation using that figure, the time needed to power Earth with energy from the Sun for a year is about five and a half hours – still an impressively short time.

Solar radiation is therefore a promising energy reservoir, but how can we collect it and use it?

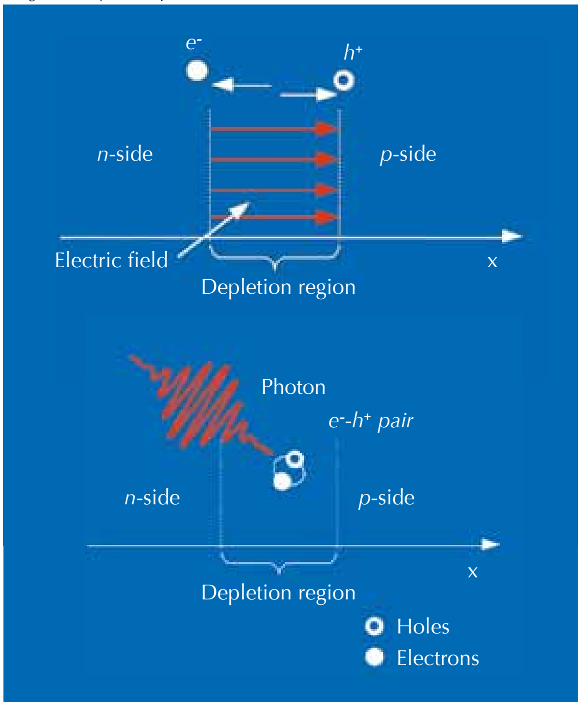
What happens inside a photovoltaic cell?

The foundations for modern solar energy collection were laid in 1839, when the French physicist Edmond Becquerel observed an increase in the electrical conductivity of some materials when they were exposed to light; this became known as the photovoltaic effect. It was not until quantum mechanics was developed, though, that the phenomenon was explained. Electromagnetic radiation can be described as a stream of quantum objects called photons. When these photons are absorbed by some materials, they can promote electrons in the material into a higher energy state (the conduction band), potentially enhancing the material's conductivity.

Semiconductors, such as silicon, are photovoltaic because a photon's energy matches that required to move one of the semiconductor's electrons up into the conduction band. However, semiconductors themselves have few free electrons and, therefore, low conductivity. To increase their electrical conductivity, tiny amounts of other materials (impurities) can be added, a process called doping.

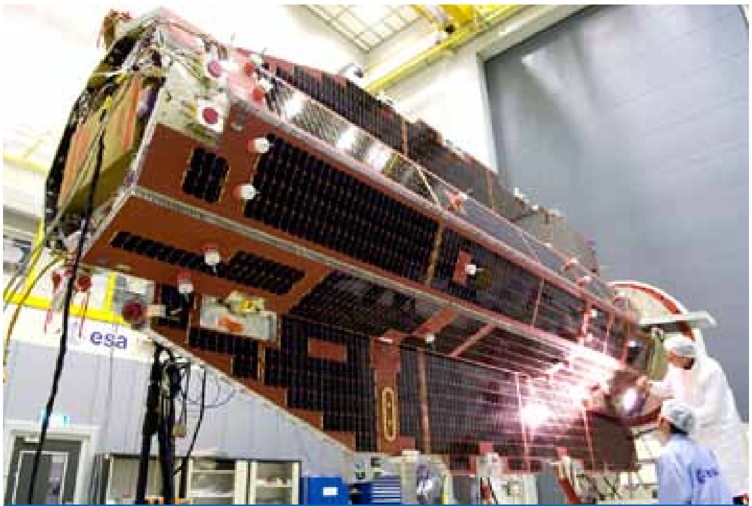
Doped silicon is the most frequently

Image courtesy of Enrique García-García



An electric current is generated at the interface of the n-p junction

Image courtesy of ESA



Solar panel inspection during final testing of ESA's GOCE satellite, which maps Earth's gravity. The spacecraft is equipped with four body-mounted and two wing-mounted solar panels. In orbit, the same side of the satellite remains facing the Sun. Due to this configuration, the solar panels will experience extreme temperature variations, so materials have been used that will tolerate temperatures as high as 160 °C and as low as -170 °C

used material in electronics. Pure silicon has four valence electrons that it shares with four neighbouring atoms. Adding impurities with more or fewer valence electrons (such as phosphorus or boron) modifies the conductivity properties of the material. Phosphorus has five valence electrons and, when a phosphorus atom is surrounded by silicon atoms, the fifth electron is only loosely bound. This means it can easily reach the conduction band, helping to increase the material's conductivity. Phosphorus-doped silicon is called n-type (negative type) since doping increases the number of negative free charges (electrons). In contrast, boron has only three valence electrons, and the lack of one electron in the silicon lattice creates a 'hole'. As free electrons move through the lattice, from one hole to another, the positively charged holes appear to move through the material. Boron-doped silicon is known as p-type (positive-type) silicon.

Image courtesy of Aomorikuma; image source: Wikimedia Commons

Mobile-phone base station powered by photovoltaics

These phenomena can be exploited in solar cells to collect energy from the Sun and transform it into electrical energy. The simplest solar cell is formed by the junction of two semiconductors, one p-doped and one n-doped, called a p-n junction. At this junction, the electrons in the n-type silicon 'see' the holes in the p-type silicon and travel to fill them – creating electron-hole pairs. When a photon strikes one of these pairs, however, it breaks apart and the flow through the material of these newly freed charge carriers, both positive and negative, generates an electric current.

Not all the freed charge carriers generated by this process will contribute to the current, however. Instead, a significant proportion of the electrons and holes will pair up again, generating heat. This reduces the energy conversion efficiency of a photovoltaic material: the percentage of the incoming solar energy that is converted into electrical energy. This is one of the most important parameters of a solar cell's quality. Currently, commercially available silicon solar cells are approximately 20 % efficient, but extensive efforts are being made to improve this value.

Photovoltaics in practice

We now know what is happening inside a solar cell, but what are the practicalities of using solar cells to capture energy from the Sun? A standard solar module is approximately 1.3 m^2 and consists of an array of around 50 single solar cells. Depending on the technology, one module will deliver about 200 W, so an assembly of five modules can supply the energy needs of an average household – about 1 kW. In theory, the total energy demand of Europe could be satisfied by covering just 1 % of the continent with solar cells. Realistically, however, solar power is only going to be part of the solution to our energy needs.

In Europe in 2010, about 7 % of energy was obtained using photovoltaic technology, but optimistic estimates of what proportion of Europe's energy needs could, realistically, be met by solar power range from 30 to 50 %. More precise figures are not yet possible because the necessary technological innovations are still being developed.

One of the limitations of solar energy is that the amount of electricity generated by solar cells is strongly dependent on environmental factors including cloudy weather; the angle at which the sunlight strikes the panel; snow, rain, leaves and other debris on the surface; and, of course, night time. One way to address these issues is by incorporating solar energy into a *smart grid*, a new concept of a power grid that co-ordinates electricity production from several sources – including solar cells, thermal generators and nuclear plants – to meet consumer demand. In this kind of power distribution, solar cells are playing an increasingly important role. They are also becoming more popular on a smaller scale where the electricity produced may be used on-site – in people's houses, for roadside telephones, at industrial plants, and on boats, cars and even the International Space Station[w1].

So while we are still unreachably far from meeting our annual global energy needs from five hours of sunshine, photovoltaic technology is increasingly a feasible source of energy. Next time you switch on the kettle or the television, think of the sunlight that helped to power it.

Web references

w1 – To learn more about how solar energy is used to power space missions, download the European Space Agency's booklet *Satellite Power Systems: Solar Energy Used in Space* from www.esa.int or use the direct link: http://tinyurl.com/7vz3vh7

w2 – Situated in Grenoble, France, ESRF operates the most powerful synchrotron radiation source in Europe. To learn more, see: www.esrf.eu

To find out more about organic photovoltaics at ESRF, see: www.esrf.eu/news/spotlight/spotlight132

w3 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research

@ EIROforum

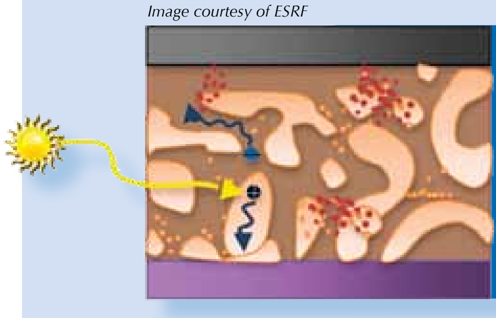
Organic photovoltaics

Photovoltaic panels based on crystalline semiconductors – as described in this article – are relatively expensive to produce and process. An alternative is offered by organic photovoltaic materials, which allow large solar panels on flexible substrates to be produced using low-cost processes such as inkjet printing. However, much more research is necessary to improve their efficiency.

Most organic photovoltaic devices are based on thin films comprising an electron-accepting component (such as a fullerene derivative) and an electron-donating component (usually a conjugated polymer) between two electrodes. An important requirement is to mix these two components to obtain a continuous network of donor and acceptor paths for the carriers (electrons or holes) to reach the appropriate electrode (see image). Analysis with synchrotron X-rays at the European Synchrotron Radiation Facility (ESRF) is a good way to examine these materials closely, enabling their characteristics to be improved.

To learn more, see the ESRF website[w2].

Image courtesy of ESRF



This plastic film is made of a blend comprising a continuous network of donors (pale brown) and acceptors (dark brown), which allow charge transfer between the two electrodes (grey and magenta bands at the top and bottom, respectively)

ESRF is a member of EIROforum[w3], the publisher of *Science in School*.

Image courtesy of Hans Weingartz; image source: Wikimedia Commons

A solar-powered racing car

Image courtesy of Túrelio; image source: Wikimedia Commons

Photovoltaic array on a timber-framed house near Bonn, Germany

Image courtesy of Magnus Manske; image source: Wikimedia Commons

Solar-powered boat on the Rhine, Germany

organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

To learn more about how the Sun's energy is absorbed by Earth's atmosphere, see:

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

To learn how to build your own solar cell, see:

Shallcross D, Harrison T, Henshaw S, Sellou L (2009) Looking to the heavens: climate change experiments. *Science in School* **12**: 34-39. www.scienceinschool.org/2009/issue12/climate

Tatalovic M (2010) Solar cars: the future of road transport? *Science in School* **16**: 50-53. www.scienceinschool.org/2010/issue16/solarcars

The European Photovoltaic Industry Association's website has a list of frequently asked questions and answers concerning photovoltaic materials. See: www.epia.org/solar-pv/faq.html

For an electronic book on photovoltaic materials produced by the University of New South Wales, Australia, see: http://pveducation.org/pvcdrom

The website of the US Department of Energy's National Renewable Energy Laboratory provides information on photovoltaics and solar energy. See: www.nrel.gov/solar

The EU-MENA project is investigating using deserts in the Middle East and North Africa to generate solar energy for the region, and also for Europe. For more details, see: www.desertec.org/global-mission/focus-region-eu-mena or use the shorter link: http://tinyurl.com/cv48z98

If you found this article interesting, you might enjoy the other articles in the *Science in School* energy series: www.scienceinschool.org/energy

All four authors work at the University of Salamanca, Spain.

Enrique García-García has a degree in physics and a master's degree in the physics and technology of lasers. His research interests include the electrical characterisation of solar cells and electromagnetic waves at frequencies in the terahertz range (terahertz radiation).

Dr Yahya Moubarak Meziani has a PhD in semiconductor physics from Montpellier 2 University, France. Since 2008, he has led a research group working on terahertz radiation.

Professor Jesús Enrique Velázquez-Pérez has a PhD from the Université Paris-Sud, France, in the simulation and development of high-frequency electronics components. He has been based at the University of Salamanca since the early 1990s.

Dr Jaime Calvo-Gallego's research interests include Monte Carlo computer simulations of electronic devices, heat transport and terahertz devices.

To learn how to use this code, see page 65.

Image courtesy of US Air Force photo / Airman 1st Class Nadine Y Barclay; image source: Wikimedia Commons

On 57 hectares of unused land on Nellis Air Force Base, Nevada, USA, this solar photovoltaic array will generate 15 MW of solar power for the base

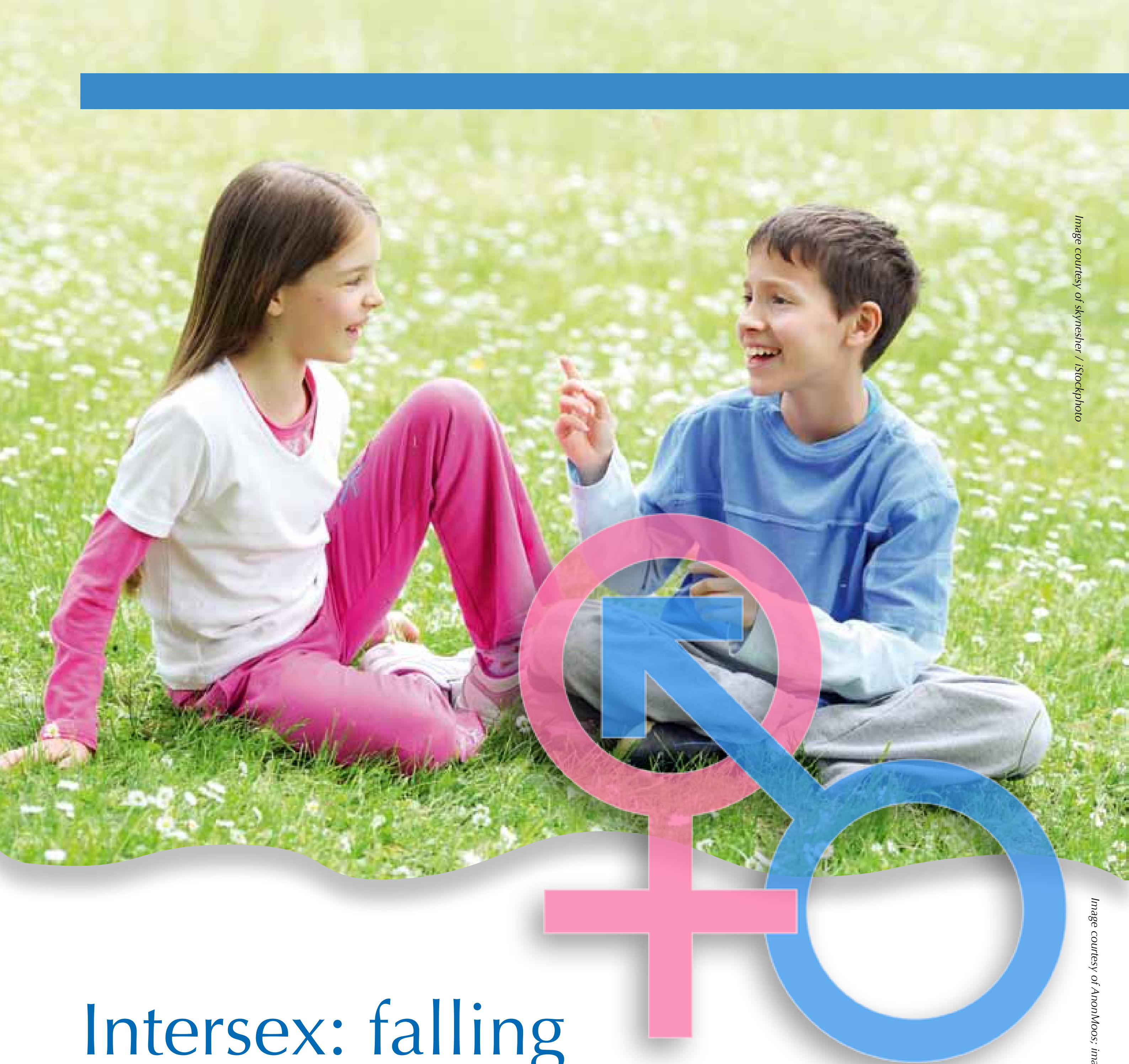


Image courtesy of skynesher / iStockphoto

Image courtesy of AnonMoos; image source: Wikimedia Commons

Intersex: falling outside the norm

Male or female? What are the issues surrounding children for whom the answer is not clear? Researchers Eric Vilain and Melissa Hines hope to provide some of the answers.

By Nina Notman

"Is it a boy or a girl?" It is often the first question asked when a child is born, and it is widely assumed to be easy to answer. XY sex chromosomes = testicles and penis = boy; XX sex chromosomes = ovaries and vagina = girl. But it isn't always that simple. Some children are born intersex, neither fully male nor fully female, but somewhere in between. For example, they may appear female on the outside but have an internal anatomy more typical of males. Or they may have ambiguous genitalia: a girl may have a noticeably large clitoris, or lack a vaginal opening, or a boy may be born with a noticeably small penis, or with a scrotum that is divided so that it looks more like labia. Furthermore, some children are born with mosaic genetics, so that some of their cells have XX chromosomes and some have XY.

Why? Well, there are many different types of intersex and we don't fully understand everything yet, but genetics and hormone levels in the mother's womb during pregnancy are two known influences.

To study the role that genetics plays in determining our sex, genes that are thought to be involved are modified and the outcome observed to see if the expected change occurred. For ethical reasons, this type of experiment cannot be conducted on humans, and so animals are used instead. Professor Eric Vilain[w1], a physician and geneticist at the University of California, Los Angeles (UCLA) in the USA, is a researcher working in this area.

In Greek mythology, Hermaphroditus, the son of Hermes and Aphrodite, possessed physical traits of both sexes

Image courtesy of Lady Lever Art Gallery, Port Sunlight Village, Wirral, UK; public domain image

REVIEW

- **Biology**
- **Sex education**
- **Human reproduction**
- **Ages 16-19**

Intersex or ambiguous sexual phenotypes are not a common topic for discussion, at school or more generally, as an aura of embarrassment or shame often prohibits any mention of sexual pathology.

This article, based on interviews with two researchers in the field, introduces the reader to this tricky topic in clear language, highlighting some of the scientific and social aspects. I particularly appreciated the consideration of the psychological impact of the intersex condition and of the issues surrounding the treatment and rearing of intersex children.

As described in the article, the status and the management of the intersex condition is a highly controversial issue, so it can be profitably used for classroom discussion, especially with upper secondary-school students. It would be particularly applicable for biology (e.g. human reproduction), or in sex education or citizenship lessons. The discussion could involve many social, cultural, bio-ethical and legal aspects, including sex and gender identity, the rights and obligations of parents of an intersex child, the principle of autonomy of patients about medical treatments, and the social acceptance of intersex persons.

Potential comprehension questions include:

1. Which of the following factors is not cited in the article as affecting sexual development in humans?
   a) X and Y chromosomes
   b) Pro-male and pro-female genes
   c) Alcohol exposure during pregnancy
   d) Hormone levels during pregnancy
2. The topic of Melissa Hines' research is:
   a) The play behaviour of CAH boys
   b) The play behaviour of CAH girls
   c) The role of genes in sexual development
   d) The play behaviour of pregnant women

Moreover, the web resources offer not only information and materials suitable for secondary-school students, but also further information about the study and management of intersex conditions.

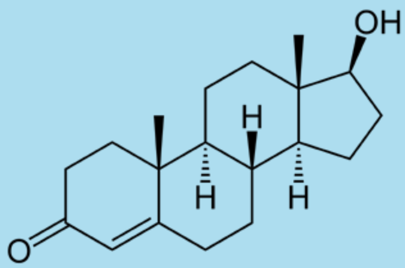
I recommend this article to science teachers and upper secondary-school students who are keen to understand this commonly hidden condition and motivated to promote a better social acceptance of intersex people.

Giulia Realdon, Italy

It used to be believed that if you had a Y chromosome, certain genes on it (known as pro-male genes) would ensure you were male; if you didn't have a Y chromosome, you would not be male, and therefore – by default – female. Eric and his colleagues, however, overturned this theory when they found pro-female genes – genes that actually code for female characteristics (Jordan, 2003). "We showed that sex determination is much more about a delicate balance between male genes and female genes," says Eric. It is now thought that a disturbance of this balance may have occurred in some types of intersex.

Another common cause of intersex in girls is a hormonal imbalance, where a genetic defect causes the adrenal gland of the fetus to produce very high levels of testosterone and other male hormones. This is called congenital adrenal hyperplasia (CAH). Professor Melissa Hines[w2], who researches the condition at the University of Cambridge in the UK, explains: "The testosterone causes the clitoris to grow larger so it looks somewhere between a clitoris and a penis, and it causes the labia to begin to fuse, so they look somewhere between labia and a scrotum." This condition is identified at birth and treated, and the children are raised as girls. Treatment involves normalising the hormone levels, often followed by surgery for cosmetic reasons or to correct problems with the urethra and the vaginal opening.

Image courtesy of NEUROtiker; image source: Wikimedia Commons



Chemical structure of testosterone, the principal male sex hormone

Psychological impact

Although there are clinical treatments available for most types of intersex conditions, the matter is fraught with psychological and ethical issues. Eric is one researcher keen to find a better way to manage intersex and its perception in society.

"Parents are extremely stressed over the birth of a baby with ambiguous genitals," he explains. An eagerness to 'fix' the child can lead to genital surgery very early in life – often in the first year. But whether this is the best thing for the child is unclear. As well as feeling that they would not have chosen to have the treatment themselves, children born intersex can have issues with shame and secrecy when they grow up. "A lot of patients I see with intersex conditions were not told what happened to them until very late in their adolescence, and they are often very angry at their family for having shielded them." Early operations can also have a negative impact on sexual function later in life.

So, would it be better not to interfere with nature? "We really don't know," says Eric. "There are a very small number of patients who have not been operated on, so we don't know what life would be like living with ambiguous genitals, and maybe it's also problematic psychologically."

But how about gender identity: do children born intersex have problems feeling they truly belong to one sex

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Sex determination in mice

EMBL

Scientists at the European Molecular Biology Laboratory (EMBL)[w4] and the UK's National Institute for Medical Research have discovered that if the *Foxl2* gene located on a non-sex chromosome is turned off, cells in the ovaries of adult female mice turn into cells typically found in testes.

It has traditionally been assumed that the female pathway – the development of ovaries and all the other traits that make a female – was a default: if an embryo had a gene called *Sry*, located on the Y chromosome, it would develop into a male; if not, then the result would be a female. But in adult animals it is the male pathway that needs to be actively suppressed, as Mathias Treier and his team at EMBL discovered.

"We were surprised by the results," said Mathias. "When we switched off the *Foxl2* gene in the ovaries of female mice, we expected the mice to stop producing oocytes, but what happened was much more dramatic: somatic cells that support the developing egg took on the characteristics of the cells that usually support developing sperm, and the gender-specific hormone-producing cells also switched from a female to a male cell type."

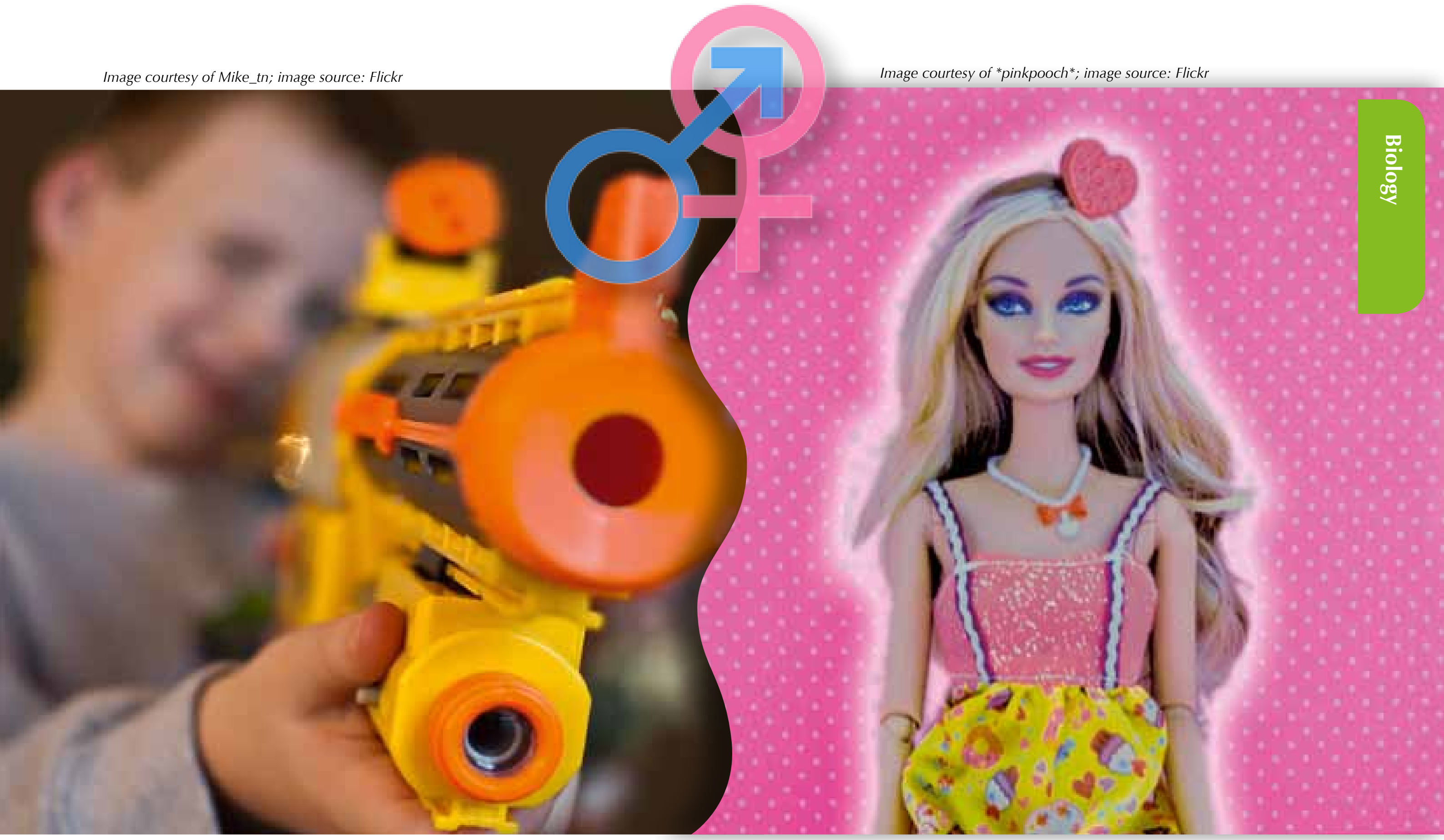
These findings will have wide-ranging implications for reproductive medicine and may be used in the treatment of intersex children.

For further details, see the online interview with Mathias Treier[w5] and the research paper (Uhlenhaut *et al.*, 2009).

EMBL is a member of EIROforum[w6], the publisher of *Science in School*.

Image courtesy of Mike_tn; image source: Flickr

Image courtesy of *pinkpooch*; image source: Flickr



or another? No, answers Eric. "Most intersex people I know are actually fine within a certain gender."

Behavioural matters

Meanwhile, Melissa is keen to figure out what impact CAH has on gender behaviour – how the behaviour of intersex children compares to that of typical girls or boys – later in life. "We, and others, have found that the play behaviour of girls with CAH is different to that of other girls," she explains. Her team assesses the toy choices made by three- to eight-year-old girls who had been treated for CAH immediately after birth. "Most girls tend to select dolls more than they would select vehicles or guns. Boys tend to grab the vehicles or the weapons. But girls with CAH are in between. They show more interest in the boy-typical toys and less interest in the girl-typical toys."

This CAH behaviour research is part of a wider study led by Melissa, into gender development in all children. "Why do girls and boys like different toys? Why do children group together to play with others of the same sex? Why are boys, say, more rough and tumble than girls are?" are just some of the questions she is trying to answer. And comparing play behaviour and maternal hormone levels during pregnancy is her tool of choice.

Male fetuses produce a surge of testosterone between weeks 8 and 24 of pregnancy. This then tapers off, and apart from a small surge after birth, the testosterone levels in boys and girls remain approximately the same until puberty. In a study of 14 000 children, Melissa has found that mothers with higher testosterone levels during pregnancy were more likely to have girls who were more masculine within the normal range, and that mothers with lower testosterone levels were more likely to have girls who were less masculine.

Melissa's observational studies allow the direct study of humans, in contrast to and complementing Eric's genetic approach. Eric is hopeful that his, and other scientists', research into intersex conditions will eventually lead to an easier life for those that fall outside society's accepted parameters of normal. "I'll feel happy if I achieved the goal of communicating to the general public that all those variants of sexual development, sexual orientation and gender identity are natural variants, and if, because we understand that they are natural variants, they become accepted in society."

Acknowledgements

This article is based on interviews given by Professor Eric Vilain and Professor Melissa Hines to the editors of *Science in School*, Dr Eleanor Hayes and Dr Marlene Rau. Some material was also taken from Melissa Hines' lecture[w3]. The lecture and interviews took place during the conference 'The Difference between the Sexes – from Biology to Behaviour', at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany.

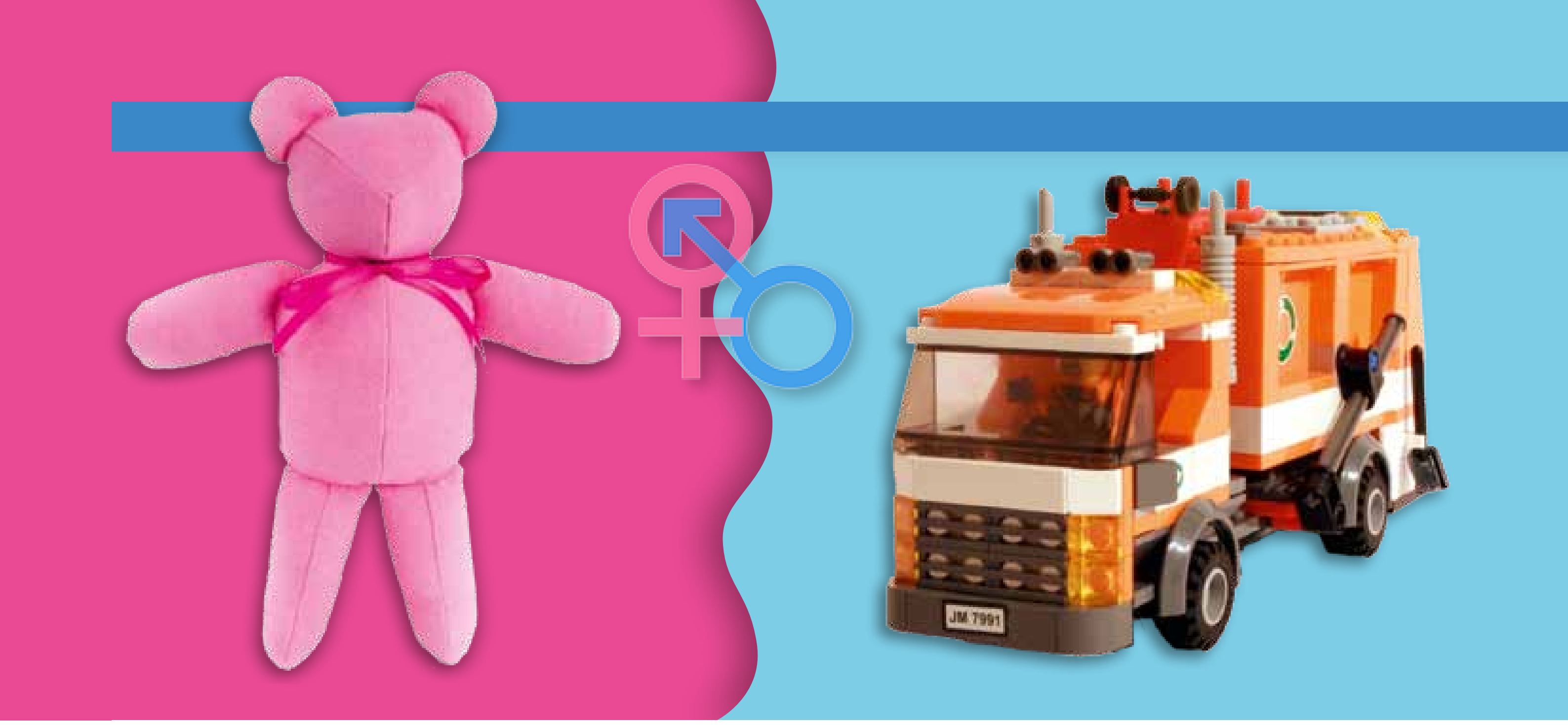


Image courtesy of ddpool; image source: Flickr

Image courtesy of James F Clay; image source: Flickr

References

Jordan BK (2003) Wnt4 overexpression disrupts normal testicular vasculature and inhibits testosterone synthesis by repressing steroidogenic factor 1/β-catenin synergy. *Proceedings of the National Academy of Sciences of the United States of America* **100(19)**: 10866–10871. doi: 10.1073/pnas.1834480100

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 resources

w1 – To find out more about the research of Eric Vilain and his team, see the Gender Center website: www.genetics.ucla.edu/gendercenter

w2 – To learn more about Melissa Hine's research, see the University of Cambridge website (www.neuroscience.cam.ac.uk) or use the direct link: http://tinyurl.com/melissahines

w3 – For a video of Melissa Hine's talk , see: www.embl.de/melissahines

w4 – EMBL is Europe's leading laboratory for basic research in molecular biology, with its headquarters in Heidelberg, Germany. To learn more, see: www.embl.org

w5 – To listen to Mathias Treier discussing his study of sex determination in mice, visit: www.youtube.com/watch?v=-oL7RKUNchY

w6 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

To learn more about intersex and its ethical and physiological implications, see the website of the Intersex Society of North America: www.isna.org

The Howard Hughes Medical Institute (HHMI) website offers an interactive online activity to investigate sex and gender within the context of testing female athletes. See the HHMI website (www.hhmi.org, search for 'gender test') or use the direct link http://tinyurl.com/hhmigender

For a series of HHMI holiday lectures on sex determination, given by specialists in the field and aimed at secondary-school students, see the HHMI Biointeractive website (www.hhmi.org/biointeractive) or use the direct link: http://tinyurl.com/hhmisexdetermination

The website also includes downloadable animations to accompany the lectures.

For the transcript of another interview with Eric Vilain, see the Anneberg Learner website (www.learner.org; search for 'vilain'), which provides resources for school teachers, or use the direct link: http://tinyurl.com/c3uszbw

If you found this article interesting, you may like to browse the rest of the medicine-related articles in *Science in School*. See: www.scienceinschool.org/medicine

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Dr Nina Notman is a science writer and editor. After her PhD in synthetic organic chemistry at the University of Bristol, UK, she started a career in publishing, managing the peer-review process of a number of the UK's Royal Society of Chemistry journals. She then moved into science journalism, working on the society's flagship magazine, Chemistry World. In early 2012, Nina left the magazine and went freelance.

To learn how to use this code, see page 65.


Image courtesy of NASA

Mars

The white continent as a stepping stone to the red planet

For scientists at the European Space Agency, a mission to Mars means going to Antarctica first.

By Oli Usher

Three kilometres above sea level, 1000 km inland and -60 °C, Dome C, an ice plateau deep in the Antarctic interior, is one of the most remote and inhospitable places on Earth. Since 2005, it has also been home to the staff of the French-Italian Concordia research station[w1].

The tough environment is a constant challenge to the team that lives there year round. Concordia is busy for the short Antarctic summer, when up to 50 staff call the base home. But after the last plane of the season leaves in late February, Concordia is cut off from the world. For the next eight months, the skeleton crew of 12-14 scientists, engineers and support staff are on their own.

This combination of isolation and extreme conditions makes Concordia an interesting place for the European Space Agency (ESA; see box on page 54): it's about as close to a space mission as you can get without leaving Earth. So while Concordia's scientists study astrophysics, glaciology, seismology and the hole in the ozone layer, an ESA-sponsored researcher lives among them, observing the station's crew for clues about how a long space mission might affect the physical and mental health of astronauts.

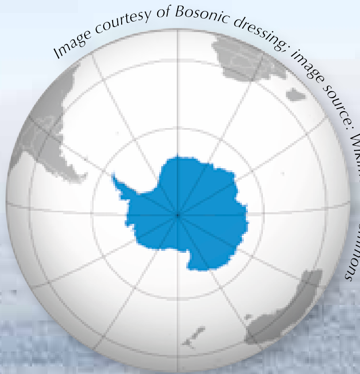
Image courtesy of Bosonic dressing; image source: Wikimedia Commons

REVIEW

- Biology
- Medicine
- Physics
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- Human biology
- Physiology
- Space
- Antarctica
- Ages 11+

This article explains how an investigation of daily life for the crew living at the Concordia research station, on an ice plateau deep in the Antarctic, has enabled scientists to gain a deeper understanding of the implications of long space missions on astronauts' physical and mental health.

There is a great interdisciplinary potential in this article. At lower secondary-school level it can be used as a starting point for a group discussion around the relationship between science, technology and society. Alternatively, students could list the major health challenges facing astronauts during a space trip, which are referred to in the article, and discuss the solutions presented based on research findings.

For upper secondary-school level, I believe the most appropriate subject would be biology, using the article as a starting point to reflect on homeostatic mechanisms and on how the body is influenced by external factors (such as light). Students could also discuss astronauts' health challenges. This can be extended by investigating and reflecting on other major challenges that will have to be considered in future space missions, which are not referred to in the article. Students should suggest possible ways of investigating the impact of those factors.

Betina da Silva Lopes, Portugal

Images courtesy of ESA

Crew training for Marswalk at the simulated Martian terrain of the Mars500 experiment

Mars500's 'one year in isolation' photo

"If you look at the expected characteristics of a future mission to Mars, for example," says Oliver Angerer, ESA's co-ordinator for research at Concordia station, "those scenarios typically also have a very small crew size, even smaller than the crew of Concordia: most scenarios have four to six crew members. And those people are also in a confined space, in a very harsh environment – of course, the vacuum of space; where the normal day and night cycles are absent, where you have very limited resources, where you have to deal with any emergency that comes up with the resources that you have at hand."

ESA's interest in this kind of scenario also underpinned the recent Mars500 experiment[w2], in which volunteers were sealed in a spaceship simulator for 520 days, the expected duration of a round trip to the red planet. In some ways, such as the very close confinement and the selection of the crew, the Mars500 simulation was more similar to a space mission than the Concordia scenario. The crew of Mars500, however, were exposed to no real dangers and were carrying out a scientific programme well beyond what would ever be reasonable in a space mission. In those respects, Concordia provides a more realistic analogue of space travel. "When researching space travel, we need both simulations and analogues; they are complementary, as their advantages and disadvantages essentially mirror each other," explains Oliver.

The small group that lives at Concordia over the Antarctic winter is a little bigger than the crew of a space mission, but the pressure on their mental and physical health is similarly intense. For this reason, nobody lives on the base permanently – the staff members are exchanged every summer. This goes for the ESA-sponsored researcher too – the latest arrival is Alexander Kumar[w3], a British doctor who arrived at Concordia in January 2012.

This regular turnover has allowed for interesting comparisons between different crews. Research on the very first group to spend winter on the base, in 2005, revealed that they generally coped better than those that came after them, perhaps because they had to work together on the big task of finishing the construction and commissioning of the station. This kind of shared objective is an important way of keeping morale up.

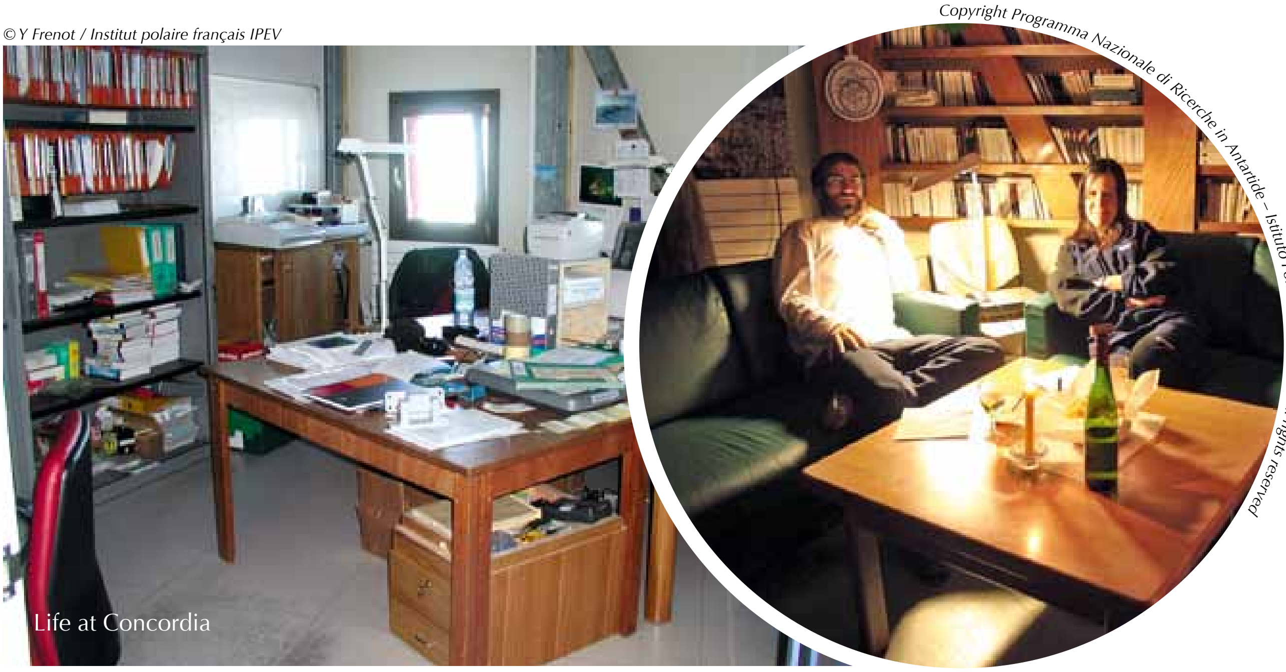
Sitting down together to share meals also helps, Oliver says, particularly in the three months in the middle of winter when the Sun does not rise above the horizon. "It's something that gives a bit of a structure," he says, "especially because there is no obvious day or night." Shared meals aren't

More about ESA

The European Space Agency (ESA)[w6] is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world.

ESA is a member of EIROforum[w7], the publisher of *Science in School*.

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



Life at Concordia

always possible, though – life at Concordia is busy. A lot of the research there is astronomy, and the astronomers are often on a different schedule to the rest of the crew.

Under normal conditions, a surprising amount of our physiology and behaviour follows a *circadian* (daily) rhythm – not only our sleeping and eating patterns, but also our core body temperature, blood pressure, metabolic rate, brain-wave activity and hormone levels. Our circadian rhythm responds to the regular cycles of light and dark. The lack of an apparent night and day for part of the year, therefore, is a big issue facing the crew of the Concordia, and would face the crew of a Mars mission, too.

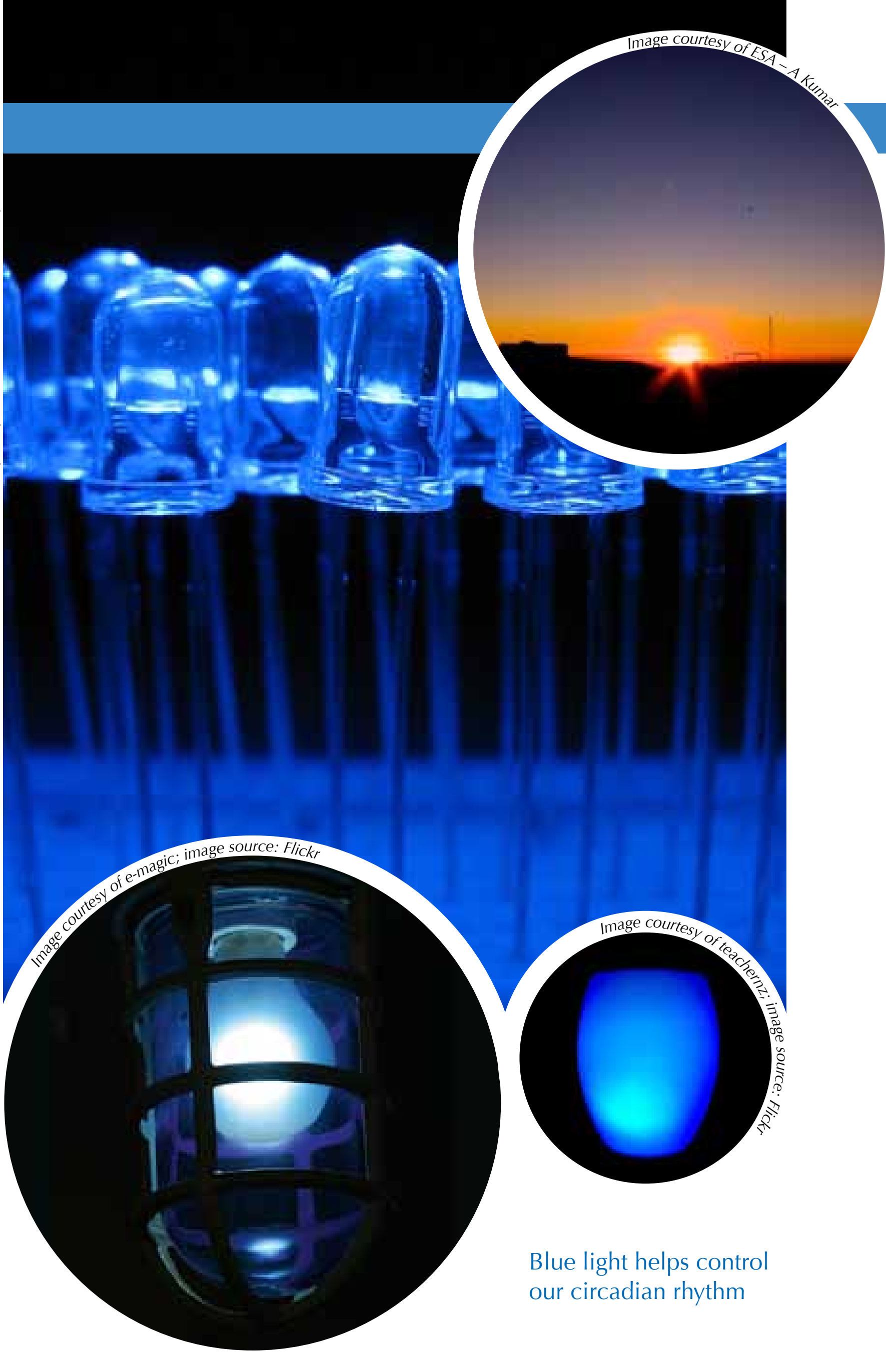
There are some surprisingly simple things that can be done about it though. One of the experiments at Concordia, for example, involved subtly changing the colours of the lights inside the station's buildings. "Tests have shown that we don't only have rods [the cells that detect light and dark] and cones [which give us colour vision] in our eyes as light receptors; there is also a third receptor that is especially sensitive to blue light," Oliver explains[w4]. "And that is not only used for vision, if at all, but also more directly linked to the sensors in the brain that control our circadian rhythm."[w5]

It turns out that standard indoor lighting, even though it looks white to us, is missing a lot of the blue part of the spectrum that our brains expect during daylight hours, so our bodies don't perceive the subtle clues that keep our body clock ticking normally. The solution? Install bluer lighting in the working areas of the station, and redder (less blue) lights in the sleeping quarters. Result? A better night's sleep.

Living in a small group in confined spaces also has an effect on the physical health of the station's crew. The isolation means they get no infections from outside, leading to their immune systems weakening. But at the same time, living at such close quarters means that any infections that are present in the station are soon shared by everyone. One more way in which life at Concordia is similar to life in space.

"If you're there, you really get the impression that you are as close to being on a different planet as you could be while staying on Earth," says Oliver. With the last flight of the Antarctic summer having left, Alexander Kumar will be finding out just how true that is.

The Concordia research station



Concordia enjoying its last sunset for four months

Blue light helps control our circadian rhythm

Acknowledgement

This article is based on an interview given by Dr Oliver Angerer to the editor-in-chief of *Science in School*, Dr Eleanor Hayes.

Web references

w1 – To find out more about the Concordia Base and the scientific research carried out there, visit: www.concordiabase.eu

w2 – To learn more about the Mars500 project, see: www.esa.int/mars500

w3 – Alexander Kumar's website includes a blog and details of his work. See: www.alexanderkumar.com

w4 – For more information on how the human eye perceives colour, see the 'Neuroscience for kids' pages on the University of Washington website (www.washington.edu; search for 'retina kids') or use the direct link: http://tinyurl.com/c3sl9c5

Some of the 'Neuroscience for kids' pages are available in Belarusian, Chinese, Dutch, German, Italian, Japanese, Korean, Portuguese, Russian, Serbian, Slovene, Spanish, Telugu and Turkish.

w5 – To learn more about the link between blue light and the circadian rhythm, see the article 'Bring back the night – your health and wellbeing depend on it' by neuroscientist Professor Russell Foster on the *Guardian* website (www.guardian.co.uk; search for 'circadian blue') or use the direct link: http://tinyurl.com/6xafcr3

To listen to or download a podcast interview ('The science of sleep and circadian rhythms') with Professor Russell Foster, visit the *Guardian* website (www.guardian.co.uk) or use the direct link: http://tinyurl.com/c2a7m9s

w6 – For more information about ESA, see: www.esa.int

w7 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

To read the blog of Alexander Kumar's predecessor, Eoin Macdonald-Nethercott, see: http://eoin-at-antarctica.blogspot.com

If you found this article interesting, why not take a look at the full list of articles on science topics published in *Science in School*? See: www.scienceinschool.org/sciencetopics

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Oli Usher is a science writer. He has a postgraduate degree in the history and philosophy of science, and has worked in journalism and science communication. He is currently the public information officer for the NASA/ESA Hubble Space Telescope.

To learn how to use this code, see page 65.

Nuclear options: a teacher at CERN

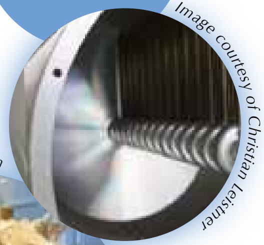
Physics teacher Günter Bachmann explains how his CERN residency has inspired both him and his students.

By Susan Watt

When Günter Bachmann, head teacher of a school in the German state of Saxony, enrolled on a one-week training course at CERN, the world's largest particle physics laboratory (see box), he had high expectations of the course – but he wasn't expecting to be asked back as a teacher in residence. However, that's exactly what happened. As a teacher of physics for some 30 years, Günter knew how to make the most of the opportunity, and now views it as the most exciting moment of his career so far.

"It's widened my understanding of modern physics and international science management enormously," he says. "It's also given me the chance to interest students in new questions and developments."

During his residency in 2011, Günter worked with Rolf Landua, the head of education at CERN, to develop a



A particle accelerator at CERN's LINAC2 experiment

Image courtesy of Christian Leistner

A segment of the LHC

Image courtesy of Yassin Haijan

Visiting the ATLAS experiment at the LHC

Image courtesy of Yassin Haijam

Experimenting with superconductivity

Image courtesy of Yassin Haijam

Aerial view of CERN with the LHC marked in red

Image courtesy of CERN

One of the CERN buildings

Image courtesy of CERN

Physics

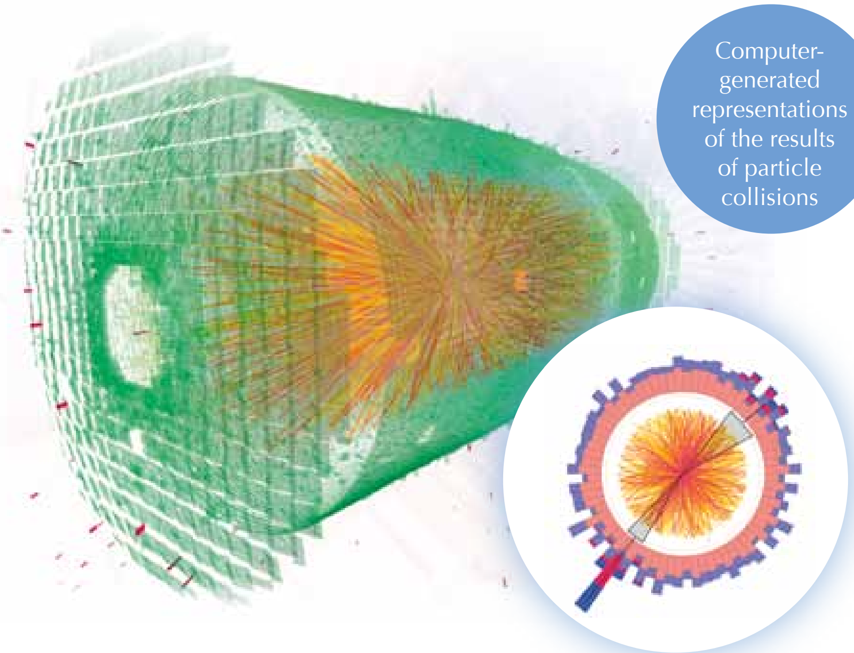
collection of teaching materials for students aged 14 to 16 on the topic of cosmic radiation. The resource was designed with clear ideas about what was needed: it should add "joy and interest" to the study of physics, and – as far as possible – avoid mathematical and specialist terminology.

Since then, Günter has been busy passing on the benefits of his experience to his students. "I've tested the materials with a class of students and received remarkably positive feedback – especially considering that this class is not among the highest achieving at the school," he says. The material will soon be available on the CERN website, in both English and German[w1].

His time at CERN also emphasised for Günter the importance of current research results being covered in the school physics curriculum, to show the true, open-ended nature of scientific enquiry. "The methods of working [at CERN], which were open to many different conclusions, were very unfamiliar to me, since they represent quite the opposite of the totally organised life at school," he explains.

Initially, it took a while for Günter to settle in to life at CERN. "I had some problems in finding my way around the large CERN grounds, and also getting used to speaking English, which is the standard working language there," he says. But this gave him another educational insight. "Students should be educated in both science subjects and the English language," he argues. "One cannot work properly without the other." He believes that learning English is a significant advantage for talented science students, as they will need it if they go on to study at an advanced level.

Günter now feels that such opportunities of practical training at research institutions should be available to more science teachers (see Furtado Neves, 2012, and box)[w2]. He would also like to see more support given to physics teachers to help them keep up with developments in their subject.



Computer-generated representations of the results of particle collisions

Images courtesy of CERN

"As some time has passed since my graduation from university, I would like to see a course of lectures – perhaps online – about the discoveries and developments in physics during the past 40 years," he says.

He firmly believes that modern physics should have a stronger presence in his classes – but this is easier said than done. "In Saxony, more than 90 % of the physics curriculum is predetermined. For the remaining 10 %, teachers must choose between set topics – which means they have very little chance to introduce their own ideas," Günter says. He would especially like to see more coverage of particle physics, including the *standard model* – the established theory of fundamental forces and particles that was developed in the 1970s.

Günter himself graduated from the University of Leipzig, Germany, as a mathematics and physics teacher in

More about CERN

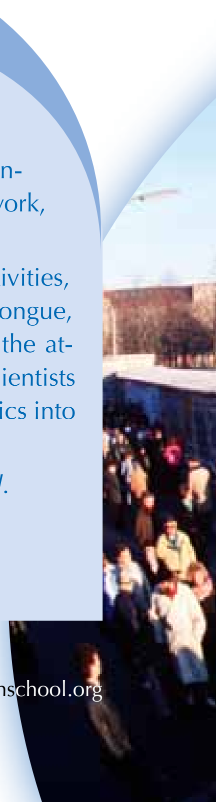
EIROforum

The European Organization for Nuclear Research (CERN)[w4] is one of the world's most prestigious research centres. Its main mission is fundamental physics – finding out what makes our Universe work, where it came from, and where it is going.

CERN's mission also covers education. As part of its education activities, CERN offers courses for physics teachers in English or in their mother tongue, lasting between three days and three weeks. Participants experience the atmosphere of frontier research at the Large Hadron Collider, meet scientists and teaching colleagues, and find new ideas for bringing modern physics into the classroom.

CERN is a member of EIROforum[w5], the publisher of *Science in School*.

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



1980, and has worked in this capacity since then, initially in East Germany and since 1990 in the unified Germany. His love of science was inspired by activities at home in his early years, as he explains: "As a child, I often built wooden water wheels with my grandfather, and tested them on small creeks. Sometimes we used the water wheels to power small-scale wooden hammer mills. I think my interest in the forces of nature and how they can be used by people developed during that time."

But his choice of physics was due not only to such inspirational experiences, but also to the political situation at the time. "I chose science as my field of study because, in former East Germany, I wanted to be able to teach subjects that were independent of any ideology or political propaganda," he says.

Early in 2012, Günter returned to CERN with 20 of his keenest students, for a packed three-day programme[w3]. While there, the group constructed their own cloud chamber for detecting particles (see Barradas-Solas & Alameda-Meléndez, 2010) and analysed data from CERN's giant particle accelerator, the Large Hadron Collider (LHC; see Landua & Rau, 2008, and Landua, 2008).

Now back at his school, what other changes would Günter like to see in physics teaching in his region? "There should be more freedom for teachers in designing the curriculum," he says, "and an additional hour of physics each week would give sufficient time to reinforce fundamental knowledge and conduct experiments." All good training for the aspiring scientists of Saxony.

References

Barradas-Solas F, Alameda-Meléndez P (2010) Bringing particle physics to life: build your own cloud chamber. *Science in School* **14**: 36-40. www.scienceinschool.org/2010/issue14/cloud

Furtado Neves S (2012) Diving into research at the EIROforum teacher school. *Science in School* **22**. www.scienceinschool.org/2012/issue22/efschool

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

Web references

w1 – The teaching materials that Günter developed while at CERN can be downloaded (in both English and German) from the CERN website: http://education.web.cern.ch/education

w2 – The Science on Stage international science teaching festivals offer participating teachers the chance not only to exchange inspiring teaching ideas, but also to attend lectures and presentations on cutting-edge scientific topics.

Physics

The Berlin wall in 1989, shortly before it was torn down. The Brandenburg Gate can be seen in the background

Image courtesy of Ben-nb; image source: Wikimedia Commons

One of the few remaining stretches of the Berlin wall in 2010

Image courtesy of Andrew Brown

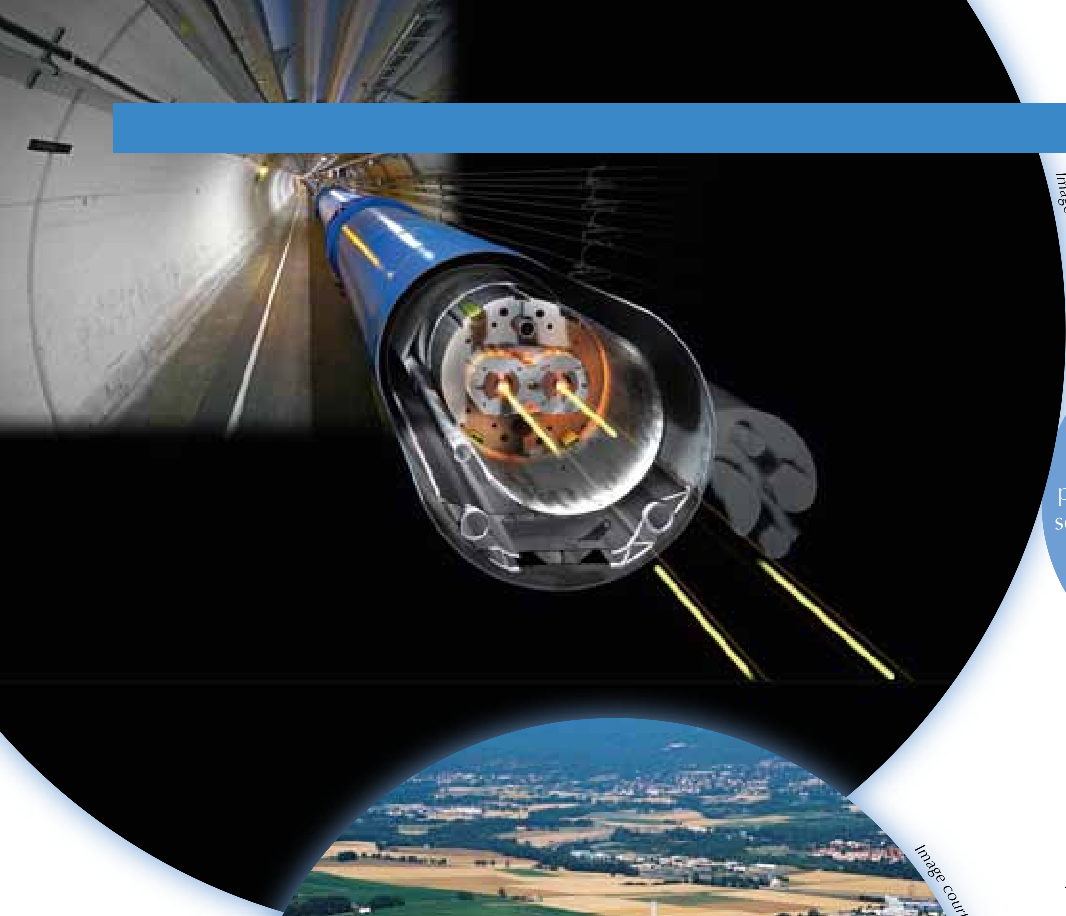


Image courtesy of CERN

Cross-section of one of a series of LHC magnets, used to keep particles on the circular path through the tunnel. CERN scientists are interested in what happened when two streams of particles collide

Image courtesy of CERN

Aerial view of CERN's main site

The next festival, in April 2013, will take place in Słubice-Frankfurt (Oder) on the Polish-German border. Each country will be represented by a delegation of teachers selected in national events. Participation is free for the delegates. To be considered for your national delegation, contact your national organisers as soon as possible, because the selection events are already beginning in some countries. There will also be a limited number of places for non-delegates, who will be charged a registration fee. See the Science on Stage Europe website: www.scienceonstage.eu

Science on Stage was launched in 1999 by EIROforum[w5], the publisher of *Science in School*.

w3 – The students' report (in German) of their trip to CERN is available on the school website: www.graupnergym.de/8Schulleben/studienfahrt.html or via the shorter link: http://tinyurl.com/7c7yr9r

w4 – To learn more about CERN, visit: www.cern.ch

w5 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

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

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Susan Watt is a freelance science writer and editor. She studied natural sciences at the University of Cambridge, UK, after which she did a master's degree in the philosophy of science. After several years spent producing science exhibitions for the Science Museum (London) and for the British Council, she moved into publishing. Currently, Susan is a school governor.

To learn how to use this code, see page 65.

High-powered research: physicist Adrian Mancuso

Adrian Mancuso

Image courtesy of European XFEL

Physicist Adrian Mancuso works at the cutting edge of 3D imaging, at what will be Europe's newest and brightest X-ray facility.

By Susan Watt

The use of 3D imagery has gone beyond the gimmickry of monsters leaping out to scare you in the cinema. Today, using ultrahigh-powered X-rays instead of light, it's being used to yield precise knowledge of the shape of molecules. At the European X-ray Free Electron Laser (European XFEL)[w1] in Hamburg, Germany, this knowledge could, in a few years, enable new drugs to be tailor-made to control diseases.

Working at the forefront of X-ray 3D imaging is physicist Adrian Mancuso, a scientist with a life-long curiosity about all aspects of the physical world. As a child, Adrian was an avid observer of the natural world and a keen reader of science books, which started him on the path to his current position as a leading scientist at the European XFEL, a giant X-ray laser that is currently under construction.

"What we're trying to do is make high-resolution 3D images of biological molecules, as well as of other materials, so we can better understand how they work," says Adrian. "In particular, we're trying to image the kinds of molecules that can possibly only been seen with an X-ray laser."

So how did a physicist like Adrian find himself working on biological molecules? He says: "I took a physics PhD that focused on how to use laser-like X-rays for imaging – really exploring the methods of X-ray imaging. That background, and my subsequent experience of performing this kind of experiment, provided me with the right knowledge to design an instrument for X-ray diffractive imaging at the European XFEL."

Which is exactly what he is now doing. Adrian says: "Right now I'm building an instrument to do a kind of X-ray imaging called single-particle imaging. These single particles can be anything from tiny crystals to biomolecules to novel materials that we want to understand the structure of. This work is fascinating, because it combines new ideas in physics and mathematics with state-of-the-art technology to produce practical, applied research that just might change the world around us for the better."

Adrian clearly enjoys his job, enthusing that "every day is different, fun and challenging". His enthusiasm

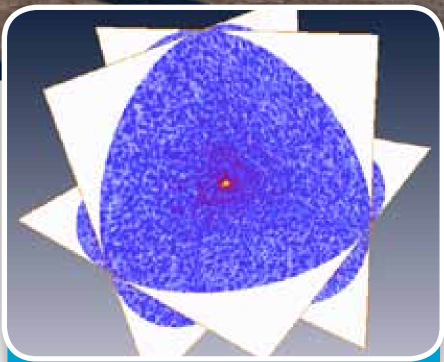
An artist's impression of how the central building of European XFEL will look. The tunnels from which the laser-like X-ray flashes are led to the experiment stations will end in the underground experiment hall beneath the main building. This will house laboratories and offices, seminar rooms, an auditorium and a library

Image courtesy of European XFEL

for research and physics goes back to his early years, as he recalls: "I was always naturally curious. I wanted to understand how things worked, how the Universe works. My parents helped feed that curiosity when I was young by giving me mountains of science books to read. I guess it kept me out of trouble!" Adrian's curiosity became focused on physics when he found one of his father's physics textbooks. "I read it from cover to cover. I just found it so interesting that there was so much to understand about the physical world around us."

Adrian's interests were encouraged at school too. "I was fortunate to have enthusiastic science teachers, who allowed and even encouraged me to use the physics lab out of hours, design experiments, test ideas – and occasionally break stuff."

After he left school, Adrian studied for a science degree at the University of Melbourne in Australia, with a major in physics, followed by a PhD at the same institution. So although he has come halfway around the world, from Australia to Hamburg, to work at the European XFEL, he clearly feels it's been a good move.



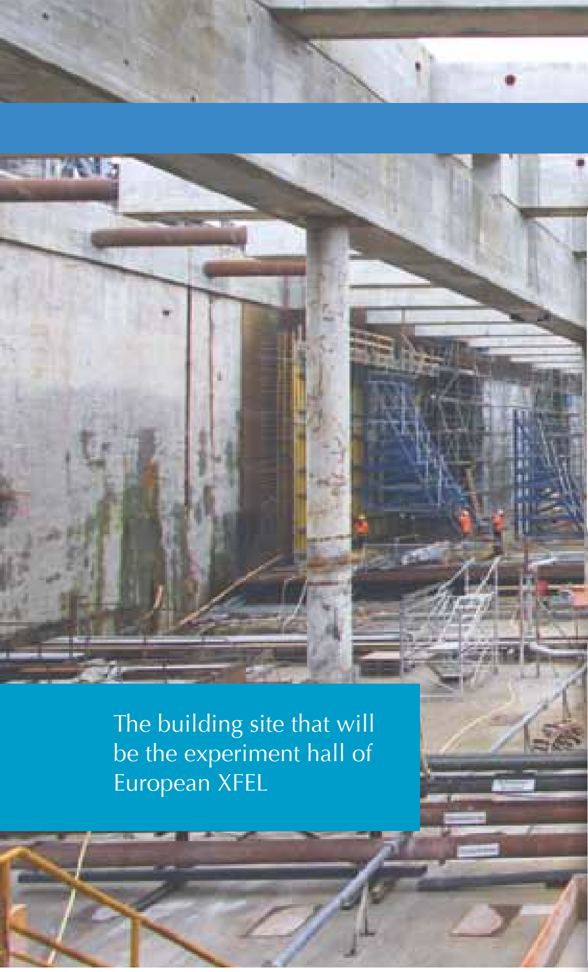
Visualisation of the 3D simulated diffraction pattern of a 3-phosphoglycerate kinase molecule. This is a representation of what 'perfect' diffraction data collected at European XFEL may look like

Image courtesy of Z Jurek and B. Ziaja (CFEL), and AP Mancuso (European XFEL)

"There are very few places in the world where one can hope to image non-crystalline biomolecules well enough that the imaged structure may be useful for drug design, or practical applications," he says. "The European XFEL is at the forefront of single-particle imaging research worldwide."

Adrian also thrives in the international team environment at European XFEL, where the staff come from six continents and more than 18 countries. He believes that the cross-cultural interactions and opportunities to learn about different parts of the world from colleagues is a "wonderful bonus to the top-class work we get to do each day". He explains: "People from different places sometimes see the world around us in different ways. These different perspectives can have a positive influence by diversifying how we think about things – which can be essential for solving scientific problems."

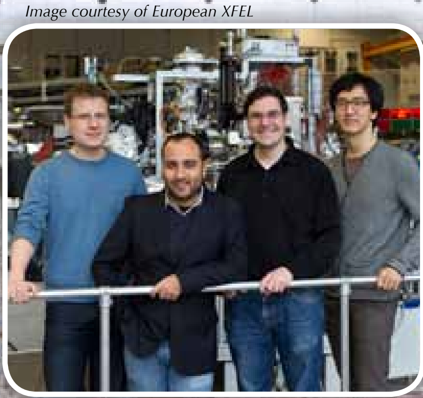
As well as being passionate about his research, Adrian feels it is important to convey the joys of science to a wider audience – and he has had plenty of fun in the process. From helping to put on a science show for junior students while he was at high school – which was so popular he became known as "the guy from the science show" – to inviting high-school students to see how science is done in universities and laboratories and what it's really like to work in them, Adrian has been involved in sharing his enthusiasm for science at every stage of his career. He says he found the activities with students "very rewarding, as the students got a clearer picture of 'doing' science in practice, not just in the classroom".



The building site that will be the experiment hall of European XFEL

Image courtesy of European XFEL

Image courtesy of European XFEL



Adrian Mancuso (second from the left) and his colleagues in the experiment hall of the free-electron laser FLASH at DESY (the German Electron Synchrotron) in Hamburg, Germany

Adrian Mancuso in front of the coherent X-ray imaging (CXI) instrument at the SLAC National Accelerator Laboratory in Stanford, California, USA

Image courtesy of DESY

Adrian Mancuso in the X-ray tunnel that connects the near and far experimental halls of the Linac Coherent Light Source at the SLAC National Accelerator Laboratory in Stanford, California, USA

So what advice would Adrian give to a student wanting to follow in his footsteps? "A good start would be to study physics. If you want to make images of things, it helps to have some knowledge of optics – in our case, especially the strange but fun world of X-ray optics," he says. "This is an increasingly popular field of research, as there is rapid progress in the use of bright, laser-like X-ray sources across the world."

And he would have no hesitation in recommending the intellectual pleasures to be gained from a career in research. Adrian says: "That moment when you realise that you and your colleagues in the room are the only people on the planet that, at that moment, have observed something unique – that's something that one always remembers."

Web reference

w1 – To learn more about European XFEL, see: www.xfel.eu/overview/in_brief

Resources

To find out more about Adrian Mancuso's work, read the abstract of a talk he gave at the recent EIROforum teacher workshop ('Finding the structure of biomolecules using ultrabright, ultrashort pulses of X-rays'): www.epn-campus.eu/eiro-teachers-school/programme/lectures

To learn more about the EIROforum teacher workshop, see:

Furtado Neves S (2012) Diving into research at the EIROforum teacher school. *Science in School* **22**. www.scienceinschool.org/2012/issue22/efschool

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

Susan Watt is a freelance science writer and editor. She studied natural sciences at the University of Cambridge, UK, after which she did a master's degree in the philosophy of science. After several years spent producing science exhibitions for the Science Museum (London, UK) and for the British Council, she moved into publishing. Currently, she is a school governor.

To learn how to use this code, see page 65.

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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. Readers 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, readers 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
- Care is taken with normal laboratory operations such as heating
- Good laboratory practice is observed when chemicals or living organisms are used
- 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.

Credits

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EIROforum

***Science in School* is published and funded by EIROforum, a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combines the resources, facilities and expertise of its member organisations to support European science in reaching its full potential. See: www.eiroforum.org**

CERN

The European Organization for Nuclear Research (CERN) is one of the world's most prestigious research centres. Its main mission is fundamental physics – finding out what makes our Universe work, where it came from, and where it is going. See: www.cern.ch

EFDA-JET

The Joint European Torus (JET) investigates the potential of fusion as a safe, clean, and virtually limitless energy source for future generations. It can create the conditions (100-200 million °C) in the plasma sufficient for fusion of deuterium and tritium nuclei to occur – and it has observed fusion power to a maximum of 16 MW. As a joint venture, JET is collectively used by more than 40 European fusion laboratories. The European Fusion Development Agreement (EFDA) provides the platform to exploit JET, with more than 350 scientists and engineers from all over Europe currently contributing to the JET programme. See: www.efda.org/jet

EMBL

The European Molecular Biology Laboratory (EMBL) is one of the world's top research institutions, dedicated to basic research in the life sciences. EMBL is international, innovative and interdisciplinary. Its employees from 60 nations have backgrounds including biology, physics, chemistry and computer science, and collaborate on research that covers the full spectrum of molecular biology. See: www.embl.org

ESA

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. See: www.esa.int

ESO

The European Southern Observatory (ESO) is the foremost inter-governmental astronomy organisation in Europe and the world's most productive astronomical observatory. It operates telescopes at three sites in Chile – La Silla, Paranal and Chajnantor – on behalf of its 15 member states. At Paranal, ESO's Very Large Telescope is the world's most advanced visible-light astronomical observatory. ESO is the European partner of the revolutionary astronomical telescope ALMA, and is planning a 40-metre-class European Extremely Large optical / near-infrared Telescope, the E-ELT. See: www.eso.org

ESRF

The European Synchrotron Radiation Facility (ESRF) is one of the most intense sources of X-rays in the world. Thousands of scientists come every year to ESRF to carry out experiments in materials science, biology, medicine, physics, chemistry, environmental science, and even palaeontology and cultural heritage. See: www.esrf.eu

European XFEL

The European XFEL is a research facility currently under construction in the Hamburg area of Germany. It will generate extremely intense X-ray flashes to be used by researchers from all over the world. See: www.xfel.eu

ILL

The Institut Laue-Langevin (ILL) is an international research centre operating the most intense steady neutron source in the world. Every year, more than 800 experiments are performed by about 2000 scientists coming from all over the world. Research focuses on science in a variety of fields: condensed matter physics, chemistry, biology, nuclear physics and materials science. See: www.ill.eu

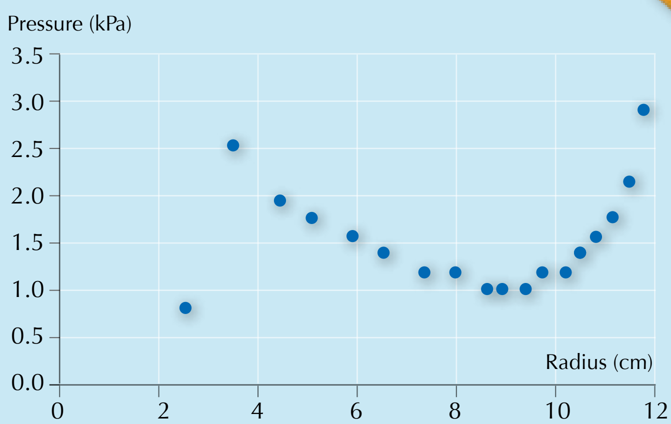
Image courtesy of Zscout370; image source: Wikimedia Commons

Science on Stage: a Slovak-British relationship

Image courtesy of Anomie; image source: Wikimedia Commons

For two science teachers from opposite ends of Europe – **David Featonby** and **Zuzana Ješková** – Science on Stage was the beginning of an inspiring and enjoyable collaboration.

Our collaboration began in 2009, when David ran a workshop entitled 'What Happens Next?' at the Science on Stage teaching festival[w1] in Berlin, Germany. There, he challenged the participants to predict the results of simple experiments that have unusual outcomes (Featonby, 2007). Zuzana was particularly intrigued by one experiment – the 'two balloons surprise' (figure 1) and decided to investigate it further with her students back home in Košice, Slovakia. Correspondence



Images courtesy of David Featonby

Figure 1: The 'two balloons surprise'. What happens when the tap is opened? The small balloon blows up the bigger one, but why? The graph gives a clue: the air in the smaller balloon – which has a radius of 3-4 cm – is (counter-intuitively) at a higher pressure than that in the larger one, which has a radius of 6-8 cm. To equalise the pressure, the air rushes from one balloon to another. It is also possible for a larger balloon that has been inflated to near its maximum size to inflate a smaller balloon *(Featonby, 2009; Ješková et al., in press)*

Image courtesy of Zuzana Jeskova

David and Zuzana presenting their workshop at Science on Stage 2011 in Copenhagen

flowed between the UK and Slovakia as we modified the experiments and explored more ideas (Ješková et al., in press).

As a result of our correspondence, we developed and led a joint 'What Happens Next?' workshop at the 2011 Science on Stage international science teaching festival in Copenhagen, Denmark, sharing our new experiments and results with teachers from 27 European countries.

Science on Stage festivals offer a unique opportunity for teachers from across Europe to share their experiences and develop new ideas, and it doesn't have to stop when the participants return home – as we demonstrated. To encourage even more effective exchange of ideas, participants from the 2011 festival could apply for travel scholarships so that teachers from one country could share their ideas and skills with larger groups of teachers elsewhere. We successfully applied, and in March 2012, David flew to the University of PJ Šafárik in Košice to run a workshop with Zuzana for Slovakian physics teachers.

The workshop was part of a Slovakian teacher-training course, 'Inquiry activities in physics education', which was inspired by Science on Stage and encourages the use of interesting and stimulating ideas, experiments and projects in teaching. Through lectures and workshops, excursions to research sites and independent activities, the participants develop their own ideas for motivating and attracting students to science. After 40 hours of direct learning and 25 hours of distance learning spread over the academic year, each participant develops a project to trial at his or her school. The course is planned to be run each year in Košice. The best ideas will be selected for the Slovakian national Science on Stage festival[w2]. There, some of them may even be chosen to be a part of the international festival.

During the workshop in March, we challenged participants to predict 'What Happens Next?'. The experiments, which use everyday equipment, were chosen to highlight misconceptions and to develop thinking skills. In many ways, this put the teachers in the position that students often find themselves in – that of being unsure of the answers. Puzzling outcomes were then discussed; many of the Slovak teachers spoke English, but Zuzana was on hand to translate if necessary. Some of the experiments are detailed below, others can be found in Featonby (2007).

Balanced spoon

Balance a wooden spoon at its centre of mass. Then cut the spoon at that point and weigh the two halves. Which is heavier, or do the pieces weigh the same?

Image courtesy of David Featonby

The centre of mass of the head is nearer to the pivot than that of the spoon´s handle. Applying the principle of moments in equilibrium, the head must weigh more

Backwards clock

What happens to a backwards clock when we look at its reflection in the mirror? See images at the bottom.

Floating orange

On a balance, place an orange with a glass of water beside it. What is the reading? Next place the orange in the glass, so it floats without touching the sides. Does the reading on the balance stay the same, increase, or decrease? See images below.

Finger in water

Place a glass of water on a balance and note its mass. Lower your finger into the water without touching the sides. What happens to the mass this time? See images below.

Our Slovak-British exchange was beneficial not just to the participants on the course. Both of us learned from

Images courtesy of David Featonby

The mass stays the same, regardless of whether the orange is inside or outside the glass, so the reading does not change. This is because the same material is on the balance. The apparent loss in mass of the orange is compensated by the weight of water it displaces: the upthrust on the orange has a consequent down-thrust on the water

Images courtesy of David Featonby

The mass increases due to the reaction force acting on the water, itself the result of buoyant force acting on your finger

Images courtesy of David Featonby

Backwards clock (left) and its reflection in the mirror (right). When viewed in the mirror, the anticlockwise rotation of the hands of the backwards clock becomes clockwise and the figures' positions change to that of a normal clock our collaboration, developing further ideas for experiments and co-operation, and also discovering different national approaches to teaching and teacher training. And to our surprise, we realised that the challenge of explaining ideas in a foreign language can actually help make the explanations clearer. We found that international co-operation between science teachers can greatly enrich the quality of teaching – and also form the basis of long-lasting friendships.

References

Featonby D (2007) What happens next? A teaching strategy to get students of all ages talking. *Science in School* **7**: 24-27. www.scienceinschool.org/2007/issue7/whathappens

Featonby D (2009) Balloons hold the key to inflation. *Physics Education* **44**: 344. doi: 10.1088/0031-9120/44/4/F05

Ješková Z, Featonby D and Feková V (in press) Balloons revisited. *Physics Education*

Web references

w1 – Science on Stage is a network of local, national and international events for teachers, initially launched in 1999 by EIROforum, the publisher of *Science in School*. At each national Science on Stage event, a delegation of teachers is selected to represent their country at the Science on Stage international teaching festival. The next international festival will be held on 25-28 April 2013, in Słubice-Frankfurt (Oder) on the Polish-German border. During the festival, 350 teachers from 27 countries will share their most innovative teaching ideas in workshops, on-stage performances and the teaching fair.

Participation is free for delegates. For other science teachers, there will be a limited number of places for which a registration fee will be charged. See the Science on Stage Europe website for details: www.science-on-stage.eu

Science on Stage was launched in 1999 by EIROforum[w4], the publisher of *Science in School*.

w2 – For more information (in Slovak) about Science on Stage Slovakia, see: http://ufv.science.upjs.sk/_projekty/science-on-stage

w3 – The Institute of Physics is a UK-based society that promotes physics. The society provides resources for schools, including professional development courses for teachers, student careers resources and high-quality teaching materials. See: www.iop.org/education/teacher/resources

w4 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

If you found this article inspiring, you might like to browse the rest of the Science on Stage articles in *Science in School*. See: www.scienceinschool.org/sons

David Featonby is a recently retired physics teacher from Newcastle, UK, with 35 years experience in the classroom. He now works as a teacher network co-ordinator for the UK's Institute of Physics[w3], and has recently become a member of the executive committee of Science on Stage Europe.

Zuzana Ješková is an assistant professor of physics at Faculty of Science, PS Šafárik University, in Košice, Slovakia. She works in physics education, dealing with pre-service and in-service teacher training.

To learn how to use this code, see www.scienceinschool.org/help#QR

Image courtesy of David Featonby

David in the physics lab with a group of enthusiastic Slovak teachers

The PhET website

Reviewed by Eric Deeson, UK

Physics Education Technology (PhET to its friends) is the slick but not very meaningful title of a site that offers a wide range of excellent interactive physics simulations for secondary-school and university students. Based at the University of Colorado, PhET includes simulations not only of pure physics, but also of physical phenomena in biology, chemistry and earth science. There is also a category of mathematics simulations. The fact that the site is US-based is not a problem, even in terms of units – which are metric.

The PhET simulations have been specially designed so that they can be easily translated. As a result, most of the simulations are available in an astonishing variety of languages – from German, Hebrew, Czech and Vietnamese, to Finnish, Greek and Serbian. You can use all of the simulations either by running them live on the website or by downloading them.

PhET is a great resource and is regularly updated (you can follow the latest developments on Facebook and Twitter), so do not be put off by the fact that the site looks rather dated and is difficult to navigate. Checking what is new is a danger in itself, as you can easily lose several hours in play… I mean exploration. At the time of this review, examples of simulations in the 'new sims' section of the website include 'isotopes and atomic mass', 'states of matter', 'membrane channels', 'gravity and orbits' and 'build a molecule'.

After selecting a simulation, you are presented with a list of sample learning goals in addition to downloadable teaching resources related to the simulation in question, such as student worksheets. These resources have been written by teachers and those that I have seen are of a very high quality. These are four of my favourites.

- The 'States of matter: basics' simulation, aimed at about Year 7 (ages 11-12), allows students to investigate the three main states of matter, exploring how raising and lowering the temperature affects samples of neon, argon, oxygen and water at the particle level.
- Students in Year 9 and above (ages 13+) can use the 'Gas properties' simulation to investigate the effects of volume, pressure, temperature and gravity on a gas, and discover how these properties vary in relation to each other.
- The 'Electric field hockey' simulation, suitable for students in Year 6 and above (ages 10+) is a more serious game. You have to try to control the path of a charged particle (the 'ball') through a complex space in which you place almost any number of fixed particles of the same and opposite charge. You can determine the charge and positions of the fixed particles, the mass of the ball, and the degree of difficulty, and choose whether or not to display the field lines and the ball's trajectory.
- Using the 'Capacitor lab' simulation, good Year 10 and more advanced students (ages 14+) can explore the workings of a parallel plate capacitor, altering the plate separation, area and dielectric to observe the resulting charge, field, voltage and stored energy and to perform the calculations as the applied voltage is changed. An extended version of this simulation on a separate tab allows the students to combine two or three capacitors in various ways and observe the effects.

You must visit this site if you are involved in teaching science or physics – preferably when you have an hour or two to spare. PhET is the best source of free and effective interactive simulations in physics that I have come across!

Details

URL: http://phet.colorado.edu

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Physics

The Wonder of Genetics: The Creepy, the Curious, and the Commonplace

By Richard V. Kowles

Reviewed by Michalis Hadjimarcou, Cyprus

The Wonder of Genetics is a user-friendly guide through the wonderful – and, to some, scary – world of genetics. Everyone can benefit from reading it: lay readers will have the opportunity to learn, in the first few chapters, the basic principles of genetics, whereas more knowledgeable readers will appreciate the more complicated material that follows (with the help of accompanying diagrams and the extensive glossary). Readers who are reasonably fluent in English will have no problem with the level of language used in the book.

Although they might be tempted to skip a few introductory pages, biologists and even geneticists will have a lot to learn from *The Wonder of Genetics*. The book contains the most recent facts and figures on well-known topics, clarifications of misconceptions about common applications of genetics, and the latest discoveries and advances in the field.

Every aspect of genetics, from the most common and well known that affect our daily lives and decisions to the most bizarre and unfamiliar, is explained in this book. The reader can learn how genetics might be responsible for, or at least involved in, a long list of traits and processes such as alcoholism, criminality, IQ, schizophrenia, ageing, evolution, genetically modified organisms and foods, gene therapy, DNA fingerprinting and cloning.

But *The Wonder of Genetics* is more than a collection of issues affected by genetics. Instead, the author goes a step further, discussing the implications of genetics and genetic discoveries for important areas, such as economics, politics, ethics, religion, racism, the media and even the movie industry.

A secondary-school biology teacher can find an endless supply of good quality instructive material in this book, including diagrams, descriptions of molecular genetic techniques and examples of genetically influenced diseases, their frequency in the population and current developments in the efforts made to cure them.

Students in advanced secondary-school biology classes (aged 16-18) can use *The Wonder of Genetics* to enhance their understanding of genetics and its many applications. They can also find excellent case-study material suitable for small projects, for example to look at the pattern of inheritance of various genetic traits. Furthermore, the book's coverage of issues that have provoked debates all over the world could be useful for interdisciplinary studies that encompass subjects from biology and sociology to religion and economics. Examples of such controversial topics are nature versus nurture, evolution versus creationism, the use of stem cells, and the creation of genetically modified organisms.

Details

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Inflight Science: A guide to the world from your airplane window

By Brian Clegg

Reviewed by Friedel Krotscheck, Austria

Holding this book in my hands as I boarded what would be an eight-hour flight, I planned to read the modest 204 pages whilst airborne. When we landed, I had managed just 70, thanks to all the observation, thinking and note-taking that *Inflight Science: A guide to the world from your airplane window* inspired.

Inflight Science uses science to explain every technical detail of a commercial aeroplane flight and helps address many of our preconceptions about flying. The book is best described as a science encyclopaedia written like a novel. It grabs you and will not let you go; every other page introduces a new flight-related scientific topic, connected to the next in logical sequence.

The author, Brian Clegg, keeps the reader entertained by covering a most interesting combination of unexpected topics, including archaeology, Newton's laws, the taste of aeroplane food, Maxwell's equations and brain function. Despite their broad range of subject matter, the chapters are neatly categorised, following the progress of a normal flight and covering topics that feature in the science curriculum of students aged 12-18.

The scientific information is not only presented in an unusual context, but also often explained in a very funny way, making it easy to remember. Understanding the principles of relativity or grasping the function of the human eye has never been easier. And reading the book while actually on a flight makes the learning experience even better – you can understand events as they happen.

Younger students (aged 12-16) could use *Inflight Science* as the basis of a project that simulates a flight, performing experiments and building models detailed by the author (some of these are even suitable to be carried out during a flight!). Such a project could be carried out over a whole school year, by the end of which students could become very literate in the relevant areas of science. With older students (aged 17-18), the book could be used more like a textbook.

I highly recommend *Inflight Science* to all science teachers who have been airborne at least once. Its use in the classroom will enrich the learning of numerous students through their teachers' new approach to familiar science. For this reason, it would be fair to change the last sentence of the book from "With science as your guide, the everyday will never appear quite so ordinary again" to "With *this book* as your guide, everyday *science* will never appear quite so ordinary again".

I have only one wish: that the book be translated into all languages so it can be available on every aeroplane.

Details

Publisher: Icon Books Ltd
Publication year: 2011
ISBN: 9781848312418

To date, only a translation into German (*Warum Tee im Flugzeug nicht schmeckt und Wolken nicht vom Himmel fallen*) is available.

Resources

If you found this review interesting, why not browse all the reviews in *Science in School*? See: www.scienceinschool.org/reviews

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