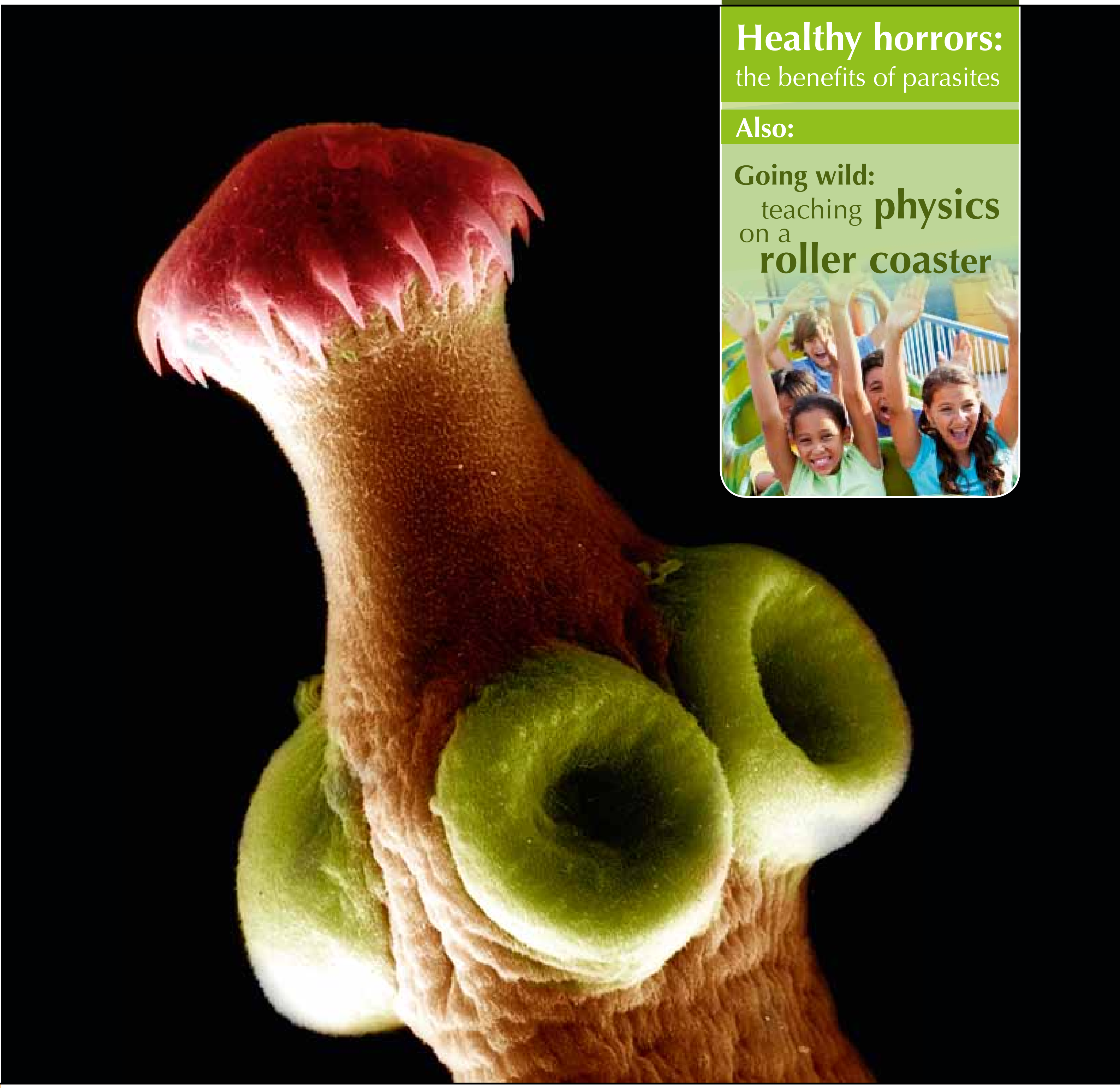
Autumn 2011 Issue 20

SCIENCE in SCHOOL

Highlighting the best in science teaching and research



In this issue:

Healthy horrors:
the benefits of parasites

Also:

Going wild:
teaching **physics** on a **roller coaster**

Published and funded by EIROforum

Editorial

I am delighted to announce that our publisher, EIROforum, has agreed to fund *Science in School* for a further two years, with enough money to cover the online production. We are also making every effort to continue printing your favourite science-teaching journal, for you to read on the train, refer to again and again, or share with colleagues, students and friends – but we need your help.

We have decided not to charge subscription fees, but this will only work with your support. Through the donations button on our website, you can now make your contribution to better science education in Europe: every cent we receive will go towards the costs of printing and distributing *Science in School*. For more details, see our website (www.scienceinschool.org). Please also encourage your friends and colleagues to donate, and help us continue the print journal – for you and your colleagues across Europe.

If you prefer to donate time rather than money, why not help us make our articles available to the many European teachers whose English is not at good as yours? With the help of many volunteers, we currently offer online articles in 28 European languages. Some languages – such as Spanish, Polish and Greek – are well represented, but we have very few translators for other languages – such as Croatian, French, Hungarian, Russian and Turkish. If you would like to translate *Science in School* articles from English into your mother tongue, please read the guidelines on our website (www.scienceinschool.org/submissions/translators) and then contact us.

The current issue contains enough exciting and useful articles to whet the appetite not only of budding translators but also of any *Science in School* reader. Dive deep into the human body to find out how parasites can be good for you (page 14); whether you are descended from a Neanderthal (page 6); or what – exactly – is happening in your guts (page 2). If that's all too close to home, you could give your students the physics lesson of their lives – in an amusement park (page 44); exploit their interest in cars (pages 36); fascinate them with some explosive and fizzy experiments (page 24); or get them to combat global climate change (page 60).

Or you could cast your thoughts still further afield and take a trip to the Arctic to see why fish don't freeze (page 18); get your students to search the skies for asteroids (page 30); or learn about electromagnetic radiation and its implications in astronomy (page 51). Finally, in our online-only articles, find out how young scientists are challenging pseudoscience or browse the many books and websites that our readers have reviewed.

Eleanor Hayes
Editor-in-Chief of *Science in School*
editor@scienceinschool.org
www.scienceinschool.org

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

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

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To read the whole issue, see: **www.scienceinschool.org/2011/issue20**

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Google, guts and gravity

Science in School is published by EIROforum, a collaboration between eight European inter-governmental scientific research organisations. This article reviews some of the latest news from the EIROforum members.

CERN: the 2011 Online Google Science Fair

CERN has teamed up with Google, Lego, *National Geographic* and *Scientific American* in a global science competition. More than 7500 international entries were received from students aged 13-18, who were competing for great prizes including internships and scholarships.

A public vote based on YouTube videos selected 60 semifinalists, and a jury of teachers and university professors narrowed this down to 15 finalists, whose projects ranged from winged keels to water turbines, from prosthetic limbs to computer programming. In the final round the grand prize went to 17-year-old Shree Bose from the USA, who worked on drug resistance in treating ovarian cancer. She will have the unique opportunity to spend three days at CERN, visiting the labs and experiencing science in the making. "I'm so excited to have the opportunity to travel to CERN and actually see the Large Hadron Collider," says Shree. "If it is running when I visit, I might be allowed to sit in the control room with the physicists – an incredible, once-in-a-lifetime experience."

For more information and to enter next year's competition, see: www.google.com/events/sciencefair and the CERN Bulletin (see: http://cdsweb.cern.ch/journal) or use the direct link: http://tinyurl.com/cerngoogle

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

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

Image courtesy of CERN

The control room at CERN, where winner Shree Bose hopes to visit

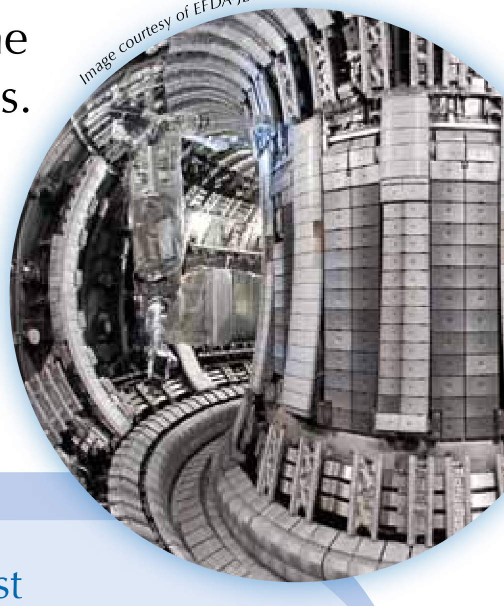


Image courtesy of EFDA-JET

The interior of the JET vessel with the new beryllium and tungsten tiles

EFDA-JET: just another brick in the wall?

Following the replacement of its carbon tiles with 4500 new beryllium and tungsten tiles, the Joint European Torus (JET) is gearing up for a crucial new set of experiments, to start in Autumn 2011. The interior tiles play a crucial role in any fusion experiment – acting as the first point of contact with the immensely hot fusion plasma (100-200 million °C). As well as withstanding the heat, they have to be resistant to the retention of tritium (a radioactive gas used as a fusion fuel) and to damage from the fast neutrons created in the fusion reaction. As part of the two-year renovation, JET's plasma heating power was increased by almost 50% – enabling scientists to study hotter plasmas that are closer to those likely to be produced by future fusion reactors.

The results from the 'new' JET will help to determine the interior configuration of ITER, the international successor to JET, and of the first fusion power plants.

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.jet.efda.org.

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

Image courtesy of ESA

AMS inside the ESTEC Test Centre's Maxwell electromagnetic radiation chamber for electromagnetic compatibility and interference testing

EMBL: gut reactions

One day, your doctor might ask you not just about your allergies and blood group, but also about your gut type. This is one of the implications of a new study carried out by Peer Bork's group at the European Molecular Biology Laboratory, and collaborators from the international MetaHIT consortium (Metagenomics of the Human Intestinal Tract). In an analysis of data from more than 100 people from three continents, the scientists found that, depending on the combination of bacteria in their gut, each person could be said to have one of three gut ecosystems, or enterotypes.

Although these gut types as such are not related to traits like a person's age, gender, weight or nationality, certain bacterial genetic markers are: for example, bacteria in older people's guts tend to produce more starch-degrading enzymes. Such markers could one day help diagnose medical conditions, and treatments could be adapted to a patient's gut type, as different gut types may react differently to medication and diet.

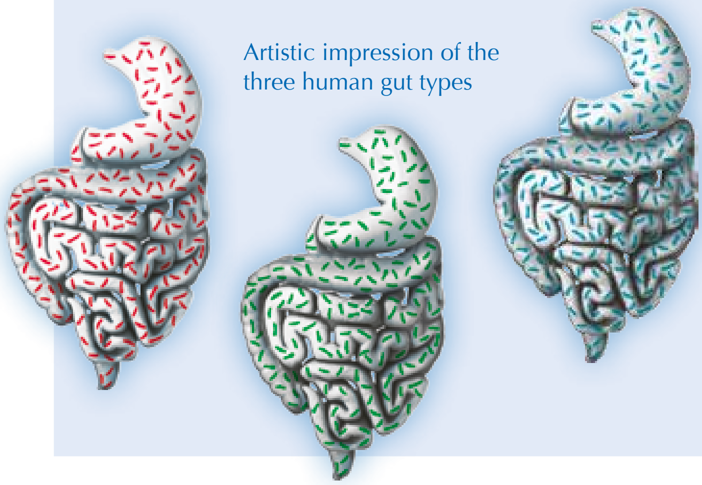
For more information, see the press release (at www.embl.de or via the direct link http://tinyurl.com/guttypes) and the research paper:

Arumugam M et al. (2011) Enterotypes of the human gut microbiome. *Nature* **473**: 174-180. doi: 10.1038/nature09944

Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2011/issue20/eiroforum#resources), or subscribe to *Nature* today: www.nature.com/subscribe

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

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



Artistic impression of the three human gut types

Image courtesy of EMBL / Petra Riedinger

ESA and CERN: in search of dark matter and antimatter

On 16 May 2011, the Alpha Magnetic Spectrometer (AMS) was launched on board the DAMA mission. Accompanied by astronaut Roberto Vittori from the European Space Agency (ESA), and his five crewmates, AMS is the result of a large international collaboration involving both ESA and CERN. AMS, mounted on the outside of the International Space Station, is a particle detector that uses a giant 1.2 tonne magnet – generating a field 4000 times stronger than that of Earth – to analyse the composition of high-energy primary cosmic rays with unprecedented accuracy.

AMS will use the unique environment of space to study the Universe and its origins by searching for antimatter and dark matter particles, looking for answers to questions such as 'Does nature have a preference for matter over antimatter?' and 'What makes up the invisible 90% of the mass of the Universe?'.

For more information, see the AMS website (www.ams02.org) and the CERN press release (see http://press.web.cern.ch or use the direct link: https://tinyurl.com/amscern).

To learn more about the DAMA mission and ESA's involvement in the AMS project, see: www.esa.int/SPECIALS/DAMA_mission

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

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

A computer-generated image based on 3D scans of the skull of the *A. sediba* child

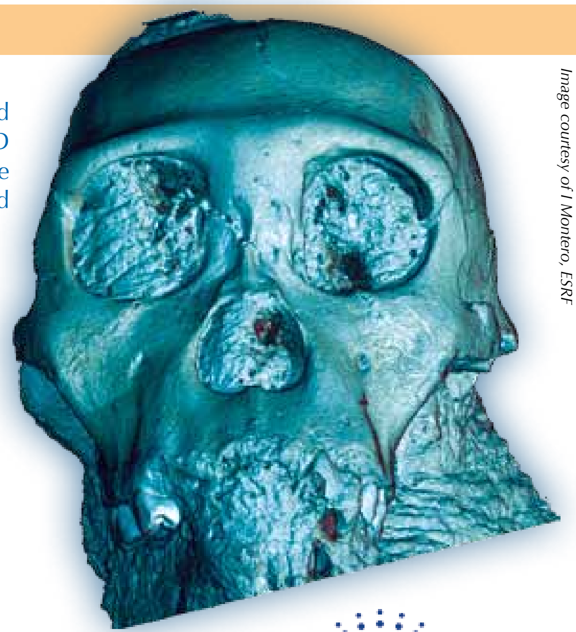


Image courtesy of I Montero, ESRF

ESO: press releases for the young

Life has just become easier for parents and educators of children curious about astronomy. The European Southern Observatory (ESO) has teamed up with the education project Universe Awareness (UNAWE) to produce Space Scoop, aimed at children aged 7-11. This service feeds children's curiosity about the Universe, offering simply written versions of ESO's science and photo releases. In the classroom, teachers can share and discuss the latest discoveries with their pupils or direct them to reputable and easily understandable online sources of information.

Space Scoop is made available online at the same time as the original version of a release, so children can learn about the latest developments in astronomy as they happen.
To subscribe to Space Scoop, send an email to news@unawe.org

For the first Space Scoop release, see: www.eso.org/public/news/eso1113/kids

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

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

ESRF: a new human ancestor

The skull and bones of *Australopithecus sediba*, a 1.9 million-year-old hominid species discovered in South Africa in 2010, have recently been investigated at the European Synchroton Radiation Facility (ESRF). The first specimen of this species, Karabo (named in a nationwide contest for children), is the skeleton of a young boy, discovered by nine-year-old Matthew Berger, son of American paleoanthropologist Lee Berger.

Karabo and an adult skeleton of the same species, discovered nearby, are extraordinarily well preserved. This encouraged Professor Berger to team up with Paul Tafforeau, an ESRF scientist who pioneered the investigation of fossils with a non-destructive method known as X-ray synchrotron microtomography, which has revolutionised palaeoanthropology in the past decade. Their preliminary results on *A. sediba* have identified what may be remains of the brain, as well as fossilised eggs of insects that could have fed on the flesh of the hominid after death.

For more information and a 3D reconstruction of the skull, see www.esrf.eu/news or use the direct link: http://tinyurl.com/5vodjyk

Paul Tafforeau has already used his method to study the origins of orang-utans. See:

Tafforeau P (2007) Synchrotron light illuminates the orang-utan's obscure origins. *Science in School* **5**: 24-27. www.scienceinschool.org/2007/issue5/orangutan

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

EIROforum

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

European XFEL: more than meets the eye

European XFEL, scheduled to open in 2015 near Hamburg, Germany, will be an outstanding facility to generate ultrashort X-ray flashes. Constructing its eight underground shafts and its buildings, both above and below ground, will take time but progress is visible.

Deep underground, 22 500 m^3 of concrete have been used to complete the shell of the seven-storey injector complex, with the walls and floors more than a metre thick. Nearby, the enormous tunnel-boring machines move steadily forward. You can follow them online (www.xfel.eu/project/construction_progress).

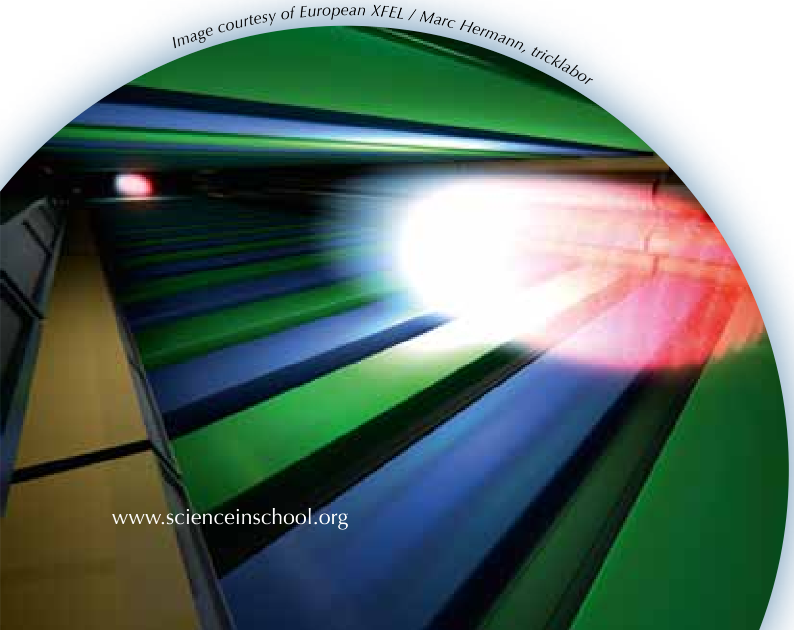
Above ground, the first pieces of intricate machinery are arriving in Hamburg for their test runs: the first undulator segment of the X-ray laser's beamlines, constructed in China; the first module for the superconducting linear accelerator, assembled in France; and the first of three cryogenic test benches, manufactured in Russia.

For more information, visit the European XFEL website (www.xfel.eu) or sign up for its newsletter: www.xfel.eu/news/newsletter

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

To generate the extremely short and intense X-ray laser flashes, bunches of high-energy electrons are directed through special arrangements of magnets (undulators)

Image courtesy of European XFEL / Marc Hermann, tricklabor



The instrument PF2, a powerful source of ultra-cold and very cold neutrons

Image courtesy of ILL / Artechnique

ILL: analysing gravity at the atomic scale

How does gravity work at the (sub)atomic scale? Do Newton's laws apply, as they do for stars and planets, or do different laws apply at this scale? This important question is being addressed with gravity resonance spectroscopy, a technique developed by scientists from the Institut Laue-Langevin (ILL) and from the Vienna University of Technology, Austria. The new technique involves bouncing ultra-cold neutrons on a mirror vibrating at a precisely defined frequency. When this frequency corresponds to the energy difference between two quantum states, the neutrons are excited to the next higher energy state.

The technique provides measurements of unrivalled precision, which can be used to test whether gravity accelerates all objects equally, regardless of their mass, even at the atomic level. This is what would be expected from the equivalence principle, proposed in the 16th century.

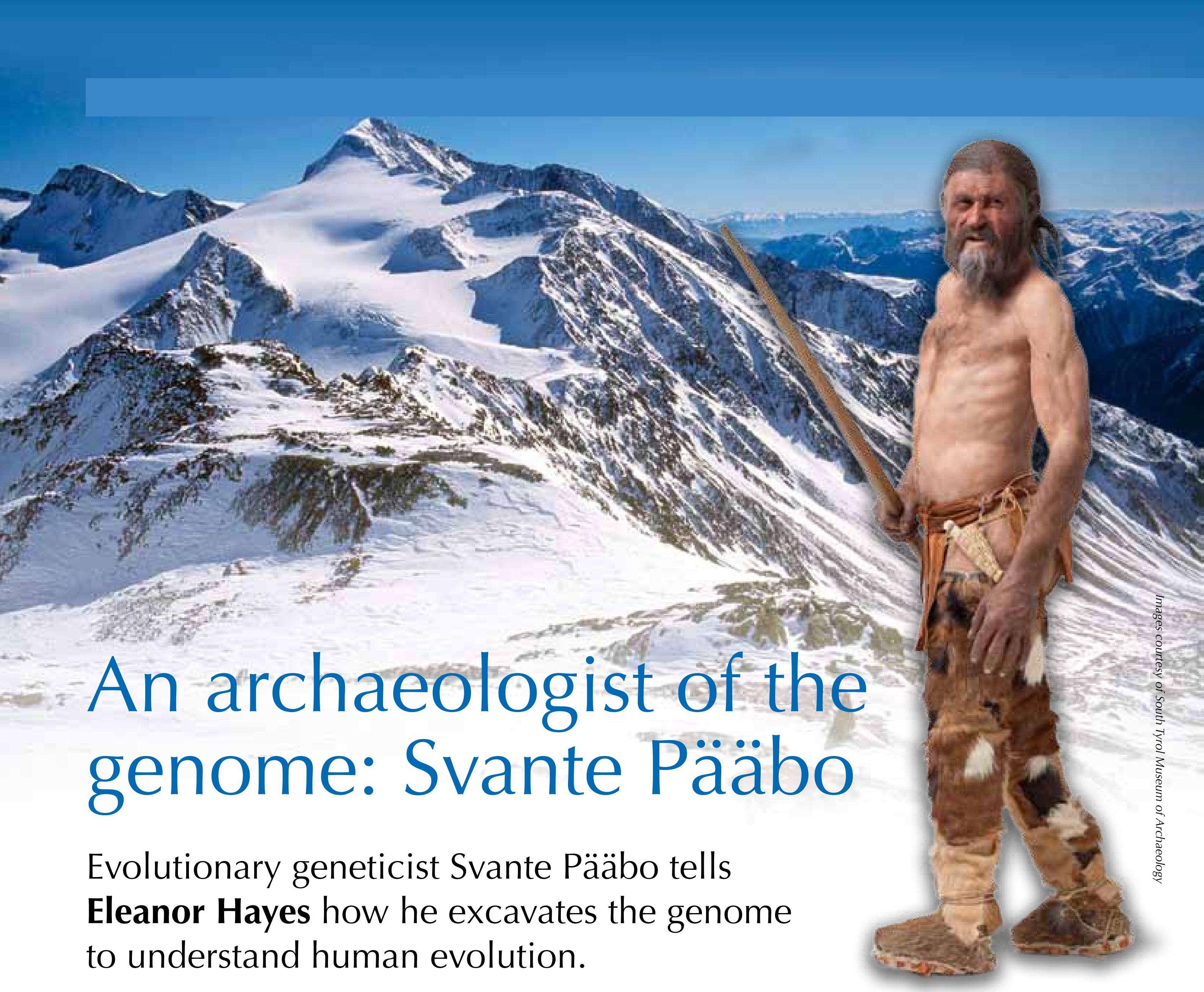
Some physicists also believe that the experiments will reveal a slight divergence from quantum energies calculated using Newton's laws of gravity. This could provide evidence of dark matter particles known as axions, or of the extra dimensions suggested by string theory.

To learn more, see the press release (at www.ill.eu or via the direct link http://tinyurl.com/illgravity) and the research paper:

Jenke T et al. (2011) Realization of a gravity-resonance-spectroscopy technique. *Nature Physics* **7**: 468-472. doi: 10.1038/nphys1970

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

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



Images courtesy of South Tyrol Museum of Archaeology

An archaeologist of the genome: Svante Pääbo

Evolutionary geneticist Svante Pääbo tells **Eleanor Hayes** how he excavates the genome to understand human evolution.

I'd always imagined that archaeologists were to be found up to the knees in mud, digging up bones, pot shards or ancient jewellery. But when I met Svante Pääbo, an 'archaeologist of the genome', he wasn't at all muddy, nor were we out in the open air. Instead, we met – appropriately enough – in the shiny new Advanced Training Centre at the European Molecular Biology Laboratory in Heidelberg, Germany. Designed to reflect the DNA molecule, the building has two helical corridors of offices and interconnecting glass bridges to represent the hydrogen bonds[w1].

Why the link between DNA and archaeology? "In a way, my colleagues and I do what archaeologists do," explains Professor Pääbo. "Excavations not in an old cave, but in our genome. We study our DNA sequences for traces of our history, for example to find out where we came from and how we interacted with other forms of humans."

How, I ask, did he get into this field of research? He explains that an early fascination with Egypt, fuelled by holidays there with his mother, led him to study Egyptology at the University of Uppsala, Sweden. There, however, his romantic dreams were dashed: "We learned about ancient Egyptian word forms, rather than excavating mummies and pyramids in Egypt as I had imagined." Disappointed, he decided to study medicine instead, and then started a PhD in molecular immunology.

The lure of Egypt persisted, however. In the 1980s, DNA sequence analysis was just beginning. Surely, thought

Image courtesy of sculpies / iStockphoto

REVIEW

- Biology
- History
- Ethics
- Genetics
- Evolution
- Ages 16+

Cutting-edge science is not just about the future – modern technology can also deepen the understanding of the past. This article about how the study of the genome contributes to archaeological research can be used in biology lessons to interest students in genetics and evolution. It could also form the starting point of some interdisciplinary research linking biology and history, perhaps using 'Ötzi'.

Suitable comprehension and extension questions include:

1. Using your knowledge about the DNA structure, comment on the architecture of the DNA-shaped building.
2. Explain PCR technology.
3. Explain the evidence for the claim that "from a molecular genomic point of view, we're all Africans".
4. Explain how the scientists sequenced the mitochondrial genome. Why did they focus on the mitochondrial rather than the nuclear genome?

The article could also be used as the basis of discussions, for example about:

- The importance of replication of experiments and controls (why PCR was so important)
- The development of scientific knowledge (for an individual or humans generally – see also Rau, 2010)
- The interdisciplinarity of science
- Ethics (despite differences such as skin colour, 'we're all Africans').

Betina da Silva Lopes, Portugal

Svante Pääbo, someone must have tried to extract and analyse DNA from Egyptian mummies? "I knew from my Egyptology studies that there are thousands of mummies in museums and hundreds more discovered every year in Egypt. But there seemed to be nothing in the literature about DNA extraction from them, so I started working on that myself." Knowing that his PhD supervisor would not approve, he enrolled the help of his previous Egyptology professor, and then did the laboratory work at night and weekends. The result was every young scientist's dream: a paper in *Nature* (Pääbo, 1985).

After his PhD and on the strength of his *Nature* paper, Svante Pääbo moved to the University of California at Berkeley, USA. There he began to realise how difficult it was to avoid contamination when working on ancient human samples – had the DNA he had extracted from the mummies really been ancient Egyptian DNA, or had he been sequencing the DNA of previous anthropologists? He therefore concentrated on extracting DNA from other ancient specimens, including those of the extinct marsupial wolf and of the moa – a giant, flightless bird.

When in 1990 he moved to the University of Munich, Germany, to take up a professorship at the age of only 35, he continued working on the DNA of ancient organisms, including mammoths. The advent of the polymerase chain reaction (PCR) enabled scien-

Image courtesy of EMBL Photolab

The newly built Advanced Training Centre at the European Molecular Biology Laboratory in Heidelberg, Germany. Can you see the similarities to the DNA double helix?

Image courtesy of pialhovik / iStockphoto

Images courtesy of South Tyrol Museum of Archaeology

Excavations at the site where 'Ötzi' was found in the Ötztal Alps

'Ötzi', the 5000-year-old body found preserved in the ice in the Ötztal Alps, in 1991

tists to rapidly replicate samples of DNA and thus made it easier to check for DNA contamination by running many identical experiments and using controls. That encouraged Professor Pääbo to start working on ancient human DNA again. This time, he was part of the team looking at the DNA of one of the ancient Egyptians' European contemporaries: 'Ötzi', the 5000-year-old body found preserved in the ice in the Ötztal Alps on the Austrian-Italian border in 1991.

Inspired by the success of the research, which showed that Ötzi's mitochondrial DNA (see diagram on page 10) was very similar to that of modern central and northern European populations (Handt et al., 1994), Svante Pääbo moved further back in time – about 38 000 years into the past. He wanted to use DNA analysis to investigate human origins.

"One of the big insights from this field in the past 20 years is that modern humans came from Africa rather recently," Professor Pääbo explains. Although many fewer people live in Africa than outside Africa, "if we look at variations in the DNA sequences of humans, we find that most of the variation exists in Africa and everybody outside Africa is a subset of that variation. It turns out that within the past 100 000 years, a group of Africans left Africa and colonised the rest of the world. So I like to say that from a molecular genomic point of view, we're all Africans; either we're living in Africa or we've been recently exiled."

"From a molecular genomic point of view, we're all Africans."

But modern humans, *Homo sapiens*, were not the only humans around at the time. Roaming Europe and western Asia (the Near and Middle East) from around 300 000 to 30 000 years ago were our relatives: the Neanderthals, *H. neanderthalensis*. Ever since the discovery in 1856 of some odd-looking human bones in the Neander Valley near Düsseldorf, Germany, controversy has raged over the fate of the Neanderthals. When modern humans migrated from Africa to Europe, did they kill the Neanderthals? Outcompete them? Or interbreed with them? When Europeans see a picture of a

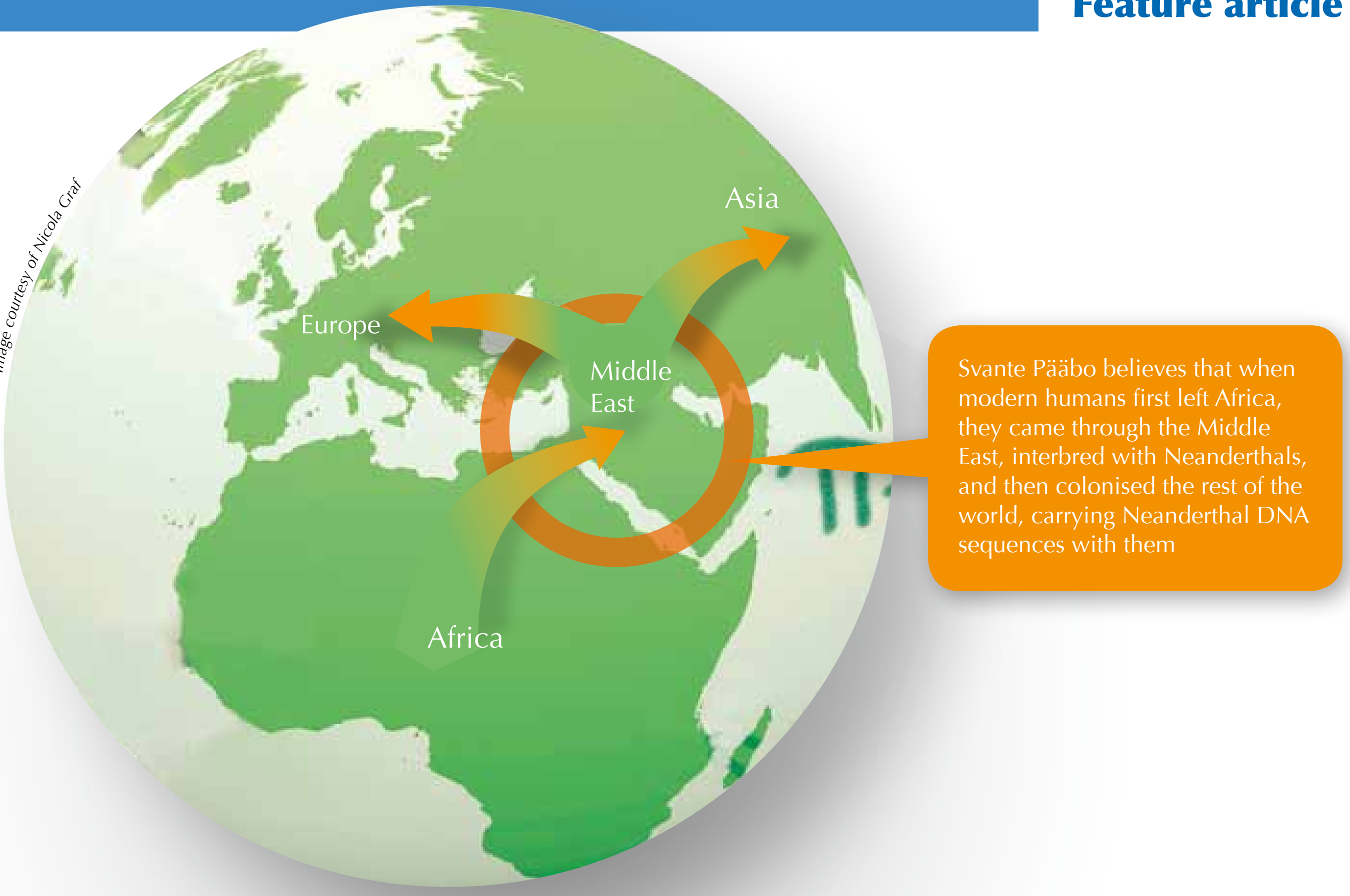


Image courtesy of Nicola Graf

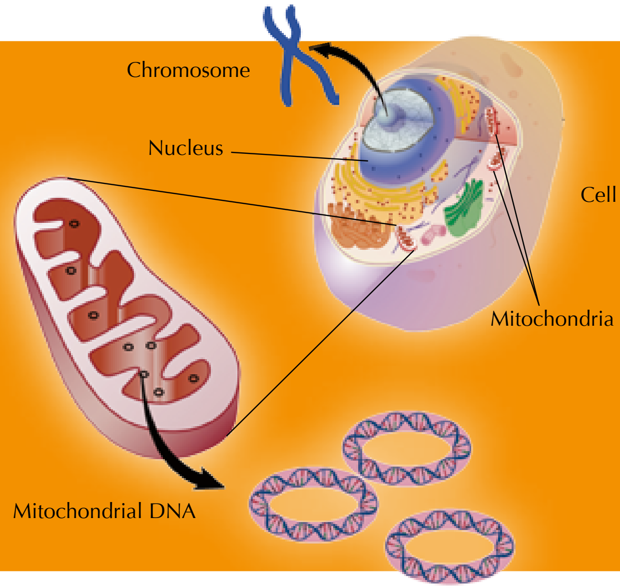
Image courtesy of Neanderthal Museum, Germany

What happened when modern humans encountered Neanderthals?

The entire set of genetic instructions found in a cell is known as the genome. In humans, the genome consists of 23 pairs of chromosomes found in the nucleus (the nuclear genome), as well as a small chromosome found in the cells' mitochondria (the mitochondrial genome). These chromosomes, taken together, contain approximately 3.1 billion (3.1 x 10^9) bases of DNA sequence.

Nuclear DNA is inherited from both parents: each parent contributes one chromosome to each pair, so that offspring get half of their chromosomes from their mother and half from their father.

In contrast, mitochondria, and thus mitochondrial DNA, are passed from mother to offspring



Images courtesy of Darryl Leja, NHGRI / NIH

Neanderthal, are we looking at one of our distant ancestors? Svante Pääbo and his colleagues decided to find out, by comparing DNA extracted from the bones of a 38 000-year-old Neanderthal specimen to DNA from various populations of modern humans.

The results were fascinating: non-African modern humans carry some DNA sequences that are similar to Neanderthal sequences but are not found in Africans. In fact, the scientists' data suggest that between 1 and 4% of the genome of non-Africans is derived from Neanderthals (Noonan et al., 2006).

"The simplest explanation is that when modern humans first left Africa, they came through the Middle East and then went on and colonised the rest of the world. In the Middle East, modern humans interbred with Neanderthals, and their descendants carried the Neanderthal DNA sequences with them – to Australia or Papua New Guinea or the Americas," explains Professor Pääbo. Only the African populations were unaffected (see diagram on page 9).

"What's so fascinating to me is that with DNA sequence analysis, we can answer questions that we cannot address by looking at the skeletons of early humans or the stone tools that they left behind."

Since 1997, true to his early fascination for human origins, Professor Pääbo has been a director of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. There, researchers from the sciences and the humanities investigate the history of humankind by comparing the genes, cultures, cognitive abilities, languages and social systems of past and present human populations, as well as those of primates closely related to human beings.

How, I ask him, does he do his research? "My work is in the laboratory, but we collaborate with the people who excavate bones or with the curators of museums that receive the bones. And increasingly, because we can look not just at small parts of DNA but also at entire genomes, it's crucial to analyse the data with computers." Svante Pääbo, a hands-on laboratory researcher, finds this frustrating sometimes. "I don't really know the nuts and bolts of bioinformatics, so I'm in the hands of the people who do. Now, when we train our students, we make sure they learn both sides: young scientists who are primarily working with computers need to spend some time in the laboratory to understand what goes on, and vice versa."

Currently, Professor Pääbo is working on an even more distant human relative than the Neanderthals. And at first glance, he and his colleagues had very little to go on: just the tip of a little finger bone, found in southern Siberia. The scientists knew that this bone belonged to some sort of hominid – or human form – but initially they knew very little more about it. What did it look like? How widespread was it? Could it have been a type of hominid found right across Asia while the Neanderthals were limited to more western regions?

The scientists began by sequencing the mitochondrial genome, and found that it was very different from those of both modern humans and Neanderthals. By comparing the DNA sequences of the three groups, they were able to estimate how long ago they started to evolve their separate ways. (To learn how to do this in the classroom, see Kozlowski, 2010.) Whereas the last common ancestor of Neanderthals and modern humans lived half a million years ago, the mystery hominid diverged from the Neanderthal-human ancestor about a million years ago. That small fragment of bone belonged to a very distant human relative indeed.

This is the first time that a new hominid has been described purely by its DNA sequence but, believes Svante

@ EIROforum

ESRF research

One of the most exciting uses of the very intense X-rays produced at the European Synchrotron Radiation Facility (ESRF)[w2] is the non-invasive study of fossils. Fossil teeth in particular contain essential information, as they can be used to determine the exact age of a juvenile when it died: by counting daily growth lines in the tooth enamel.

A remarkable finding of recent studies is that Neanderthals grew to adulthood significantly faster than modern humans, *H. sapiens*, including some of the earliest groups leaving Africa 90-100 000 years ago. The pattern found in Neanderthals, *H. neanderthalensis*, appears to be intermediate between that found in early members of the genus (e.g. *H. erectus*) and modern humans (*H. sapiens*). This suggests that slow development and long childhood are characteristics of *H. sapiens*, and that the genus *Homo* shifted from a primitive 'live fast and reproduce young' condition to a 'grow slowly and learn from your parents' strategy, which has helped modern humans to achieve their current position on our planet.

To find out more, see the press releases on the ESRF website[w2] or via the direct links http://tinyurl.com/3glstjh and http://tinyurl.com/39rpg2b, or refer to the original research papers:

Macchiarelli R et al. (2006) How Neanderthal molar teeth grew. *Nature* **444**: 748-751. doi:10.1038/nature05314

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ESRF is one of the members of EIROforum[w3], the publisher of *Science in School*.

Pääbo, such analyses will become increasingly popular. "This little bone fragment has hardly any information about what the individual looked like, but if it's well enough preserved, our next step will be to reconstruct the whole genome from it. I think that in future, we will describe newly discovered organisms by their DNA rather than by how they looked."

This article is based on an interview with Svante Pääbo at the European Molecular Biology Laboratory in June 2010.

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Image courtesy of South Tyrol Museum of Archaeology

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w1 – For a virtual tour of the new building at the European Molecular Biology Laboratory (EMBL), Europe's flagship laboratory for basic research in molecular biology in Heidelberg, Germany, see: www.embl.de/events/atc/tour

EMBL is a member of EIROforum[w3], the publisher of *Science in School*. To learn more, see www.embl.org

w2 – An international research centre in Grenoble, France, ESRF produces high-brilliance X-ray beams, which serve thousands of scientists from all over the world every year. To learn more, see: www.esrf.eu

w3 – For more information about EIROforum, see: www.eiroforum.org

Resources

To find out more about some of Svante Pääbo's work on primate evolution, see the entertaining fictional dialogue between the ancient Greek philosopher Democritus and his student: www.embl.de/aboutus/science_society/writing_prize/2002_jekely_brochure.pdf

For more about what our DNA can tell us about human evolution, see the following articles by one of Svante Pääbo's recent PhD students:

Bryk J (2010) Natural selection at the molecular level. *Science in School* **14**: 58-62. www.scienceinschool.org/2010/issue14/evolution

Bryk J (2010) Human evolution: testing the molecular basis. *Science in School* **17**: 11-16. www.scienceinschool.org/2010/issue17/evolution

For a review of a fictional account of the Neanderthals, see:

Madden D (2008) Review of *Dance of the Tiger*. *Science in School* **8**: 68. www.scienceinschool.org/2008/issue8/dance

To find out how X-ray studies at ESRF can cast a light on the evolution and migration of more distant human ancestors, see:

Tafforeau P (2007) Synchrotron light illuminates the orang-utan's obscure origins. *Science in School* **5**: 24-27. www.scienceinschool.org/2007/issue5/orangutan

For more information about 'Ötzi', see the website of the South Tyrol Museum of Archaeology, where the iceman is preserved: www.iceman.it

To browse the *Science in School* evolution series, see: www.scienceinschool.org/evolution

If you enjoyed this article, you might like 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, initially for a bioinformatics company and then for a learned society. In 2005, she moved to the European Molecular Biology Laboratory to launch *Science in School*.

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

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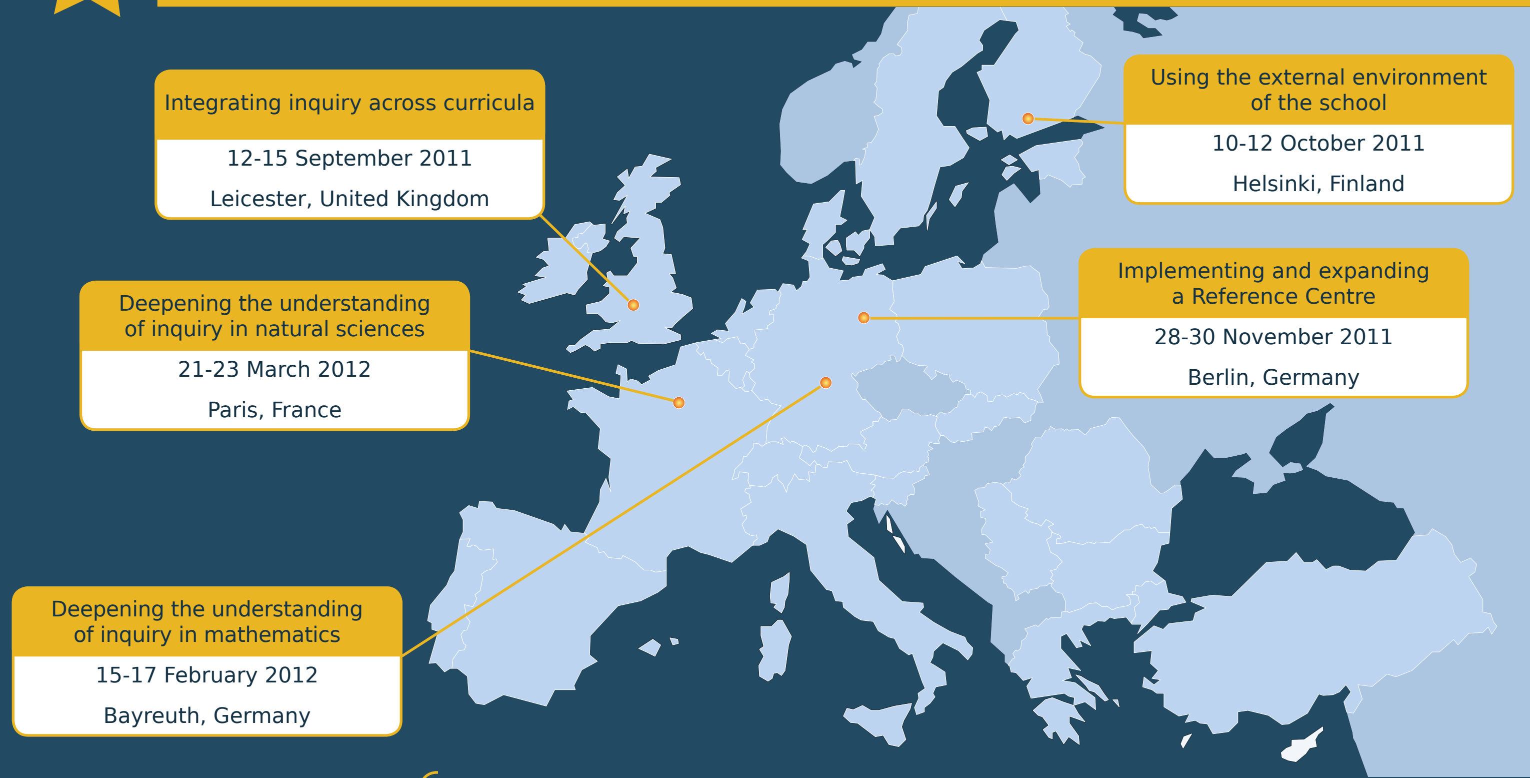

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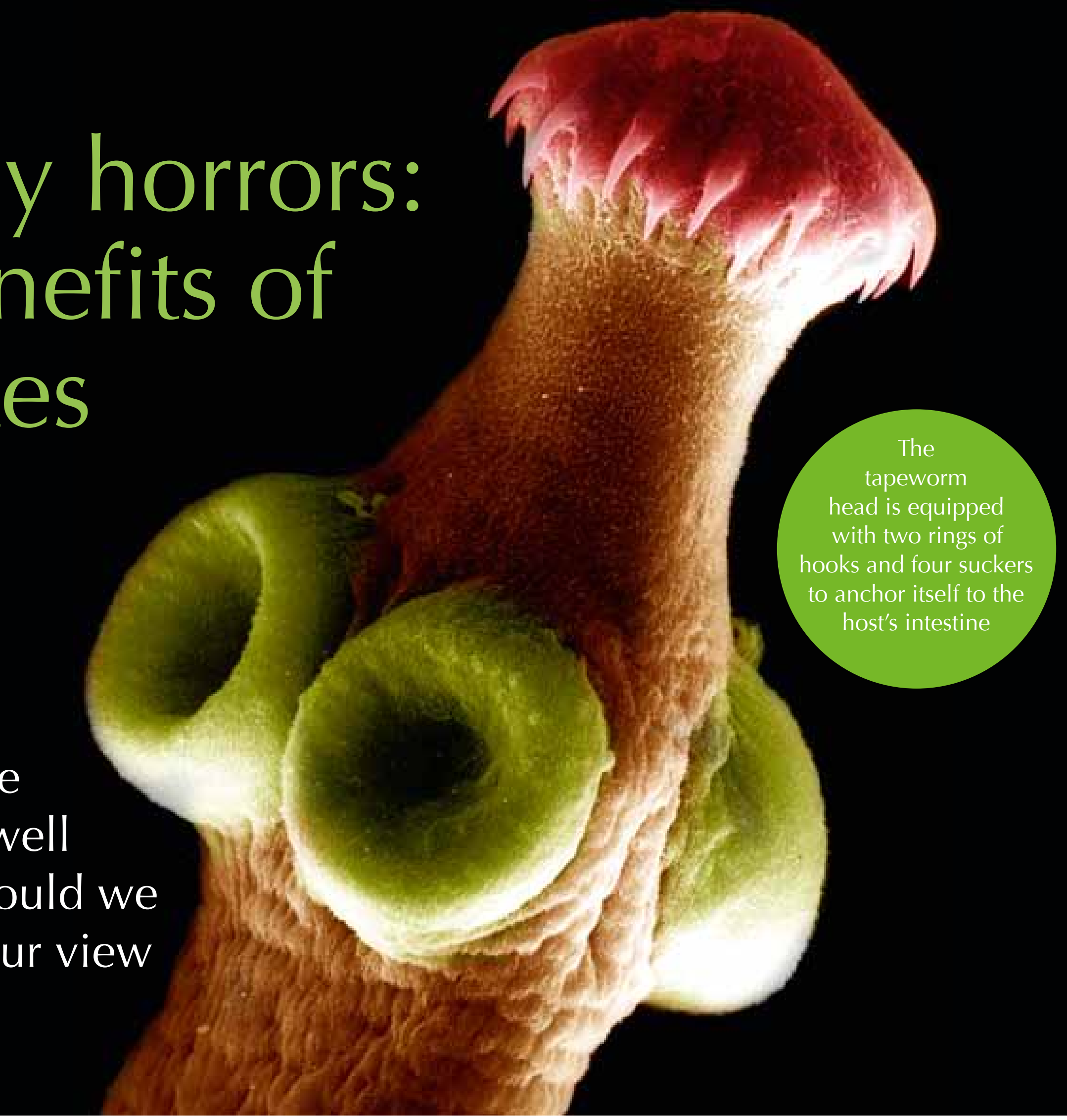
Healthy horrors: the benefits of parasites



The tapeworm head is equipped with two rings of hooks and four suckers to anchor itself to the host's intestine

Image courtesy of the Institute for Parasitology, University of Bern, Switzerland

Matt Kaplan investigates the horrors that dwell within us – should we be changing our view of them?

The definition of what it is to be a healthy human has been a somewhat stable one for more than a hundred years. In general, dictionaries list good health as a state that is free of infirmity and disease, yet research conducted in the past decade is beginning to throw this classic definition into question as the results of a number of studies suggest that various disease-causing organisms play a key role in managing the health of many animals.

One of the most straightforward examples of this involves the parasitic tapeworm genera *Anthobothrium* and *Paraorigmatobothrium*. Just like any other tapeworm, they soak up nutrients from digested food while sitting inside animal guts. However, instead of sitting inside the guts of dogs, cats or humans, these worms spend their days residing in the guts of sharks, robbing the predators of nutrients by absorbing them before the sharks can. Whereas small numbers of tapeworms simply force the animals they infest to feed more often, large populations can make host animals very ill.

Yet, a research study conducted by Masoumeh Malek at the University of Tehran in Iran and a team of colleagues found that these parasitic worms might provide a critically valuable service to their hosts.

After dissecting 16 whitecheek sharks (*Carcharhinus dussumieri)* found in the Persian Gulf and removing tapeworms that they found, the team compared the concentrations of different compounds found inside the tissues of the sharks and the worms. They discovered that the worms had astonishing 278 to 455 times higher levels of the toxic metals cadmium and lead inside their little bodies than the sharks did. So these worms, while stealing some nutrients from the sharks' guts, are likely providing an invaluable service to the sharks by functioning as filters that protect the predators from becoming poisoned by heavy metals (Malek et al., 2007).

Findings like those in this study are throwing the definition of a parasite into confusion. Parasites are supposed to take what they need, harm their host in the process, and give nothing in return. In contrast, organisms called mutualists provide a benefit to their host and receive some benefit in return; organisms called commensals provide a benefit to a host but do not get anything in return. What role the shark worms, which are traditionally considered to be parasites, are playing is difficult to determine. And such confusion is not unique to shark parasites; many parasites that have a penchant for using humans as hosts are also raising questions.

The confusion started in the 1970s, when chronic allergy sufferer and researcher John Turton, then at the UK's Medical Research Council, decided to intentionally infect himself with parasitic hookworms, *Necator americanus*. His actions might sound insane, but he suspected that something about having parasites to fight would make his immune system change its behaviour and reduce his allergic reactions. Remarkably, Turton's self-experimentation worked, and he reported in the *Lancet*, a medical journal, that his allergic reactions were reduced for the two years that the parasites were living inside him (Turton, 1976).

The logic behind Turton's actions relied on the idea that allergies, eczema and asthma are overreactions of the immune system. Under normal circumstances, the immune system searches for harmful organisms and destroys them. However, in patients suffering from allergy, eczema and asthma, the immune system attacks not only harmful organisms, but also materials that are not actually a threat.

Worms, because they have spent millions of years being attacked by the host's immune system, have developed defensive mechanisms to help them thwart it. One of the most effective of these is the release of specific compounds to desensitise the host's immune response, causing the immune system to detect fewer invaders in the body, so that parasites are less likely to be harassed.

Damping down the immune system may sound like a bad thing. To some extent it is, particularly when parasites are taking advantage of it. Yet researchers at the University of Nottingham, UK, speculate that, after mil-

REVIEW

Biology
Parasitology
Ages 13+

This article is an excellent introduction to the different types of interactions between organisms and could be used in many ways.

Several types of parasite are discussed in the article. Where do we meet parasites in everyday life? Students might, for example, thinks of endoparasites like worms in cats, dogs and aquarium fish or of ectoparasites such as ticks, lice and leeches. In which organ systems do these parasites occur and what effects do they have on their hosts? Perhaps the students could investigate the dangers and uses of leeches throughout history. They could also investigate the life cycle of a particular parasite and think about how its anatomy is adapted to its way of life.

The article goes on to investigate the interaction of parasites with the immune system and could be used to introduce a discussion about the immune system, its constituents and regulation. What about when the immune system itself causes problems? How much do the students know about asthma and allergies? Do any of them suffer from allergies? What are the causes, how can these allergies be treated in the long run and how should the students react in an emergency?

The author then introduces the idea of using parasites or parasite extracts to treat allergy conditions. How much do the students know about conventional medicine? Perhaps they could discuss antibiotics and bacterial resistance, and whether they think parasites could, in future, be used as an alternative or supplementary medicine? They could also discuss how new treatments are developed and tested (see Garner & Thomas, 2010).

Should treatments be tested only on volunteers, or is it the duty of all citizens to undergo such testing? Who should pay for the research and who profits from it? Is it right for medicines to be patented? What about patenting things like gene sequences or genetically modified organisms?

Morten Schunck, Denmark

A shark

Image courtesy of qldian / iStockphoto

Image courtesy of Eraxion / iStockphoto

Image courtesy of BigPappa / iStockphoto

lions of years of evolution, the human immune system is so used to being attacked by parasites that without them present, it sometimes malfunctions, becoming overly aggressive when they are not around.

Although Turton's work certainly made a point, his experiment only involved a single participant, himself. Good science however requires studies with many participants, and repeated experiments to confirm results. David Pritchard and his colleagues at the Nottingham University School of Pharmacy[w1], UK, are seeking to do exactly this.

For years, Pritchard's team has been looking at allergy and asthma prevalence in both developing countries, where parasitic worms are common, and developed countries, where they are almost entirely absent. They have confirmed the results of many colleagues, who find that allergies are often absent in regions where parasitic worms are commonly found inside people. This may suggest that parasites protect people from allergies and asthma, but because so many other conditions differ between developed and undeveloped countries, which may also play a role, it is impossible to be sure.

The only way to find out for certain if such parasites really play a role in keeping the human immune system functioning properly is to infect a large number of allergy, eczema and asthma sufferers with parasitic worms, and to closely monitor their conditions to see if their allergies and asthma become less severe over time when compared to a control group of sufferers who were not infected.

Such experiments with asthmatics are currently in progress in Nottingham. Further work with worms may be warranted, depending on how patients respond to the treatment.

Of course, even if the research proves that parasites can help treat allergic conditions, the question remains whether many people would be willing to follow in Turton's footsteps, swallowing a mouthful of worm larvae as a medicine. Luckily, they may not have to: at Strathclyde University in Glasgow, UK, a team of researchers led by William Harnett is experimenting on a complex protein that is created by a parasitic worm (*Acanthocheilonema viteae*) which infects rodents. Their research suggests that even in the absence of the worm, the isolated protein has the ability to reduce allergic inflammation.

Although much work is needed to fully understand what this protein is actually doing, there is a real potential in trying to use parasite proteins to control conditions such as allergies, asthma and eczema. Perhaps the

public would find this solution a little more palatable?

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w1 – To find out more about the work of David Pritchard and his colleagues, see: www.nottingham.ac.uk/pharmacy/people/david.pritchard

w2 – For more information about William Harnett's work, see: http://spider.science.strath.ac.uk/sipbs/staff/Billy_Harnett.htm

w3 – To find out more about the author, Matt Kaplan, see: www.scholarscribe.com

Resources

To learn about further research into worm parasites, see:

Wilson A, Haslam S (2009) Sugary insights into worm parasite infections. *Science in School* **11**: 20-24. www.scienceinschool.org/2009/issue11/schistosomiasis

If you enjoyed this article, you might like to browse other science topics in *Science in School*. See: www.scienceinschool.org/sciencetopics

Matt Kaplan is a professional science journalist, based in both London, UK, and Los Angeles, CA, USA, who regularly reports on everything from palaeontology and parasites to virology and viticulture. When not stuck behind a desk, he runs wilderness expeditions in far-flung regions of the world. See his website[w3].

For *Science in School* articles, Matt waives his usual writing fee.

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

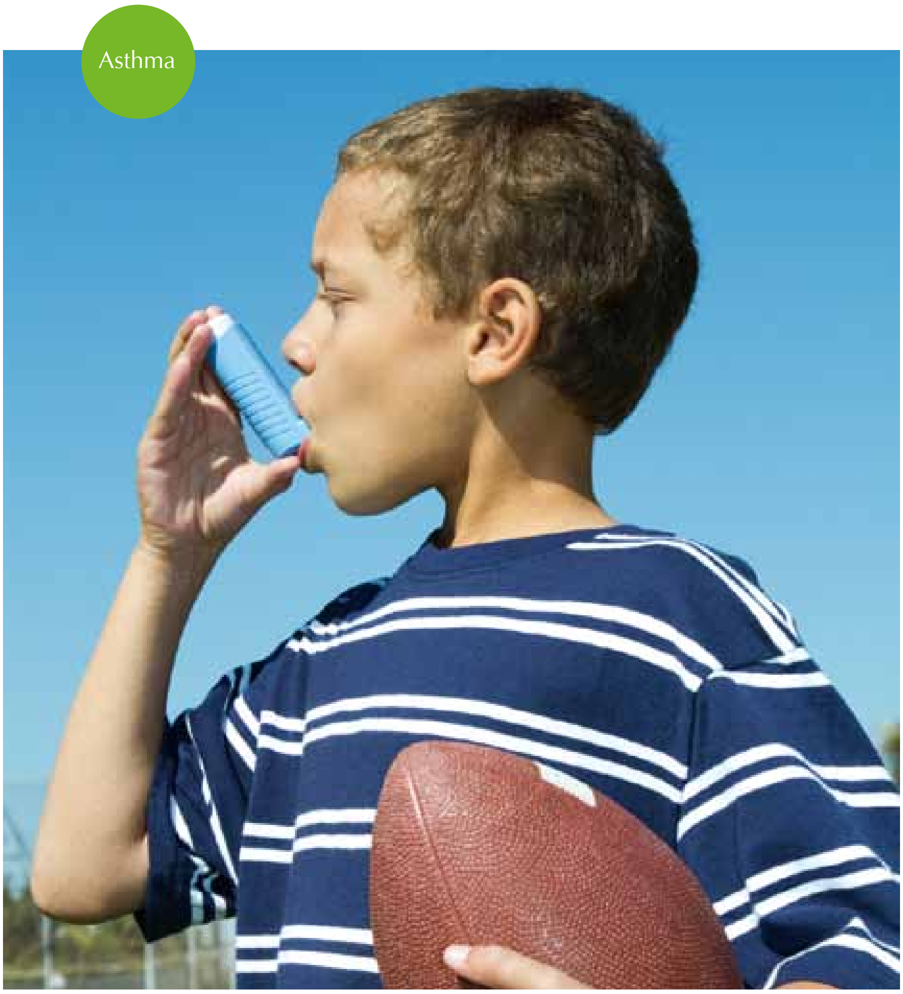


Image courtesy of CT757fan / iStockphoto

Neutrons and antifreeze: research into Arctic fish

Matthew Blakeley from ILL and his colleagues from ESRF and elsewhere have discovered how antifreeze in Arctic fish blood keeps them alive in sub-zero conditions. He and **Eleanor Hayes** explain.

When we think of the Arctic, many of us think of icebergs, polar bears and seals. Freezing temperatures, icy winds and desolate snowy wastes – a challenge to any animal that lives there. We are familiar with many of the ways in which Arctic animals have adapted to their environment: the deep fur of polar bears, the thick blubber layer of seals, the migratory habits of many birds. These animals, however, are all endotherms – they maintain a constant body temperature, well above that of their icy surroundings.

For fish, the situation is very different – they are mostly exotherms, which means that their bodies are the same temperature as their surroundings. And their surroundings are very cold indeed: the Arctic Ocean frequently reaches temperatures as low as -1 °C, when it is only prevented from freezing by the high salt content of the water. Fish blood, which is considerably less salty, would be expected to freeze at -0.5 °C. To avoid this, Arctic fish have evolved specialised antifreeze proteins (AFPs).

AFPs have a complex task. To prevent the fish from freezing to death, they must bind to ice-crystal nuclei

Images courtesy of ucumari and Rita Willaert; image source Flickr

The shorthorn sculpin (*Myoxocephalus scorpius*) also has antifreeze proteins. (Painting from 1795-97 by Krüger)

Public domain image; image source: Wikimedia Commons

- Biology
- Biochemistry
- Chemistry
- Physics
- Interdisciplinary
- Adaptations to the environment
- Crystal structure
- Protein structure
- X-ray diffraction techniques
- Ages 16+

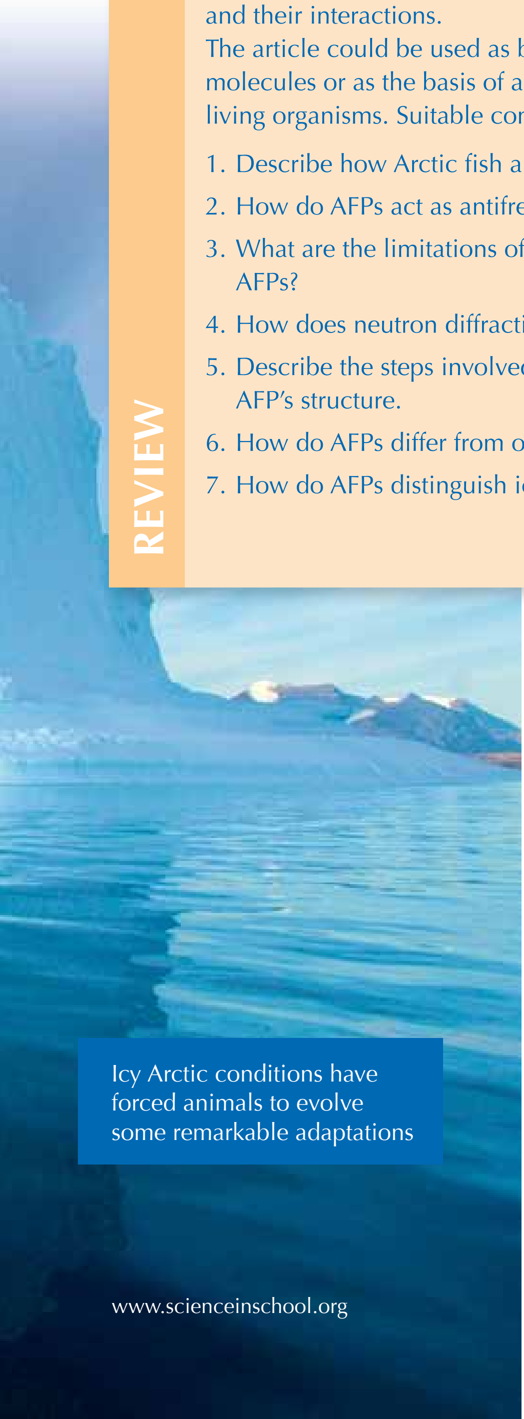
If you have ever wondered how fish can survive in icy oceans, you can find the answer in this highly engaging article, which leads the reader through a scientific investigation into the structure of proteins and their interactions.

The article could be used as background reading when studying biomolecules or as the basis of a discussion about the role of proteins in living organisms. Suitable comprehension questions include:

1. Describe how Arctic fish are adapted to the icy Arctic waters.
2. How do AFPs act as antifreeze in the fish's blood?
3. What are the limitations of X-ray diffraction when analysing AFPs?
4. How does neutron diffraction differ from X-ray diffraction?
5. Describe the steps involved in the successful examination of the AFP's structure.
6. How do AFPs differ from other proteins?
7. How do AFPs distinguish ice from liquid water molecules?

Angela Charles, Malta

REVIEW



Icy Arctic conditions have forced animals to evolve some remarkable adaptations

forming in the fish's body, preventing the nuclei from growing into ice crystals. How, though, do they distinguish ice from liquid water?

AFPs have been extensively studied using many techniques, including X-ray diffraction, revealing the existence of a specialised *ice-binding surface*. X-ray diffraction relies on the degree to which X-rays are scattered (diffracted) by the electron cloud of each atom. Many molecules have distinctive diffraction patterns. However, hydrogen (and deuterium) atoms, which have only one electron, scatter X-rays very little (Figure 1a, page 20), so the X-ray diffraction signal for water (H_2O) is much the same as for oxygen atoms (O). As a result, when scientists tried to examine how the ice-binding surface interacts with ice, they were unable to identify all the water molecules on the surface.

This is where a second technique, neutron diffraction, is beneficial. Neutrons are scattered by atomic nuclei rather than electrons, and the strength of the scattering depends on the specific nuclear forces. These forces in turn depend not only on the elements but also on the elements' isotopes, which differ in the number of neutrons in their nucleus (Figure 1b, page 20). Fortunately for us, hydrogen atoms can be easily detected by neutron scattering and the hydrogen isotope deuterium (heavy hydrogen, which has an extra neutron) can be detected even more reliably. Thus the signal for water is significantly different from that of oxygen.

We (Matthew Blakeley and his scientist colleagues) decided to investigate one type of AFP found in Arctic fish blood: type-III AFPs. To avoid the problems faced by other researchers, we used a combination of X-ray and neutron diffraction to examine the structure of the protein and its interactions with water molecules. For our experiments, we used the facili-

Image courtesy of Derek Keats; image source: Flickr

The scientists studied the antifreeze proteins of the ocean pout, *Zoarces americanus*

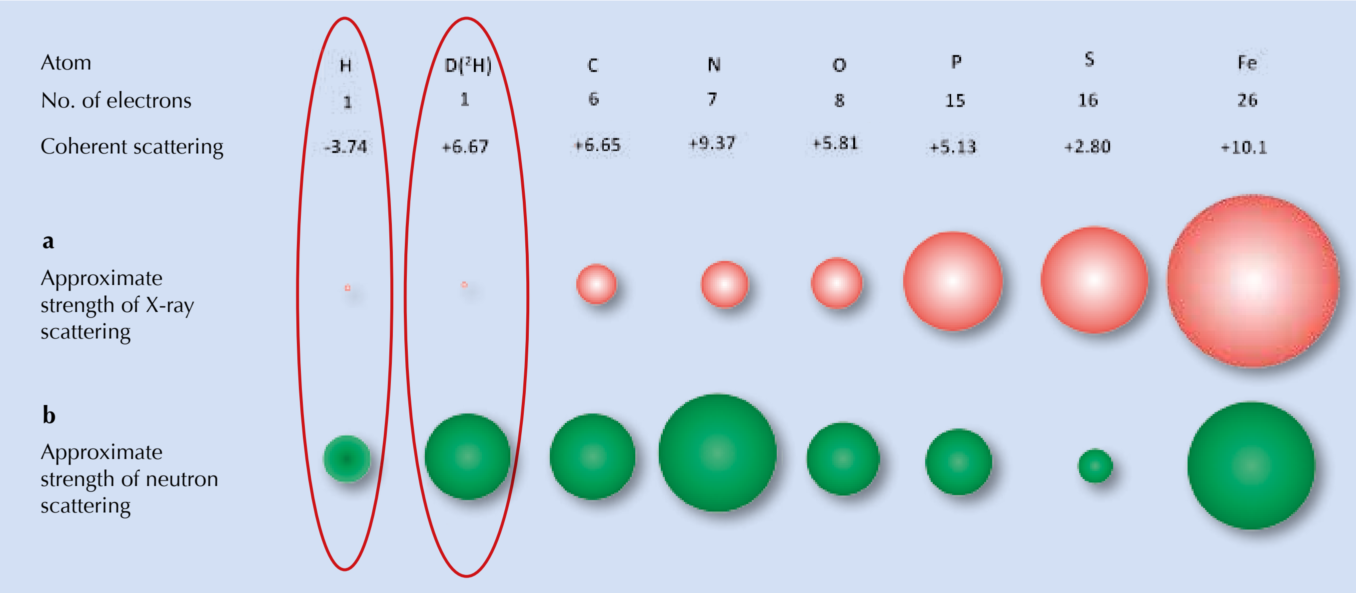


Figure 1:
a) X-rays are scattered by electrons, with the strength of the scattering being proportional to the number of electrons.
b) Neutrons are scattered by nuclei, with the strength of the scattering depending on the specific nuclear forces.

ties at the Institute Laue-Langevin (ILL)[w1] and the European Synchrotron Radiation Facility (ESRF[w2]; see box on page 21 to learn more). The neutron research with such small crystal volumes was only possible due to the advances in sample preparation and instrumentation that have taken place at ILL over the past few years.

As is typical in investigations of protein structures, we inserted the synthetic gene for the type-III AFP into *Escherichia coli*, where it was over-expressed to allow us to collect sufficient amounts of the protein. The bacteria were supplied with heavy water (containing deuterium instead of normal hydrogen atoms), to ensure that the resulting protein was perdeuterated: the positions of all H atoms were occupied by deuterium. We then crystallised the protein so that we could determine its structure, checking that the perdeuterated form had the same structure as the normal form. (See Cornuéjols, 2009, and Blattmann & Sticher, 2009, to learn more about protein crystallography and even try it yourself.)

Part of the answer to how type-III AFPs distinguish ice from liquid water lies in how the structure of the AFPs differs from that of typical proteins, which normally have hydrophobic amino acids in the core (away from water molecules in their surroundings) and hydrophilic amino acids on the surface. As has been shown by previous researchers, AFPs are unusual in having many hydrophobic amino acids on their surface, preventing the protein binding to liquid water via hydrogen bonds. These hydrophobic amino acids form part of the ice-binding surface, which binds to ice nuclei but not liquid water. How does this work?

Image courtesy of Nicola Graf

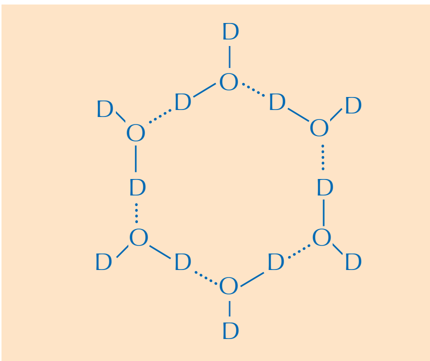


Figure 2: The six-membered water ring. D = deuterium; O = oxygen

Herein lies the second part of the answer: how the structure of ice differs from that of liquid water. Using neutron diffraction, we were able to locate the positions of water molecules on the ice-binding surface. We identified a tetrahedral cluster of water molecules bound to the protein's ice-binding surface. This tetrahedral cluster is found in liquid water (as in our experiment) but is also typical of ice; this gave us the starting point for modelling the rest of the ice crystal and deducing how it would bind to the AFP. The resulting model is composed of six-membered water rings in what is known as a *boat* configuration: six water molecules in a hexagonal arrangement, leaving a hole in the middle (see Figure 2, left). It is this hole that enables the type-III

AFPs to distinguish the structure of ice-crystal nuclei from that of water: the hydrophobic regions of the ice-binding site fit into the holes, binding with the ice via Van der Waals forces (Figure 3, right). In contrast, liquid water has no hole into which hydrophobic regions such as methyl groups can fit. This prevents a large contact surface between liquid water and the ice-binding site, which would be necessary for a tight interaction.

Although other researchers have proposed that hydrophobic residues play an important role in how type-III AFPs recognise ice-crystal nuclei, this is the first experimental data that confirms it.

In itself, it is interesting to learn more about how Arctic fish survive in their environment, but this research also has potential industrial applications. Already, type-III AFPs

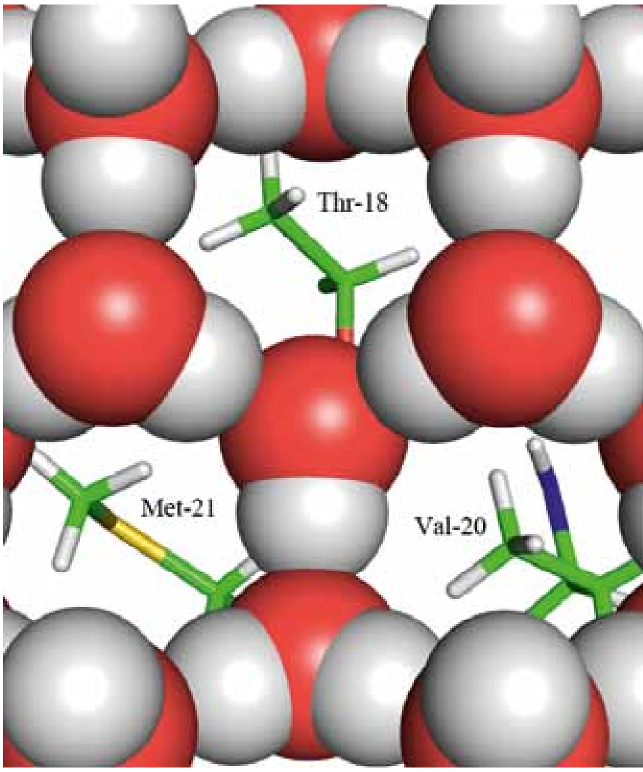


Figure 3: The interface between ice (shown as red and grey balls) and the ice-binding site, showing the methyl groups of the hydrophobic residues Thr-18, Val-20 and Met-21, which face the holes in the ice structure

More about ILL and ESRF

The Institut Laue-Langevin (ILL)[w1] is an international research centre at the leading edge of neutron science and technology. It operates one of the most intense neutron sources in the world, feeding beams of neutrons to a suite of 40 high-performance instruments that are constantly upgraded.

As a service institute, ILL makes its facilities and expertise available to visiting scientists. Every year, some 1200 researchers from more than 30 countries visit ILL in Grenoble, France. More than 800 experiments are performed every year, focused primarily on fundamental science in a variety of fields: condensed matter physics, chemistry, biology, nuclear physics and materials science.

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

The European Synchroton Radiation Facility (ESRF)[w2] is an international research centre, sharing a site with ILL in Grenoble, France. It produces high-brilliance X-ray beams, which serve thousands of scientists from all over the world, every year.

The complementarity of synchrotron X-ray beams and neutron beams can help us understand how complex systems work, such as the AFPs described in this article. To take full advantage of the synergy between synchrotron and neutron sciences, ESRF and ILL have been key actors in the creation of the Partnership for Structural Biology (PSB) and the Partnership for Soft-Condensed Matter; further partnerships are foreseen in the near future.

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

ILL and ESRF are members of EIROforum[w3], the publisher of *Science in School*.

are incorporated into some ice cream to minimise the build-up of large ice crystals and thus improve the consistency. In future, genes that code for AFPs may be incorporated into crops to allow them to be grown in sub-zero environments.

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Web references

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

w2 – To find out more about ESRF and PSB, see www.esrf.eu and www.psb-grenoble.eu

w3 – For more information about EIROforum, see: www.eiroforum.org

Resource

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Dr Matthew Blakeley is the instrument scientist responsible for the macromolecular neutron diffractometer LADI-III at ILL. After graduating from the University of Manchester, UK, with a first-class degree in chemistry, Matthew completed his PhD in 2003. He then undertook postdoctoral research until 2007 at the European Molecular Biology Laboratory outstation in Grenoble, France, after which he took up his current position. His research interests are neutron crystallography instrumentation and method development, structural chemistry and structural biology.

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, initially for a bioinformatics company and then for a learned society. In 2005, she moved to the European Molecular Biology Laboratory to launch *Science in School*.

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

What might happen to fish in the Arctic without antifreeze proteins?

Image courtesy of dwleindecker / iStockphoto

Image courtesy of craftvisioncraftvision / iStockphoto

Fizzy fun: CO_2 in primary-school science

Marlene Rau presents some fizzy and fun activities involving carbon dioxide, developed by Chemol and Science on the Shelves.

One of the El Tatio geysers in the Chilean Andes

Image courtesy of ecololo; image source: Flickr

Introduction

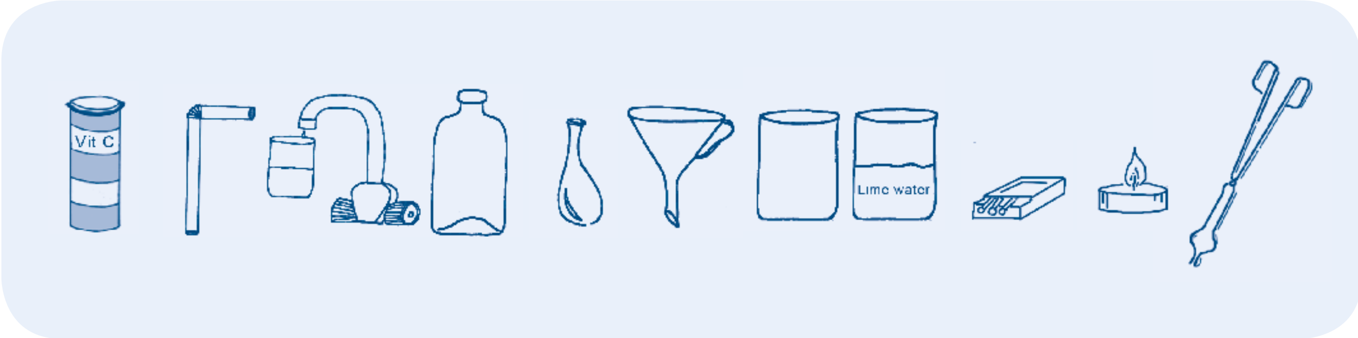
Carbon dioxide (CO_2) is not only one of the most important greenhouse gases, it is found all around us: in the air (0.0388 vol%) we breathe; in the air we exhale (4 vol%); in fizzy drinks; in cakes, which rise thanks to the CO_2 produced by baking powder; and when organic compounds such as paraffin, paper, wood or petroleum are burned. In liquid form, it is used in fire extinguishers and as a refrigerant in the food industry (for example to store and transport ice cream).

In high concentrations, CO_2 can become dangerous for humans and other animals, but it is also the source of life: during photosynthesis, plants use CO_2 and light to produce sugar, starch, fats and proteins, as well as the oxygen we need to survive.

The following teaching activities from Chemol[w1] and Science on the Shelves[w2] (see box on page 26) introduce primary-school children to this important gas. To support the activities, more background information on the chemistry, physiological importance, detection and occurrence of CO_2 is available on the *Science in School* website[w3].

Note: the amounts of carbon dioxide produced in these activities are not high enough to be dangerous.

Image courtesy of Chemol



Fizzy balloons

When you add water to effervescent (fizzy) tablets or baking powder, bubbles are formed: a gas is produced. You can use this gas to inflate a balloon without blowing it up yourself. What kind of gas is it? Let us collect and analyse it.

Materials

- Balloons
- A funnel
- Effervescent tablets (e.g. vitamin C tablets) or baking powder
- A transparent 500 ml bottle
- Water
- Beakers
- A tea light
- Matches
- A pair of tongs (or a wooden skewer)
- Lime water: mix a spoonful of cement or mortar with about 250 ml water. Let the suspension settle, then filter it using two paper coffee filters. The filtrate is lime water.
- A thick drinking straw

Procedure

The first six steps are common to both activities – then you have two options as to how to proceed.

1. Blow up a balloon and let the air out again to make the rubber more elastic.
2. Use the funnel to fill the balloon with a packet of baking powder (20 g) or five crushed effervescent tablets.
3. Pour 2-3 cm of water into the bottle.
4. Cover the bottleneck with the balloon and tip the baking soda / effervescent tablets into the bottle. You may need to hold the balloon onto the bottleneck to prevent it from slipping off.
5. Shake the bottle lightly. The balloon fills with a gas that is produced in the effervescence.
6. When the balloon has stopped inflating, twist it shut so that no gas can escape and pull it off the bottle.

Image courtesy of craftvisioncraftvision / iStockphoto

REVIEW

- ✔ **Chemistry**
- ✔ **Physics**
- ✔ **Biology**
- ✔ **Earth science**
- ✔ **Environmental studies / ecology**
- ✔ **Maths**
- ✔ **Ages 8-14**

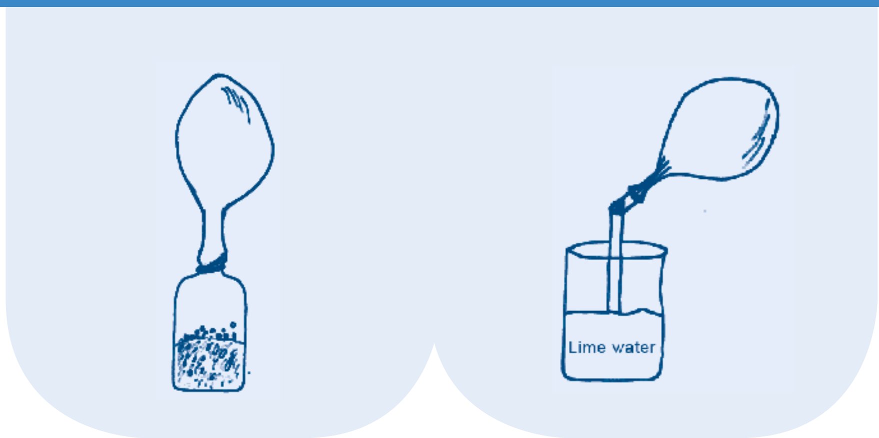
This article offers simple ways to unravel science mysteries. It helps everyone understand natural phenomena and facts, both everyday (breathing) and occasional (volcanic activity). It can inspire the class to develop further hands-on experiments. Both at a global level (climate change) and at a much smaller one (experiments), it allows students to realise that dangers exist and that it is necessary to take measures to avoid them.

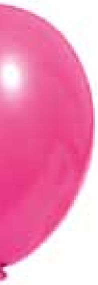
The article can be linked to current events or local natural phenomena such as Icelandic volcano eruptions or geothermal pools. It may also contribute to the awakening of a more ecological conscience. Interdisciplinary links can be made between environmental and ecological issues in chemistry and physics, biology (breathing), earth sciences, maths (measures and proportions) and literacy (instructions and rules).

Younger children will love the fizzy balloons and geysers; I would reserve the more explosive activities for the older students.

Maria João Lucena, Portugal

Image courtesy of Chemol





A) What kind of gas is it?

7. Put some lime water into a beaker.
8. Place the drinking straw into the mouth of the balloon, then slowly and carefully release the gas from the balloon into the lime water. The lime water will become cloudy.

Safety note: If you get lime water into your eyes, rinse them immediately with water. See also the *Science in School* general safety note on page 65 and on our website (www.scienceinschool.org/safety).

The lime-water test to detect CO_2 was developed by chemist Joseph Black (1728–1799). Both cement and mortar contain calcium hydroxide ($Ca(OH)_2$). When CO_2 is added to aqueous $Ca(OH)_2$, very small particles of calcium carbonate ($CaCO_3$) are produced; this is what makes the lime water cloudy.

Where did our CO_2 come from? Both baking powder and effervescent tablets contain sodium bicarbonate ($NaHCO_3$) and a solid acid (such as citric acid crystals or monocalcium phosphate). In contact with water, sodium bicarbonate and the acid react with one another, ultimately forming water and CO_2. This gas is what forms the bubbles when a fizzy tablet dissolves; it is also what makes cakes rise.

B) The gas is heavy

7. Hold the mouth of the balloon into a beaker and let the gas flow out. You cannot see anything, but we will see whether anything has happened. Put the beaker to one side.
8. Light a tea light and use a pair of tongs to place it in a second, empty, beaker (alternatively, you could stick the wooden skewer into the wax and use that to lift the tea light into the beaker). It should continue to burn.
9. Now place the tea light in the first beaker, which contains the gas from the balloon. What happens?

The candle should stop burning because the gas (CO_2) will choke the flame.

10. Repeat steps 1-7 to collect more CO2 in a beaker. Now pour the invisible contents of this beaker into yet another empty beaker. Place a burning tea light into this beaker. What happens?

BACKGROUND

The sources of these and other activities

Chemol

Chemol[w1] is a project based at the University of Oldenburg, Germany, to bring primary-school children into contact with chemistry. The team, which includes trainee teachers and is led by Dr Julia Michaelis, offers workshops for children on the topics of fire, earth, air and water, as well as training for primary-school teachers.

Further Chemol activities about carbon dioxide include building your own CO_2-based fire extinguisher, experimenting with carbonated drinks, measuring how much gas is produced by one effervescent tablet, and testing the effect of temperature on the solubility of CO_2 in water. Details can be found on the Chemol website[w1].

Science on the Shelves

Science on the Shelves is a website[w2] providing instructions for a wide range of simple science experiments using food and other supermarket products, suitable for 6- to 11-year-olds and their teachers and families. The UK-based project, coordinated by Dr Nigel Lowe, is a collaboration between the University of York and the Engineering and Physical Sciences Research Council. If you have ideas for great experiments, Nigel is waiting to hear from you.

@ EIROforum

Carbon dioxide at the workplace – on Earth and in space

Carbon dioxide can be a hazard if it builds up in sufficiently high concentrations. To monitor this and hazardous gases in the workplace, EFDA-JET[w4] uses a variety of instruments, both handheld and installed in buildings, to detect gases that lower the oxygen concentration and can thus lead to asphyxiation. The monitored gases include not only carbon dioxide and other cryogenic gases such as helium, but also nitrogen (used for fire suppression), sulphur hexafluoride (SF_6, an electrical insulation gas) and the vapour of liquid coolants such as Galden®. Before working in areas where these gases are a hazard, staff must check the installed instrumentation or request a measurement with a handheld instrument to confirm that the atmosphere is safe.

Carbon dioxide is also a potential hazard 350 km above Earth's surface – for astronauts aboard the International Space Station (ISS), a collaboration between the European Space Agency (ESA)[w5] and other international partners. When humans breathe, they consume oxygen and produce carbon dioxide. As a result, in closed habitats such as submarines, aeroplanes and the ISS, oxygen levels will fall and carbon dioxide will accumulate, endangering the crew (as described in the film *Apollo 13*). Levels of both gases there need to be regulated.

Currently, the ISS uses an open approach: trapping carbon dioxide in specific gas traps (e.g. lithium hydroxide, LiOH, which combines with CO_2 to form lithium carbonate and water), and transporting bottles of oxygen from Earth. In future, the ISS will use a closed, recycling approach: recovering O_2 from CO_2, using either physicochemical techniques (essentially 'cutting' the oxygen part from carbon part) or algae and other plants (photosynthesis).

EFDA-JET and ESA are members of EIROforum[w6], the publisher of *Science in School*.

Again, the flame is extinguished, showing that we were able to pour the gas from one beaker to another, as though it were a liquid. This demonstrates that CO_2 is heavier than air.

Making your own sherbet or fizzy drink

Mix 3 spoonfuls of sodium bicarbonate with 1 spoonful of citric acid crystals (food grade). To improve the flavour, add either 2-4 spoonfuls of icing sugar or 1 spoonful of instant jelly powder and 1 spoonful of sugar. Your sherbet is ready to taste.

The citric acid crystals dissolve on your tongue and react with the bicarbonate of soda. This produces bubbles of carbon dioxide gas, which cause the fizzing feeling on your tongue. To make a fizzy drink, mix the sherbet with water.

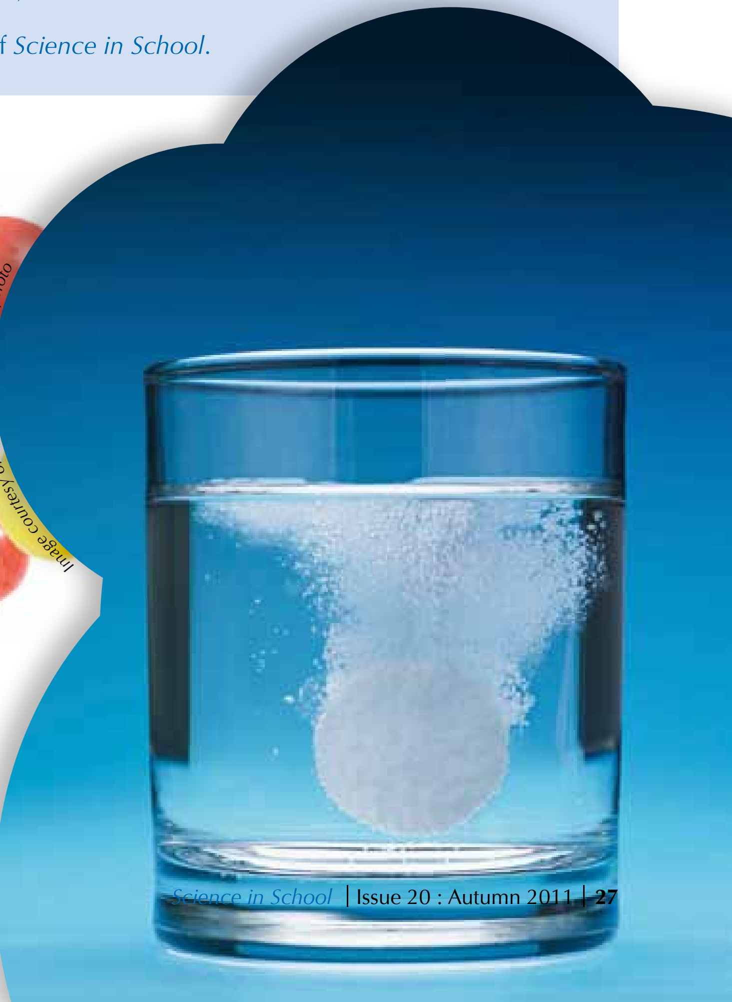


Image courtesy of diego_cervo / iStockphoto

Image courtesy of Eleanor Hayes

Plastic bottles with retractable nozzles

Fizzy explosives

Rockets and explosives work by generating huge volumes of gas in a short time. You can create your own rockets using citric acid and baking soda or effervescent tablets.

Safety note: the following experiments produce high-speed projectiles. Follow all the safety guidance below and wear safety goggles. Perform all the experiments outside, as they make a mess. See also the *Science in School* general safety note on page 65 and on our website (www.scienceinschool.org/safety).

The fizzy cannon

Materials

- An empty tube (with lid) from effervescent tablets, or a small plastic photo film canister; this will be your cannon
- An effervescent tablet, or baking soda and citric acid crystals
- Water
- A transparent plastic tube or glass in which the tube or canister can stand upright; this is your launch pad

Procedure

1. Pour about 2 cm of water into the tube or film canister, then add the effervescent tablet; alternatively, mix about ¼ teaspoon each of baking soda and citric acid crystals in the tube and add a few drops of water.
2. Quickly snap the lid on, place the cannon into the launch pad and stand well clear (at least 1-2 m away).

Image courtesy of Chemol

Safety note: Never allow anyone to look over the top once the cannon is 'charged'. If it fails to go off (as it does sometimes if the lid is not airtight), open it very carefully, keeping your face turned well away.

When the citric acid crystals and baking soda dissolve in water, they react with one another to produce carbon dioxide gas. Effervescent tablets already contain both ingredients (sodium bicarbonate and an acid), which will react with one another when water is added. The resulting gas expands, pressing on the walls and lid of the cannon. When the pressure becomes stronger than the weakest point of the surrounding wall (the lid), the cannon will explode dramatically, with the lid shooting up to 5 m into the air, releasing the gas.

3. Replace the lid and repeat the experiment.

Time how long it takes for the lid to come off and then experiment with quantities: for example, try to get the lid to come off after exactly 1 min.

The cold-water geyser in Wallenborn, Germany

Image courtesy of Sonja Pieper; image source: Flickr

The CO_2 geyser

Geyser comes from the Old Norse word *geysa*, meaning gushing. First used for The Great Geysir, a hot spring in the Haukadalur valley, Iceland, which hurls boiling water up to 70 m into the air, the term is now used more generally for springs with intermittent, jet-like eruptions of water. As well as geysers powered by boiling water, there are also cold geysers, powered by CO_2. Rising from the depths of Earth, the gas collects at the bottom of a subterranean water reservoir and builds up pressure. This is regularly released in form of a fountain of cold water. There may be one closer to your home than you think – for example in Herl'any, in Slovakia, or in Wallenborn and near Andernach, in Germany.

If not, you can build one yourself. Place 200 ml water in a plastic bottle with a retractable nozzle (for example, one that contained washing-up liquid; see image on page 28), add a heaped teaspoon of sodium bicarbonate and mix well. Add about 35 ml washing-up liquid and shake again. Using a funnel, rapidly add three heaped teaspoons of citric acid crystals. Very quickly, screw the closed nozzle onto the bottle, shake briefly and pull the nozzle up to open it.

A foam fountain up to 5 m high will shoot into the air. Alternatively, you can wait until the nozzle pops open by itself. Either way, after a short while, the pressure will be released and the fountain will stop. Close the bottle by pressing the nozzle down; about 30 seconds later, the pressure will again be high enough to start the geyser. You can repeat this several times.

Web references

w1 – For more information on Chemol (in German), see: www.chemol.uni-oldenburg.de

w2 – To find out more about Science on the Shelves, see: www.york.ac.uk/res/sots

w3 – For background information on CO_2, see: www.scienceinschool.org/2011/issue20/co2#resources

w4 – 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.jet.efda.org

w5 – ESA is Europe's gateway to space, with its headquarters in Paris, France. For more information, see: www.esa.int

w6 – To learn more about EIROforum, see: www.eiroforum.org

Resources

For variations on fizzy rockets, see:

de Vries T (2002) Vitamintabletten einmal anders. *Chemkon* **9(3)**: 144-146. doi: 10.1002/1521-3730(200207)9:3<144::AID-CKON144>3.0.CO;2-K

The Portuguese Pollen project has developed a downloadable booklet of science teaching activities with food (*The Fun-Flavoured Way to Learn Science*), available in English and Portuguese. See: www.cienciaviva.pt/projectos/pollen

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

For primary-school teaching activities with carbon dioxide and oxygen, on the topic of climate change, see:

Johnson S (2008) Planting ideas: climate-change activities for primary school. *Science in School* **10**: 55-63. www.scienceinschool.org/2008/issue10/psiclimate

In this issue, you will find a positive approach at climate change – what we can realistically do to stop it:

Shallcross D, Harrison T (2011) Is climate change all gloom and doom? Introducing stabilisation wedges. *Science in School* **20**: 60-64. www.scienceinschool.org/2011/issue20/wedges

If you enjoyed reading this article, why not browse the full collection of *Science in School* articles for primary-school teachers? See: www.scienceinschool.org/primary

You may also be interested in our series on climate change. See: www.scienceinschool.org/climate

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

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

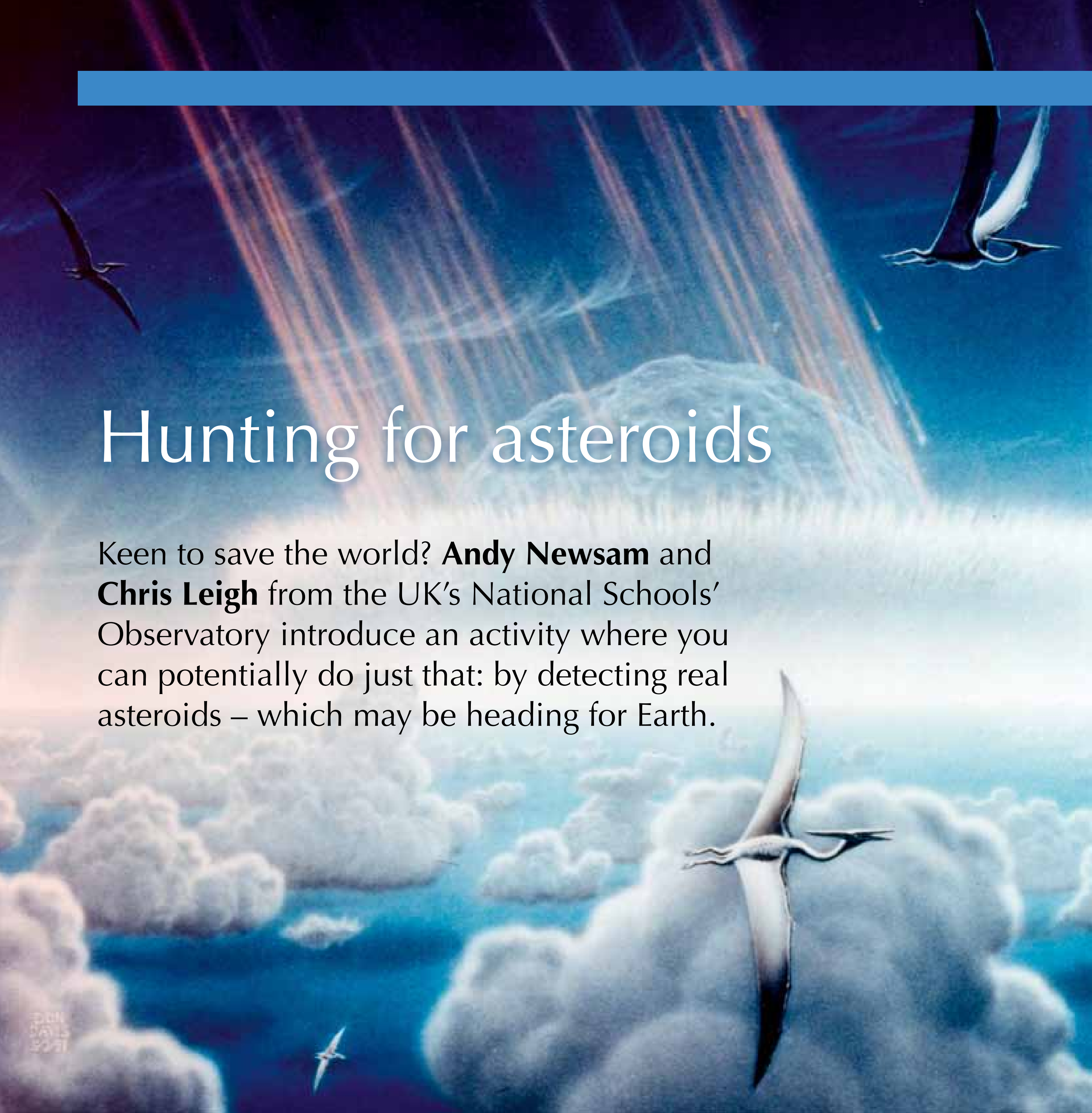


Image courtesy of NASA / JPL-Caltech

Artist's impression of an asteroid slamming into tropical, shallow seas off the Mexican coast, forming what is known as the Chicxulub crater. This asteroid impact may have caused the extinction of the dinosaurs. Fortunately, asteroids large enough (1 km or more in diameter) to cause such serious damage are thought to strike only every few million years

Hunting for asteroids

Keen to save the world? **Andy Newsam** and **Chris Leigh** from the UK's National Schools' Observatory introduce an activity where you can potentially do just that: by detecting real asteroids – which may be heading for Earth.

Introduction

Asteroids or *minor planets* are dusty, rocky, metallic objects orbiting the Sun, too small to be considered planets. Tens of thousands of asteroids have been discovered so far, and more than 12 000 officially named. The largest, Ceres, is 1000 km in diameter, whereas the smallest are only the size of pebbles. Only 15 asteroids have been detected with diameters above 240 km, and if you stuck all known asteroids together, you would still have an object smaller than the Moon (diameter 3500 km).

Most asteroids are found in the Asteroid Belt, between the orbits of Mars and Jupiter, but others have orbits which take them very close to Earth: these are known as *near-Earth objects* (NEOs). If on a collision course with Earth, they are called *meteoroids*. When

a meteoroid strikes the atmosphere at high velocity, friction causes it to incinerate in a streak of light known as a *meteor*. If the meteoroid does not burn up completely, what is left strikes Earth's surface and is called a *meteorite*.

Although many small asteroids hit Earth every day, they are too small to cause any damage. However, there have been larger ones in the past: the 1.186 km wide Barringer Crater in Arizona, USA, was created about 50 000 years ago by a meteor thought to have been just 40 m wide. Such events occur about every 1000 years, but most craters are not visible due to weathering or vegetation, or because they are under the sea.

Image courtesy of NASA, ESA and J Parker (Southwest Research Institute); image source: Wikimedia Commons

Ceres, as imaged by the Hubble Space Telescope

Although it is very unlikely that a large NEO will hit Earth in our lifetime, astronomers are trying very hard to find and track as many NEOs as possible[w1]. If they can find big Earth-threatening NEOs early enough, it may be possible to 'push' them out of the way and stop them crashing into Earth.

How do we find them? Although the positions of stars remain fixed from night to night, the Moon, planets and asteroids wander slowly between them. Unlike most planets, asteroids are too dim to be seen with the naked eye. To observe them we need binoculars or a telescope.

In the following activity devised by the UK's National Schools' Observatory[w2] (NSO; see box on page 32), students aged 7-19 can hunt for asteroids using images generated by the world's largest fully robotic telescope, the Liverpool Telescope on La Palma, on the Canary Islands, Spain (8 m high, weighing 25 tonnes, with mirrors 2 m in diameter). Using the same techniques used by profes-

REVIEW

- **Physics**
- **Earth science**
- **IT**
- **Astronomy**
- **Ages 14-19***

After a short introduction to asteroids and the Liverpool Telescope, the article presents an activity on searching for asteroids in digital images. This can be used to link classical (distance, speed, gravity) to modern physics (astrophysics) and to earth science (the Solar System, landscapes on Earth hit by asteroids). Practical work in small groups benefits both the students and the teacher, and producing real scientific results that can be used by the scientific community is guaranteed to motivate the class.

The article stimulates comprehension questions such as:

- What are asteroids and where do they come from?
- Have asteroids hit Earth? What effects can we see on Earth?
- What are the properties of asteroids in the Solar System?
- What is the Liverpool Telescope and how does it work?
- How can you calculate the speed of and distance travelled by moving objects, such as asteroids?

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

*Note that the authors use the activity with younger students

Image courtesy of ESA

The Barringer Meteorite Crater in Arizona, USA, is 1.186 km in diameter and 180 m deep. It is surrounded by a rim of smashed and jumbled boulders, some as big as houses; the shadow-casting structure on the north side of the crater is the visitors' centre (23 January 2004)

sional astronomers, students quickly learn how to detect real asteroids in real observations. Younger students may need an introduction from their teachers, for whom there are supporting materials online[w3]. Older students can go on to calculate the speed of the detected asteroids (see the advanced task, on page 35) and report back their data. The workshop combines information technology, physics and maths into a fun hour of discovery.

Asteroid Watch

Preparation

All materials required are freely available online[w3] without registration. Each student (or pair of students) will need a computer running Microsoft Windows®. An Internet connection is not required for the activity if the files are downloaded in advance.

1. Download and install the dedicated LTImage software. This image-processing tool was developed by the NSO and adapted for simplified use in schools. LTImage can work with all image data that are in the FITS image format, i.e. with images from most professional telescopes around the world. A screencast movie guide on using the software is available online.
2. Download the teacher notes, the introductory PowerPoint® presentation, and a set of student notes (available for ages 7-11 and 11-16; older students will probably not need notes).
3. Introduce the activity using the PowerPoint presentation.
4. Hand out a copy of the student notes to each student.

For details on how to use LTImage at the individual steps, see the teacher notes.

BACKGROUND

The National Schools' Observatory

The National Schools' Observatory (NSO) is a major educational website, established by Liverpool John Moores University, UK. It allows schools to make their own observations alongside professional astronomers with the world's largest fully robotic telescope – the Liverpool Telescope, which has 5% of its observing time allocated to schools in the UK and Ireland. Once the observing request has been completed, students are able to download the telescope data and use special image-processing software to analyse the resulting images. The website also provides educational resources on astronomy.

Making the observations

To detect the movement of asteroids, we need images of the night sky that were taken some time apart, so that they will have changed position between images. To make sure any motion we see is genuine, we will use four separate images, each taken about 30 minutes apart. You will find the images in the 'Data files' section of the Hunting for Asteroids activity[w3].

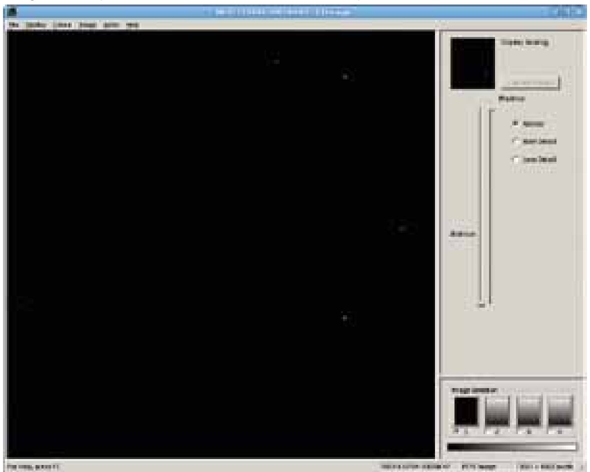
The ah_demo-1.fits to ah_demo-4.fits files are simulated data for you to practice on, while the ahunt-10-1-1.fits to ahunt-10-1-4.fits data are real observations of an NEO called 2001 GQ2, which were taken just before midnight on 5 April 2009.

1. Save all eight images to your computer. For your first attempt, use the demonstration image set (ah-demo-1, ah-demo-2 etc.) as the images contain simulated asteroids for you to spot.

Detecting asteroids

2. Start LTImage and load the first image.
   You might be disappointed, since the image is probably very dark. Do not worry, this is normal and can be corrected: the camera on the Liverpool telescope was designed to count the number of photons it receives, rather than to take pretty pictures. Some of the details in the image may be so dark compared to the surrounding bright stars that we cannot initially see them. To reveal more detail from dimmer objects, we need to adjust the scaling using the two sliders in LTImage.
3. Load and scale the other three images.
4. To look for asteroids, we use a technique known as *blinking*. To blink the images, simply look at the main viewing screen in LTImage and switch between each of the four images in quick succession. For example, look at image 1 for about half a second, then at images 2, 3 and finally 4, before

Image courtesy of the National Schools' Observatory



An image before and after scaling

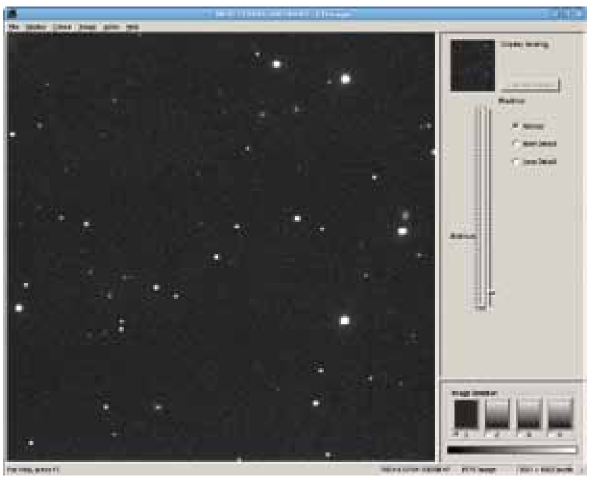
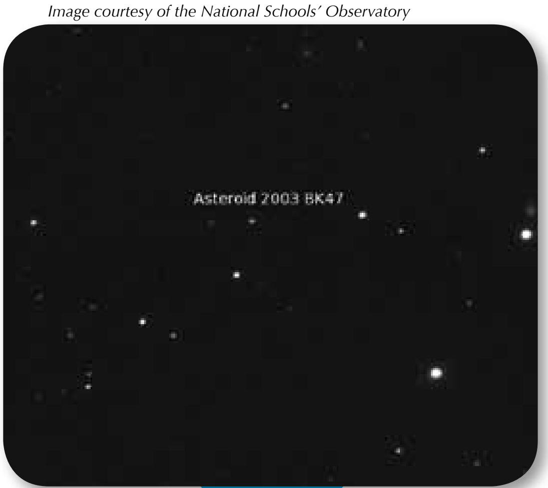


Image courtesy of the National Schools' Observatory



Can you see asteroid 2003 BK47 move?

returning to image 1 and repeating the process. The stars do not move, but an asteroid will. That is all there is to it – get several images, blink them, and if something moves (in a straight line), it is an asteroid.

In the demonstration image set, you should be able to pick out two asteroids (one is harder to spot than the other). Keep blinking the images until you are sure. You may want to try varying the time you look at each image. Note that the stars can appear to wobble due to wind and pointing variations, but asteroid movement is more obvious.

5. When you are happy that you can find at least one of the moving objects in the demonstration image set, try the four images from the real image set to see if you can discover the asteroid.

Measuring the position of an NEO

6. Once you have found an NEO by blinking the images, the next step is to measure its position. To find the pixel coordinate of it in each image, use the Image Examine tool in LTImage. See the 'Measuring the position of near-Earth objects (NEOs)' section on the Asteroid Watch activity website[w3] for detailed instructions.
7. To find the X and Y coordinates, move the mouse pointer until it is right under the cross hairs on the Examine window.
8. Repeat this for each NEO and image – remember to write down all your results.

Image courtesy of the National Schools' Observatory

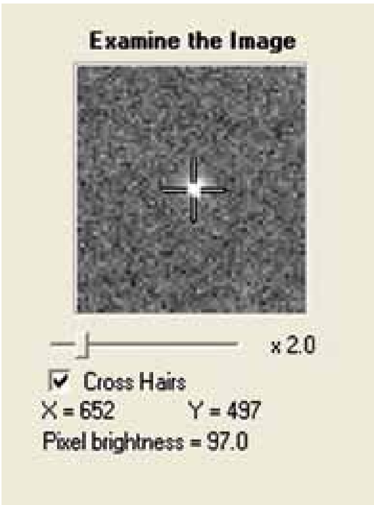


Image courtesy of J Marchant


The Liverpool Telescope's secondary mirror

The real thing

Now that you have understood how it works, you are ready to download some more recent observations of real NEOs that astronomers need to know more about. The images are of positions where recently discovered NEOs are likely to be, and the observations are needed to refine our understanding of the NEO's orbits. Because this is real research data, we do not know for certain where or even whether there will be an NEO in the image, but there *should* be. There is also a small chance of another, unknown asteroid in the same field of view, of course.

9. Go to 'Download some recent observations to analyse' on the Asteroid Watch activity website[w3], and download a set of four images. Remember to make a note of the group ID code – you will need it when reporting your results.
10. Scale and blink the images, and measure the positions of any NEO you detect. There will be at least one in most observations. In about 1 in 10 cases, there will be no NEO, and in about 1 in 100, there will be two.

Submitting your results

To submit your results (the X and Y coordinates of newly identified NEOs), go to 'Report your results' on the Asteroid Watch activity website. Useful (non-spam) results will be passed on to the International Astronomical Union's Minor Planet Center[w4] to improve orbital estimates.

Advanced task: calculating the speed of an asteroid

If you have time and feel confident about using a little maths with the students, you can use the demonstration image set and some of the LTImage tools to work out how far the asteroid has travelled and how fast it is going. For instructions, download the 'More able tasks' worksheet on the 'Hunting for Asteroids' activity website[w3].

Web references

w1 – To learn how the European Space Agency is monitoring near-Earth objects, see: www.esa.int/esaMI/NEO

w2 – To find out more about the National Schools' Observatory, see: www.schoolsobservatory.org.uk

w3 – The full Asteroid Watch workshop is described here: www.schoolsobservatory.org.uk/asteroids

For the introduction to the Hunting for Asteroids activity and to download the relevant materials, see: www.schoolsobservatory.org.uk/activ/asteroids

For information about the LTIimage software and to download it, see: www.schoolsobservatory.org.uk/astro/tels/ltimage

w4 – Useful asteroid data is passed on to the Minor Planet Center. See: http://minorplanetcenter.net

Resources

In the film *Deep Impact*, astronomers try to destroy a comet before it crashes into Earth. For a toolkit for using the film *Deep Impact* in the classroom, see:

Oberhummer H, Behacker M (2006) Deep Impact. *Science in School* **1**: 78-80. www.scienceinschool.org/2006/issue1/deepimpact

In the 'Galaxy zoo' project, you help astronomers classify galaxies in images taken by the Hubble Space Telescope, while in 'Moon zoo', you help classify structures on the surface of the Moon. See: www.galaxyzoo.org and www.moonzoo.org

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

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Andy Newsam is the director of the National Schools' Observatory and a reader in astronomy education at Liverpool John Moores University, UK. As well as carrying out astronomical research – studying objects as diverse as exploding stars, super-massive black holes and gravitational lenses – he is very active in using astronomy to promote a better appreciation and understanding of science. Because of this, he spends a lot of his time travelling to schools, sharing his enthusiasm with students and their teachers.

Chris Leigh has a master's degree in astrophysics and a PhD on the detection and characterisation of close-orbiting extrasolar gas planets, both from the University of St Andrews, UK. Chris moved to Liverpool John Moores University in 2004 and is currently the project manager for the National Schools' Observatory. He continues to be involved in research, and collaborates with exoplanet hunters around the world.

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

Image courtesy of J Marchant

The Liverpool Telescope

Plastics in cars: polymerisation and recycling

What types of plastic are used to build a car? How are they synthesised and recycled? **Marlene Rau** and **Peter Nentwig** introduce two activities from the 'Chemie im Kontext' project.

Image courtesy of Niko Guido / iStockphoto

REVIEW

- **Chemistry**
- **Biology**
- **Organic chemistry**
- **Ages 14-19**

Chemistry is usually seen by students as distant and dangerous, but we are surrounded by it and it plays a major part in the improvement of our quality of life. Activities such as the ones in this article, which use everyday materials, can help to increase the public appreciation of chemistry and encourage interest in it among students.

These activities could be used in organic chemistry lessons and also in biology, to discuss the importance of recycling. Although the authors suggest the activities for students aged 16+, they could also be used with younger students (aged 14+).

Mireia Guell Serra, Spain

Many teenagers are interested in cars, which contain lots of different plastics: polymers produced from crude oil or renewable materials. An interest in cars can therefore be used to introduce the topic of plastics and polymers, for example in organic chemistry lessons.

Take your students to look at some cars. What do they already know about the plastics used to build cars? What would they like to find out? They could categorise their ideas according to different parts of the car (see Figure 1, on page 37).

The important point is that the components of a car have specific requirements (e.g. a seatbelt needs to be strong but flexible), which means that their constituents need specific characteristics (e.g. the material should not tear), so specific types of material (e.g. polyethylene terephthalate) need to be used. If the students do not come up with these connections themselves, ask them why a single type of plastic would not suffice to build a car.

The activities in this article address two of the topics in Figure 1: plastics for the rear lights and how plastics are

BACKGROUND

The 'Chemistry in context' project

'*Chemie im Kontext*' ('Chemistry in context') is a project co-ordinated by the Leibniz Institute for Science and Mathematics Education at the University of Kiel, Germany. Between 2002 and 2008, chemistry teachers, other science educators and representatives of the school authorities developed teaching units for chemistry education – for all grades and types of schools, linking curricular requirements to everyday contexts. Examples of the resources and recommendations for developing further materials are available online[w1]. A set of resources produced by teachers can be ordered free of charge, and four of the lesson plans are freely available online (all in German). A textbook and a teacher's guide (in German) are published by Cornelsen Verlag.

This article is an extract from one of the lesson plans. The full lesson plan includes six different activities, one for each of the boxes in Figure 1.

recycled from cars. Each activity consists of a worksheet and background information. The activities are part of a longer lesson plan (see box on page 42) suitable for students aged 16+, who should work in groups of two or three. Allow one or two 45-minute lessons for each activity.

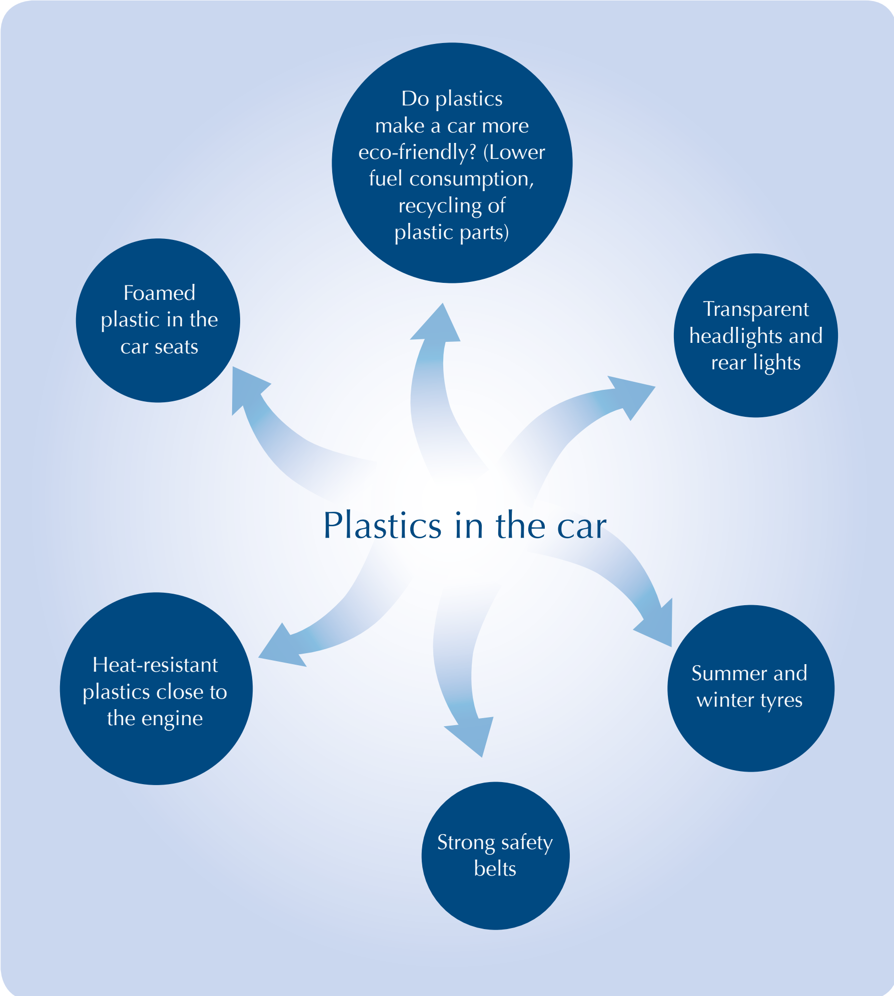


Image courtesy of the Leibniz Institute for Science and Mathematics Education

Figure 1: The use of plastics in cars

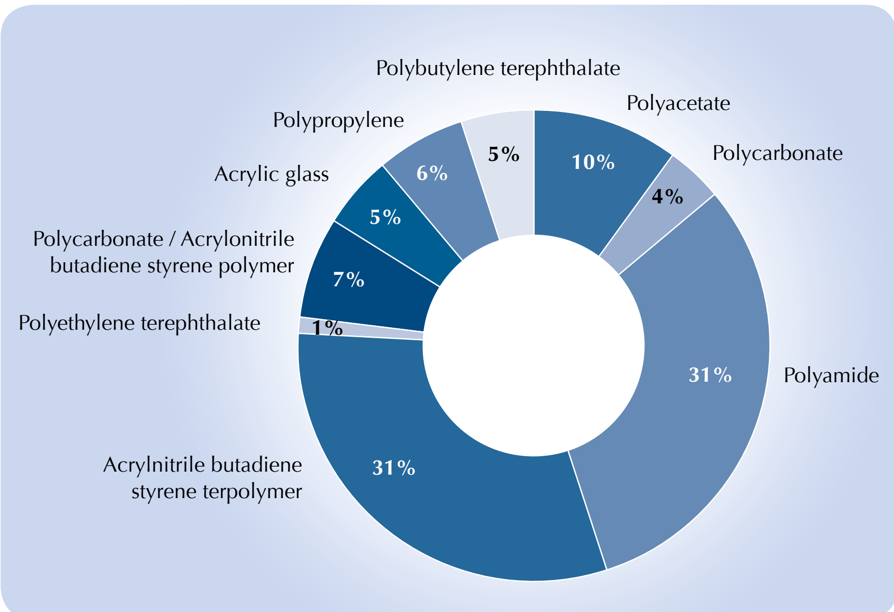


Image courtesy of the Leibniz Institute for Science and Mathematics Education

Figure 2: Plastics in automotive engineering

Polymerisation: plastic for car lights

Car lights have plastic covers to keep them clean and dry, and – in some cases – to confer a colour (e.g. red for rear lights and orange for indicators). The material used must be transparent, light, colourable, easily moulded and reasonably strong. In this activity, we will synthesise the plastic used, poly(methyl methacrylate) or PMMA.

Poly(methyl methacrylate) is commonly known as acrylic glass or plexiglass, and is one of a group of plastics called polymerisates. Their common feature is that their basic monomeric units contain one or more double bonds. Under the influence of radicals (molecules with an unpaired free electron), these units undergo radical polymerisation into long-chained macromolecules.

The characteristics of the macromolecule depend on which side chains it has, which in turn depends on the monomer used. By using different monomers in the formation of polymerisate plastics, we can create plastics for different applications in cars. For example, the bulky side chains of PMMA prevent the plastic forming crystalline structures as it solidifies, which would refract light. Instead, such *amorphous* plastics are transparent, which makes them useful substitutes for glass: lighter, more malleable and less prone to shattering.

We can illustrate radical polymerisation with the car's fuel tank, which is made of polyethene. Polyethene is formed from ethene (ethylene, C_2H_4) monomers, in a reaction initiated by dibenzoyl peroxide. When heated to 90 °C, dibenzoyl peroxide splits into two radicals. If one of these radicals binds to an ethene molecule, the ethene molecule's double bond breaks and a new, larger radical is formed. In this way, a chain reaction begins, which only stops when two radicals react with one another.

In our experiment, we will use dibenzoyl peroxide to initiate a similar process: instead of using ethene to form polyethene, we will use methyl 2-methylpropenoate to produce poly(methyl methacrylate).

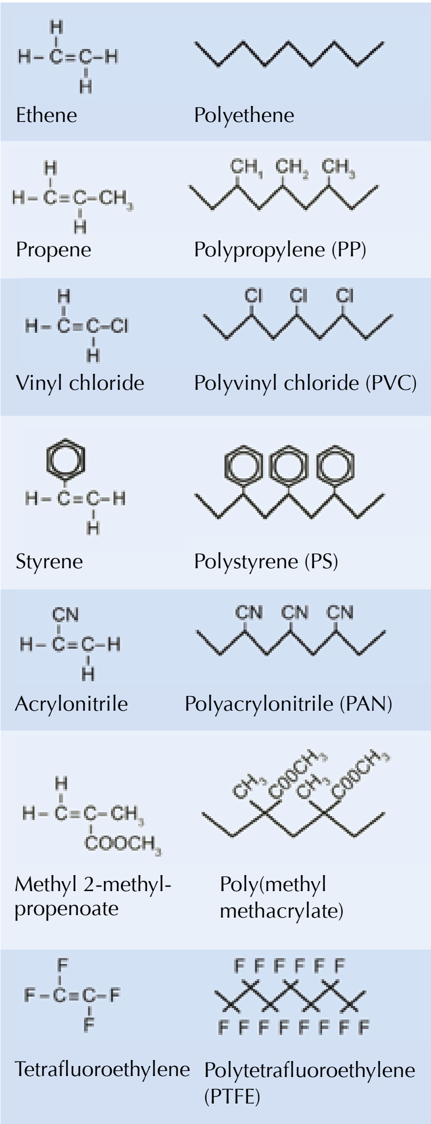
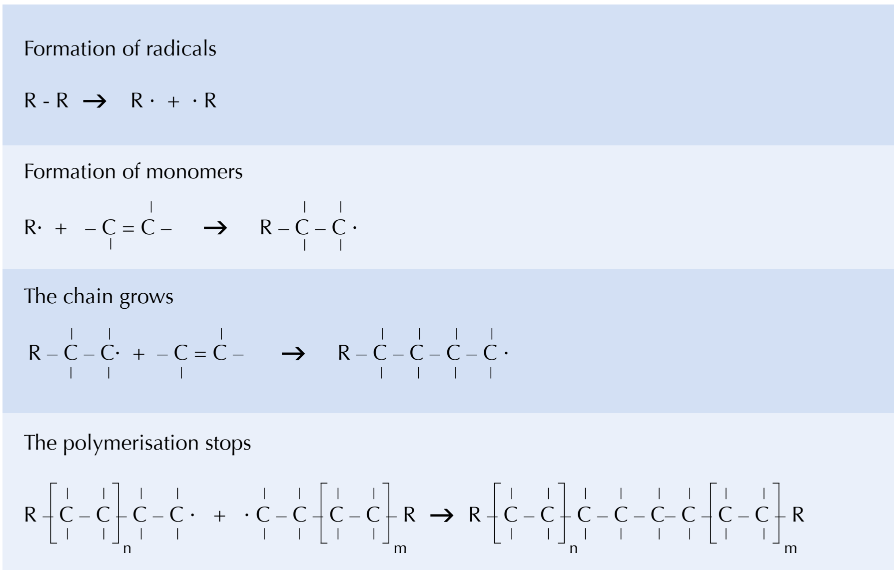


Figure 2: Plastics through polymerisation

Image courtesy of BASF 1998

Rear light made of acrylic glass



Images courtesy of the Leibniz Institute for Science and Mathematics Education

Student worksheet 1: synthesising a transparent polymer

Materials

- Methyl 2-methylpropenoate (also known as methyl methacrylate; $C_5H_8O_2$)
- Dibenzoyl peroxide ($C_{14}H_{10}O_4$)
- Sudan Red dye
- Water
- Acetone (propanone, C_3H_6O)

Equipment per group

- A balance
- A heating plate
- A test tube
- A beaker
- A watchglass
- A spatula
- A pipette
- The aluminium holder from a tea light

Safety note: use gloves, safety goggles and work under a fume hood. Methyl 2-methylpropenoate, dibenzoyl peroxide and acetone are flammable; acetone is also an irritant. All three must be used with care. Remaining Sudan Red must not be disposed of in waste water.

See also the general safety note on the *Science in School* website (www.scienceinschool.org/safety) and on page 65.

Procedure

1. Weigh 0.2 g of dibenzoyl peroxide into the test tube.
2. Add 10 ml of methyl 2-methylpropenoate.
3. To colour the resulting plastic, add a little Sudan Red (enough to cover the tip of the spatula).
4. Place the tube into a beaker full of water at 90 °C and place it on the heating plate; see Figure 3, below.

The reaction will take about 20 minutes, after which the mixture should be visibly viscous. In the meantime, read the information on page 38 and work out the reaction mechanism for the radical polymerisation of the methyl 2-methylpropenoate.

5. Pour the solution into the aluminium holder from a tea light.

If the plastic starts to solidify in the test tube, you can dissolve it again with acetone. You can then continue the experiment as described, allowing additional time for the acetone to evaporate.

6. Cover the aluminium holder with the watchglass to keep the plastic warm and allow it to harden faster.
7. Let the poly(methyl methacrylate) solidify for 24 h, then remove it from the aluminium holder.

How would you test the properties of your plastic and compare them to those of glass?

The resulting plastic

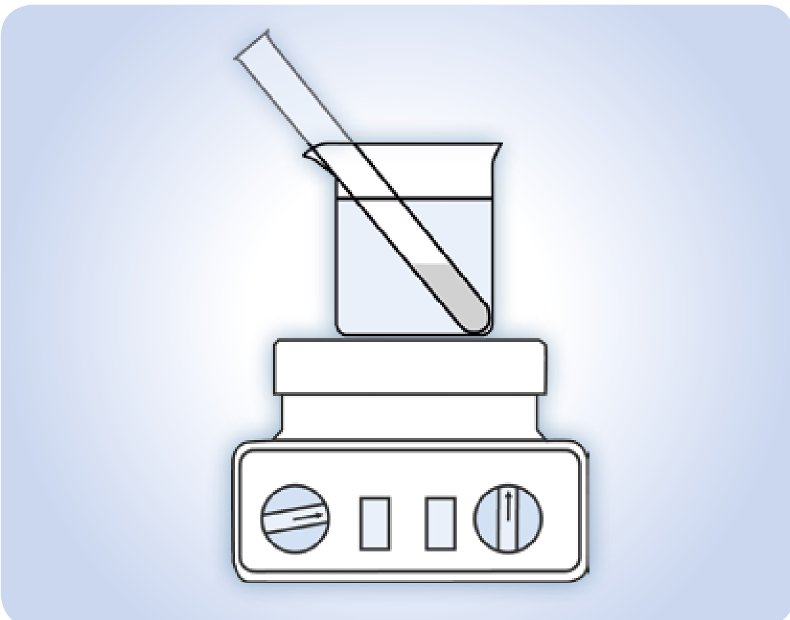


Figure 3: The experimental setup

Images courtesy of the Leibniz Institute for Science and Mathematics Education

Recycling plastics from cars

In this activity, students first learn about how plastics from cars can be recycled, then try their hand at recycling: transforming a plastic bottle into a piece of shaped plastic.

What happens when we have finished with a car? We may think of piles of rusting cars and old tyres, destined for landfill, but in fact many car parts are recycled to recover valuable resources, especially metals. The plastics in a car can also be recycled, in three ways: as parts, chemical components or fuel.

1. Cars may be repaired using old plastic parts such as bumpers. As the parts get older, however, their characteristics change, making them inappropriate for reuse: solar radiation, for example, makes most plastics brittle. Fortunately, some plastic parts can be melted down and reshaped into articles for which the quality requirements are lower, such as fence posts or garden benches.
2. Through chemical processes, some polymers can be split up into their monomeric components, which are then available for new syntheses.

   Plastics can also be used to produce other resources for the chemical industry; for example, one tonne of certain types of used plastic gives about 600 kg of methanol, which is both an important resource for the plastics industry and used in fuel cells to release energy.
3. Shredded plastics can be directly used as fuel, substituting oil and coal, for example in waste-to-energy plants. They can also replace coke used for iron production in furnaces (see Figure 4, below).

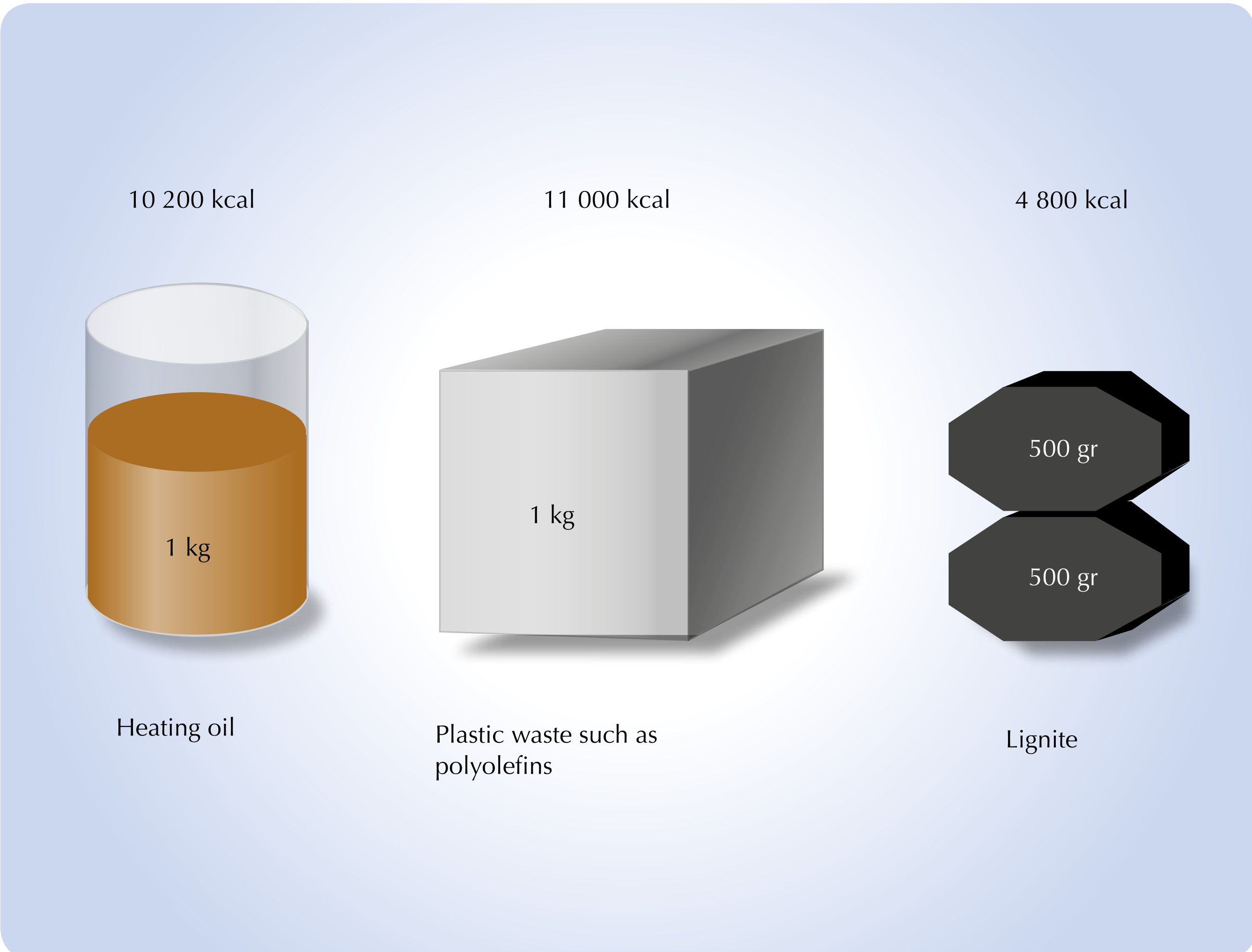


Image courtesy of the Leibniz Institute for Science and Mathematics Education

Figure 4: The calorific value of different fuels

Student worksheet 2: recycling plastic in the classroom

In this activity, you will recycle waste plastic from a bottle into shaped pieces of plastic. What you do with these is limited only by your imagination: key rings, pendants, Christmas tree decorations.

Materials per group

- A Bunsen burner
- A tripod with a wire mesh
- Biscuit cutters in different shapes
- Aluminium foil
- A knife
- Plastic waste (preferably PET bottles for mineral water)
- A selection of dyes

Safety note: Use safety glasses and work using the fume hood. Do not allow the flame to come into direct contact with the plastic. Be careful not to cut yourself.

See also the general safety note on the *Science in School* website (www.scienceinschool.org/safety) and on page 65.

Procedure

1. Use the knife to shred the plastic waste as small as possible.
2. Cover the bottom and sides of biscuit cutters with foil and fill them to a depth of about 0.5 cm with shredded plastic waste. If you wish, try adding a small amount of dye to the plastic waste.
3. Place the cutters on the wire mesh above the Bunsen burner and heat them slowly until the plastic melts.
4. Once it has cooled, take out the plastic and remove the foil.

Compare the characteristics of the plastic before and after recycling. What conclusion can you draw about plastic recycling?

In your group, discuss the three recycling methods described on page 40 and compare possible applications. Reflect on the experiment you have carried out: what are possible applications for your plastic?

Biscuit cutters

Image courtesy of hipokrat / iStockphoto

Reference

Capellas Espuny M (2009) A new look into fibre-reinforced composite materials. *ESRF News* **50**: 12-13. www.esrf.eu/UsersAndScience/Publications/Newsletter

Web references

w1 – To learn more about the project (in English and German) and download the resources (in German), see the Chemie im Kontext website: www.chik.de

w2 – An international research centre in Grenoble, France, ESRF produces high-brilliance X-ray beams, which serve thousands of scientists from all over the world every year. For more information, see www.esrf.eu

w3 – To find out more about EIROforum, see: www.eiroforum.org

Resources

To learn more about Chemie im Kontext, see:

Parchmann I et al. (2006) Chemie im Kontext: a symbiotic implementation of a context-based teaching and learning approach. *International Journal of Science Education* **28(9)**: 1041-1062

Nentwig P et al. (2007) Chemie im Kontext: situated learning in relevant contexts while systematically developing basic chemical concepts. *Journal of Chemical Education* **84**: 1439

For a drama activity about the radical polymerisation of ethene to polyethylene in class, see:

Sturm B (2009) The drama of science. *Science in School* **13**: 29-33. www.scienceinschool.org/2009/issue13/drama

To learn about research into biodegradable plastics, see:

Bradley D (2007) Plastics, naturally. *Science in School* **5**: 66-69. www.scienceinschool.org/2007/issue5/plastics

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

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

Peter Nentwig has just retired as a senior researcher at the Leibniz Institute for Science and Mathematics Education. His main interests were teacher education and projects such as Chemie im Kontext, aiming at fostering scientific interest and scientific literacy among secondary-school students.

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Studying plastics with X-rays

ESRF

At the European Synchrotron Radiation Facility (ESRF)[w2], high-performance fibres such as the plastic Kevlar® have been studied for more than a decade. Five times stronger than steel, weight for weight, Kevlar is used in bicycle tyres and body armour, racing sails and mooring lines.

Much of ESRF's work on high-performance fibres involves their *skin-core morphology*: the differences in structure between the outer layers of the fibre and its centre. These differences can influence the fibre's mechanical properties, so understanding the skin-core morphology may enable the fibres' properties to be tailored during the manufacturing process.

ESRF's microfocus X-ray beams are routinely used for new studies of these remarkable materials, for both academic and industrial research. This is because no other techniques provide similar information without sectioning the fibre and potentially altering its internal microstructure. For more information, see Capellas Espuny, 2009.

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

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

ESTABLISH

European Science and Technology in Action: Building Links with Industry, Schools and Home

Definition of Inquiry from: Linn, Davis & Bell, 2004.

Inquiry Based Science Education

through the:

★ identification of suitable model(s) for science teacher education, at both pre- and in-service levels, for inquiry based science teaching;

★ development of teaching & learning resources, IBSE Units, for use in teacher education and in teaching science in the classroom;

★ provision of authentic learning experiences for learning science through involving the relevant stakeholders in science and science education.

Establish

Teacher Education opportunities in IBSE

Available in **Ireland, Germany, Sweden, Cyprus, Czech Republic, Poland, Slovakia, Malta, Netherlands, Estonia** and **Italy** — teacher professional development workshops in IBSE provided by ESTABLISH partners.

If interested in participating please contact us.

Resources for teaching and learning in IBSE

Teaching and Learning Units for IBSE developed in Physics, Chemistry and Biology, e.g. Sound, Exploring Holes, Disability, Cosmetics, Chitosan, Forensic Science, Photochemistry, Renewable Energy & Medical Imaging.

Check out our website for details.

The ESTABLISH project has received funding from the European Community's Seventh Programme [FP7/2007-2013] under grant agreement no 244749.

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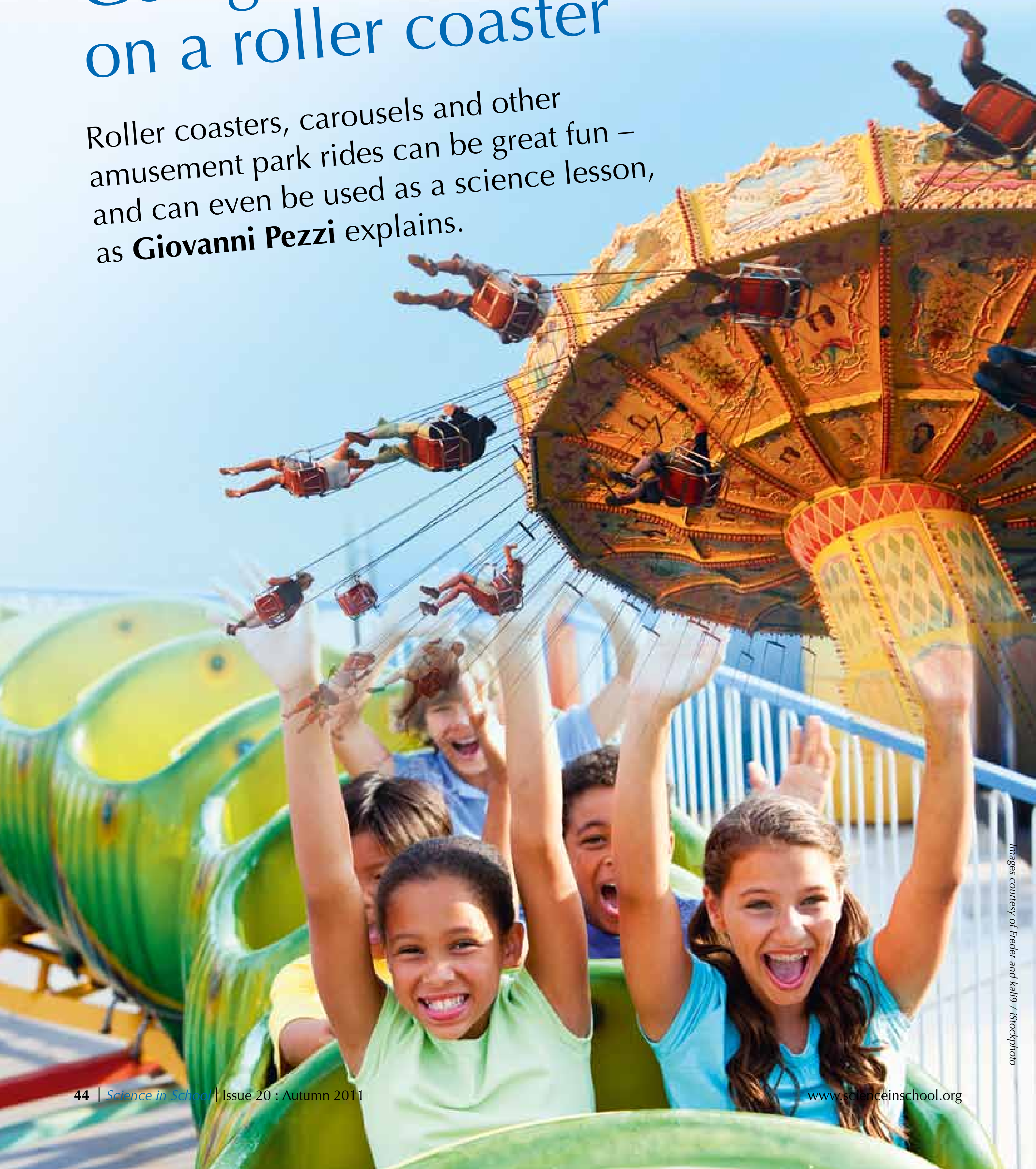
www.establish-fp7.eu

Going wild: teaching physics on a roller coaster

Roller coasters, carousels and other amusement park rides can be great fun – and can even be used as a science lesson, as **Giovanni Pezzi** explains.



Images courtesy of Freder and kali9 / iStockphoto

Image courtesy of Giovanni Pezzi and Alessandro Foschi

Vertical loops in roller coasters follow the course of a clothoid curve

An amusement park or a fun fair is an ideal place for physics experiments that could never be performed in the classroom. Several projects worldwide have developed suitable teaching activities (see 'Resources'). One of them is *Mirabilandia, un'aula senza pareti* (Mirabilandia, a classroom without walls), an Italian project started in 2002 by teachers from the secondary school Liceo Torricelli in Faenza, at their local amusement park, Mirabilandia[w1]. The initiative was so successful that the park's management decided to make it available to all schools, providing educational tours by trained science students.

Maybe you could discuss a similar arrangement with your local amusement park? Meanwhile, here are some activities suitable for any amusement park or fun fair. For some, you will first need to find out about rides' technical specifications, either from the park or online, for example at the Roller Coaster Database[w2]. To take measuring instruments on board a ride, safely tied to the students' wrists or the ride's structure, you will need the park authorities' consent. In our case, the school's headmaster contacted the park management, detailing the project we had in mind.

The activities are suitable for ages 15-19, but can be adapted for younger students. They cover the topics of rectilinear and circular motion, speed and acceleration, the three laws of motion, gravity, centripetal and centrifugal forces, and energy transformation. Students should be familiar with the basic concepts of kinematics and dynamics, and will need a basic introduction to the activities before they visit the park.

Work on each ride takes about one hour, but queuing for the ride may increase the time required. One team can perform the measurements

REVIEW

- **Physics**
- **Linear and circular motion**
- **Mechanics**
- **Energy conversions**
- **Ages 13-19**

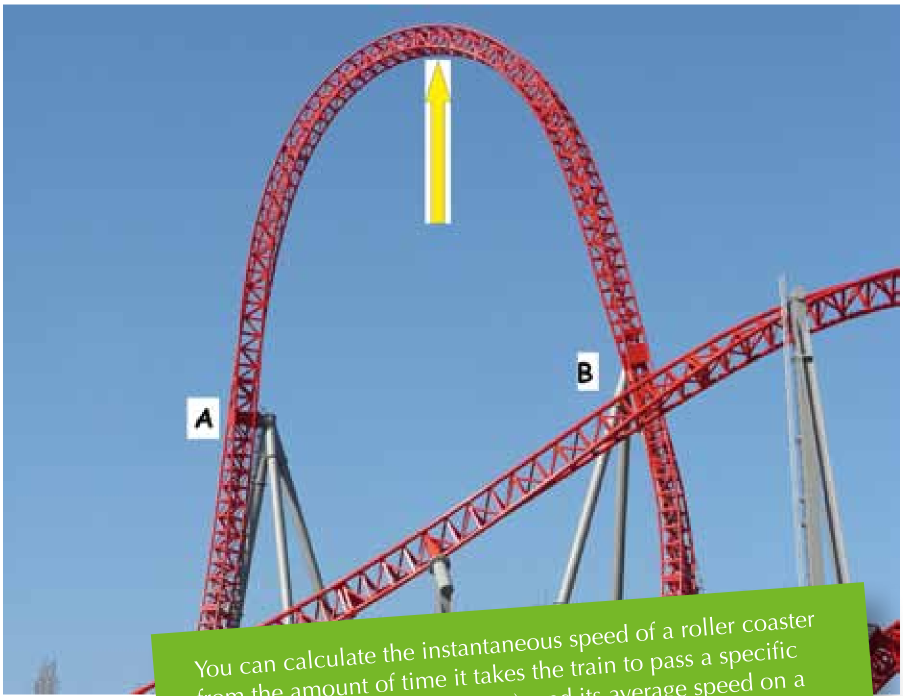
These Italian teachers have definitely found an innovative and impressive way to take physics out of the classroom. In this useful article, the activities are clearly explained, making them straightforward to reproduce. The background knowledge required for conducting the activities can easily be tackled during normal lessons; allow some time for preparing the instruments and workbooks.

The article also sheds light on safety in amusement parks, which requires careful planning. Perhaps you could to test your engineering skills by constructing your own virtual roller coaster (using www.learner.org/interactives/parkphysics) and testing it for safety. The article also links to several other useful websites.

For younger students (aged 13-16), the article could be used to address rectilinear motion; speed and acceleration; the three laws of motion; gravity; and energy transformations. Students aged 16+ could examine these topics in more detail, together with circular motion, centripetal and centrifugal forces.

Catherine Cutajar, Malta

Image courtesy of Giovanni Pezzi



You can calculate the instantaneous speed of a roller coaster from the amount of time it takes the train to pass a specific point along the ride (see arrow), and its average speed on a section of the track (e.g. between A and B)

on board, while others work on the ground. Usually there is no time for each group to repeat measurements, but data from different groups can be compared. Preliminary evaluations can be made at the park and continued back in class.

At Mirabilandia, students receive a workbook to fill in. Part of this has been translated into English and is available for download from the *Science in School* website[w3].

Roller coasters

On the ground

Draw a rough two-dimensional height profile of the roller coaster and discuss the energy transformations along the way, especially on the first descent and vertical loops.

At the top of the roller coaster, before the first descent, the gravitational potential energy is at its maximum; along the descent, which often has a parabolic trajectory where passengers can experience weightlessness for a few seconds (in an ideal case without friction, the vertical component of the motion increases with the constant acceleration *g* due to gravity as in free fall), this is transformed into kinetic energy.

Use vertical loops to discuss the role of gravity versus centrifugal force. The loops are drop-shaped, following the course of a *clothoid* curve, in which the radius of curvature is in inverse proportion to the distance from the centre, thereby lowering the centripetal accelerations prevailing in the loop to make it more comfortable for the passengers.

You can only really appreciate how fast a roller coaster moves by determining its speed:

a) Calculate the instantaneous speed by dividing the length of the roller coaster train by the time it takes for the whole train to pass a specific point along the ride.

b) To obtain the average speed of the train along a section of the roller-coaster track, choose one that is easy to see and simple in terms of shape. Count the number of sleepers (regularly spaced bars between rails) on that section and subtract one to get the number of intervals. Time how long it takes for the train to travel along this section of track. To calculate the distance travelled, multiply the number of intervals by the interval length (the distance between two sleepers). Divide this by the time taken.

Compare the instantaneous speed recorded at the end of the first (fastest) descent with the speed calculated for a body in free fall: $v = \sqrt{(2 g h)}$ where v: speed, g: gravity acceleration, h: height.

The measured speed should be lower, due to friction.

On the roller coaster

Pay attention to sensations of lightness or heaviness (acceleration) you may experience along certain sections of the ride. More accurate data can be obtained with spring accelerometers, or more complex handheld instruments[w4]. Instructions for how to build and / or obtain these and evaluate your results can be downloaded from the *Science in School* website[w3].

Image courtesy of Mirabilandia

When accelerated downwards with more than the acceleration due to gravity, the water level in a cup will rise

Image courtesy of Giovanni Pezzi

Giovanni (on the left) with a spring accelerometer and a cup of water on a drop tower

Image courtesy of Giovanni Pezzi

To test the effects of downward acceleration, you can also use a small ball tied to your wrist

Recently, smart phones including a three-axis accelerometer have become more popular. Applications for these phones allow you to draw graphs of acceleration over time or to measure tilt angles. These involve fewer safety issues since they can be kept inside a pocket.

Drop towers

Drop towers are vertical tracks up and down which the passengers travel, seated on a gondola. In one type, the gondola is dropped in free fall; in the other, it is pushed down or up with a force greater than that of gravity.

From the ground, you can calculate the average speed of the gondola by timing its descent with a stopwatch and dividing that by the height of the tower. This can be compared to the instantaneous speed of a body in free fall. To measure the height of the tower, use a protractor and basic trigonometry or geometry. For detailed instructions, see the *Science in School* website[w3].

During the ride, you can feel the acceleration in your body and measure it with portable electronic instruments[w4]. On towers where the gondola is pushed down, the acceleration can reach up to three times that due to gravity.

If you take a plastic cup full of water along, you can observe that in free fall, the water will remain inside the cup, but if the gondola is thrust downwards rather than falling, the water level in the cup will rise. Alternatively, you can tie a small rubber ball to your wrist (pierce the ball to attach the string) and place it on your palm.

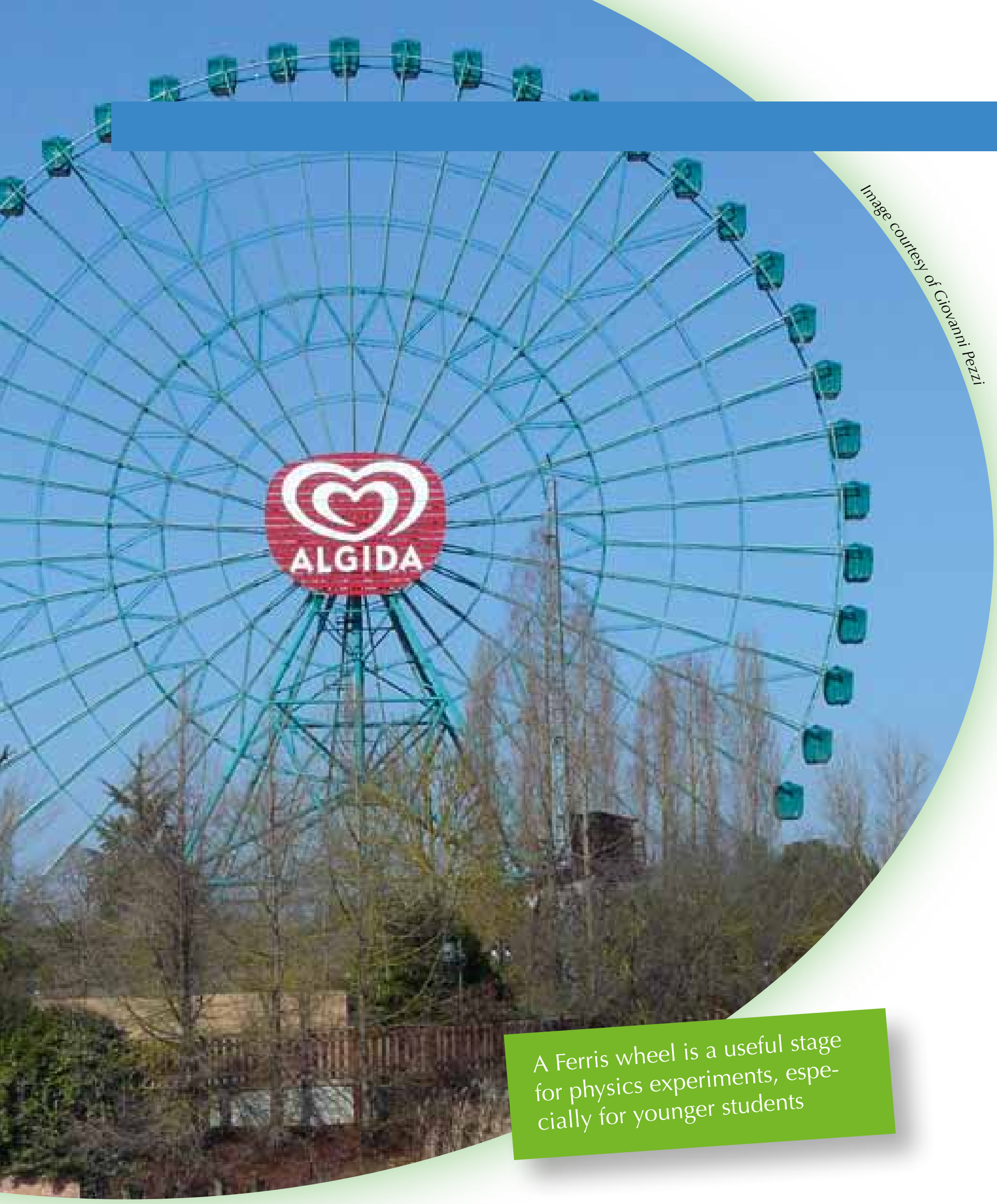
Ferris wheels

The following activities are also suitable for younger students, aged 11-14. They should be familiar with the concepts of speed and atmospheric pressure, and will learn about uniform circular motion (time, speed, frequency) and apply their knowledge about atmospheric pressure.

Either on the ground or during the ride, measure and note down the time after a quarter turn, half a turn, a three-quarter turn and a complete turn of the wheel. The students should find that the time taken for each quarter of a turn is similar, therefore the motion of the wheel is regular and the speed constant.

Calculate the length of the gondola's path (from the radius of the wheel), its average speed, and, as a maths exercise applied to the real world, the angle at the centre of the wheel between two bars that connect two neighbouring gondolas to the centre (divide 360° by the number of gondolas).

You can determine the wheel's height in the same way as that of the drop tower (see above) or by using electronic barometers to determine the change in atmospheric pressure during the ride. Every 0.1 kPa of pressure change corresponds to about 8 m of altitude change. A more accurate description of the relationship between pressure and altitude is available online[w5]. Compare the results and discuss the advantages and disadvantages of each method (accuracy, instruments, time and effort involved).

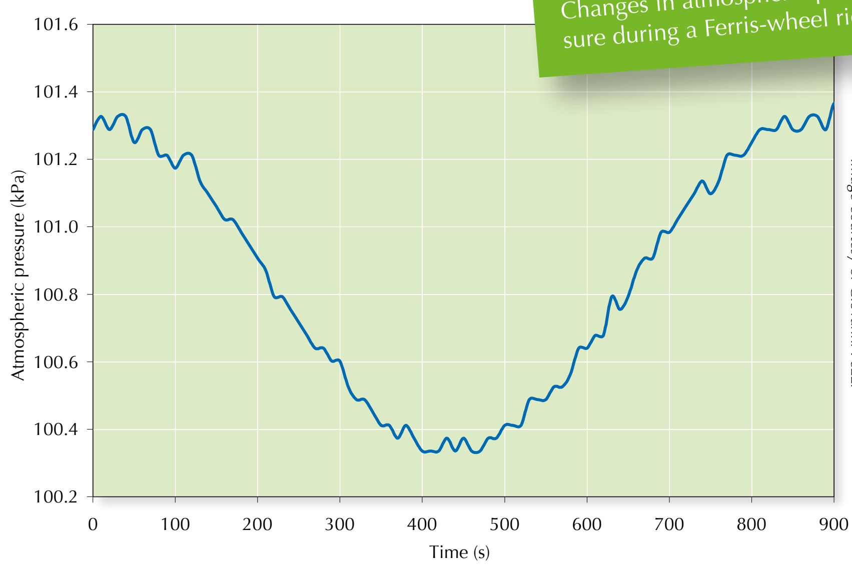


A Ferris wheel is a useful stage for physics experiments, especially for younger students

Image courtesy of Giovanni Pezzi

Carousels

A carousel is the perfect setting to study Foucault's pendulum and the Coriolis effect. Students should be familiar with the motion of a pendulum, the laws of motion, gravity, centripetal / centrifugal forces, and rotation. For details of how to perform these experiments, see the *Science in School* website[w3].



Changes in atmospheric pressure during a Ferris-wheel ride

Image courtesy of Giovanni Pezzi

Web references

w1 – To learn more about Mirabilandia, see: www.mirabilandia.it

In early September each year, Mirabilandia introduces their educational tours during an open day for teachers. See: www.mirabilandia.it/#/scuole

w2 – To access the Roller Coaster Database, see: www.rcdb.com

w3 – For the English version of part of the Mirabilandia student workbook; instructions for measuring heights using trigonometry and geometry, and studying Foucault's pendulum and the Coriolis effect with the help of a carousel; and details of how to build your own spring accelerometer or data collection kit, see: www.scienceinschool.org/2011/issue20/amusement#resources

w4 – The US companies Vernier and Pasco offer dedicated measuring instruments for use in amusement parks, which come with a full set of instructions and activities. See:

www.vernier.com/cmat/datapark.html

www.pasco.com/physhigh/amusement-park-physics w5 – For the relationship between atmospheric pressure and altitude, see the website of the atmospheric chemistry department of the Max Planck Institute for Chemistry in Mainz, Germany (www.atmosphere.mpg.de) or use the direct link: http://tinyurl.com/pressure-altitude

Resources

For a detailed report on the project in Italian, see: http://kidslink.bo.cnr.it/irrsaeer/borsric02/fisica.zip

Similar activities to Mirabilandia take place at the Liseberg Park in Göteborg, Sweden, led by physicist Ann-Marie Pendrill. For more information (in English and Swedish), see: http://physics.gu.se/LISEBERG

The Parque de Atracciones Madrid in Spain offers its physics and teaching handbooks (in Spanish) for download. See: www.parquedeatracciones.es/aulas-fisica

In the USA, physics days for schools in amusement parks, including roller-coaster design contests and worksheets, are a common concept. See:

www.aapt.org/Programs/contests/physicsday.cfm

www.physicsday.org

www.usu.edu/science/htm/2011-usu-physics-day-at-lagoon

www.kennywood.com/site/groups_education_mats.html

For an interactive guide to the physics of common amusement park attractions and an activity to design your own roller coaster, see: www.learner.org/interactives/parkphysics

A carousel

Image courtesy of Giovanni Pezzi

For more inspiration, see:

Alberghi S et al. (2007) Is it more thrilling to ride at the front or the back of a roller coaster? *The Physics Teacher* **45(9)**: 536-541. The article is freely available online.

Bakken C (2011) *Amusement Park Physics*. College Park, MD, USA: American Association of Physics Teachers. ISBN: 9781931024129

Unterman NA (2001) *Amusement Park Physics: A Teacher's Guide*. Portland, ME, USA: J Weston Walch. ISBN: 9780825142642

To find out more about roller coasters, see: http://tlc.howstuffworks.com/family/roller-coaster.htm

If you enjoyed reading this article, why not take a look at the full collection of physics articles published in *Science in School*? See: www.scienceinschool.org/physics

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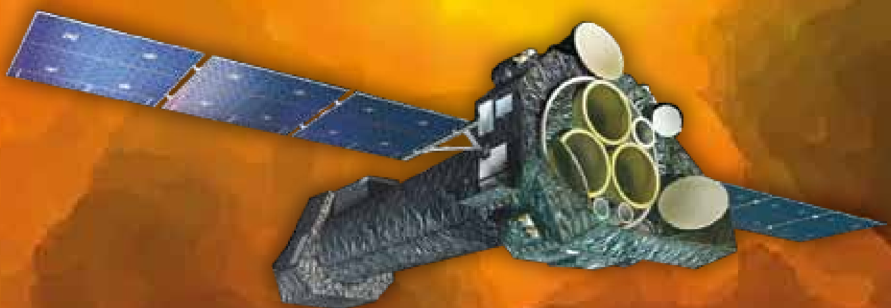
Before his retirement, Giovanni Pezzi taught physics in secondary schools in Italy and was a supervisor for the postgraduate school of teacher training at the University of Bologna. He has written many articles about physics teaching for education magazines, and contributed to physics and computer science textbooks. He holds workshops and lectures on updating teaching methods and designed and developed maths and physics activities for the launch of the Mirabilandia project.

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

Images courtesy of ESA

More than meets the eye: the electromagnetic spectrum

Claudia Mignone and **Rebecca Barnes** take us on a tour through the electromagnetic spectrum and introduce us to the European Space Agency's fleet of science missions, which are opening our eyes to a mysterious and hidden Universe.



We learn about the world around us via our senses. Our eyes play a major role, because light carries a great deal of information about its source and about the objects that either reflect or absorb it. Like most animals, humans have a visual system that collects luminous signals and relays them to the brain. Our eyes, however, are only sensitive to a very small portion of the spectrum of light – we are blind to anything but what we call 'visible' light.

Or are we? Over the course of the 19th century, scientists discovered and visualised several different types of previously invisible light: ultraviolet (UV) and infrared (IR) radiation, X-rays and gamma-rays, radio waves and microwaves. It soon became evident that visible light and these newly discovered forms of light were all manifestations of the same thing: electromagnetic (EM) radiation (see Figure 1, page 52).

The various types of EM radiation are distinguished by their energy: gamma-rays are the most energetic, followed by X-rays, UV, visible and IR light. Types of EM radiation with wavelength longer than IR light are classed as radio waves. These are subdivided into sub-mm waves, microwaves and longer-wavelength radio waves. EM radiation propagates as waves that travel even in a vacuum. The energy (E) of the wave is related to its frequency (f): $E = hf$, where h is Planck's constant, named after the German physicist Max Planck. The relationship between the frequency and wavelength (λ) of EM radiation is given by $f\lambda = c$, where c is the speed of light in a vacuum. These two relationships allow EM radiation to be described in terms not only of energy but also of frequency or wavelength.

Radiation at different energies (or frequencies, or wavelengths) is produced by different physical processes and can be detected in different

REVIEW

- Physics
- Biology
- Waves
- Satellites
- Telescopes
- Vision
- Ages 15-16

This article presents the reader with applications of the electromagnetic spectrum that are not usually considered when tackling this topic. Furthermore, it provides opportunities for teachers to engage their students and motivate further research into this fascinating topic.

The ESA vodcasts mentioned in the resource section are excellent material to engage learners in the topic of EM radiation. Teachers can also subscribe to receive the latest vodcasts.

Possible comprehension and extension questions include:

1. What type of waves are electromagnetic radiation? Transverse or longitudinal?
2. Give examples of types of electromagnetic radiation with higher and lower frequencies than visible light.
3. Describe some technological applications of light and radio waves.
4. Do you think pollution affects the amount of radiation detected? Give reasons for your answer.
5. Name one detrimental effect of UV light when it is not stopped by ozone in upper atmospheric layers.
6. What is a major hindrance in the effective use of terrestrial telescopes?

We normally associate the launch of astronomical telescopes with NASA. This article, however, makes it clear that Europe is also actively studying the skies – which should bring the topic closer to home for European students, and makes the science more relevant to them.

Angela Charles, Malta

Image courtesy of ESA / AOES Medialab

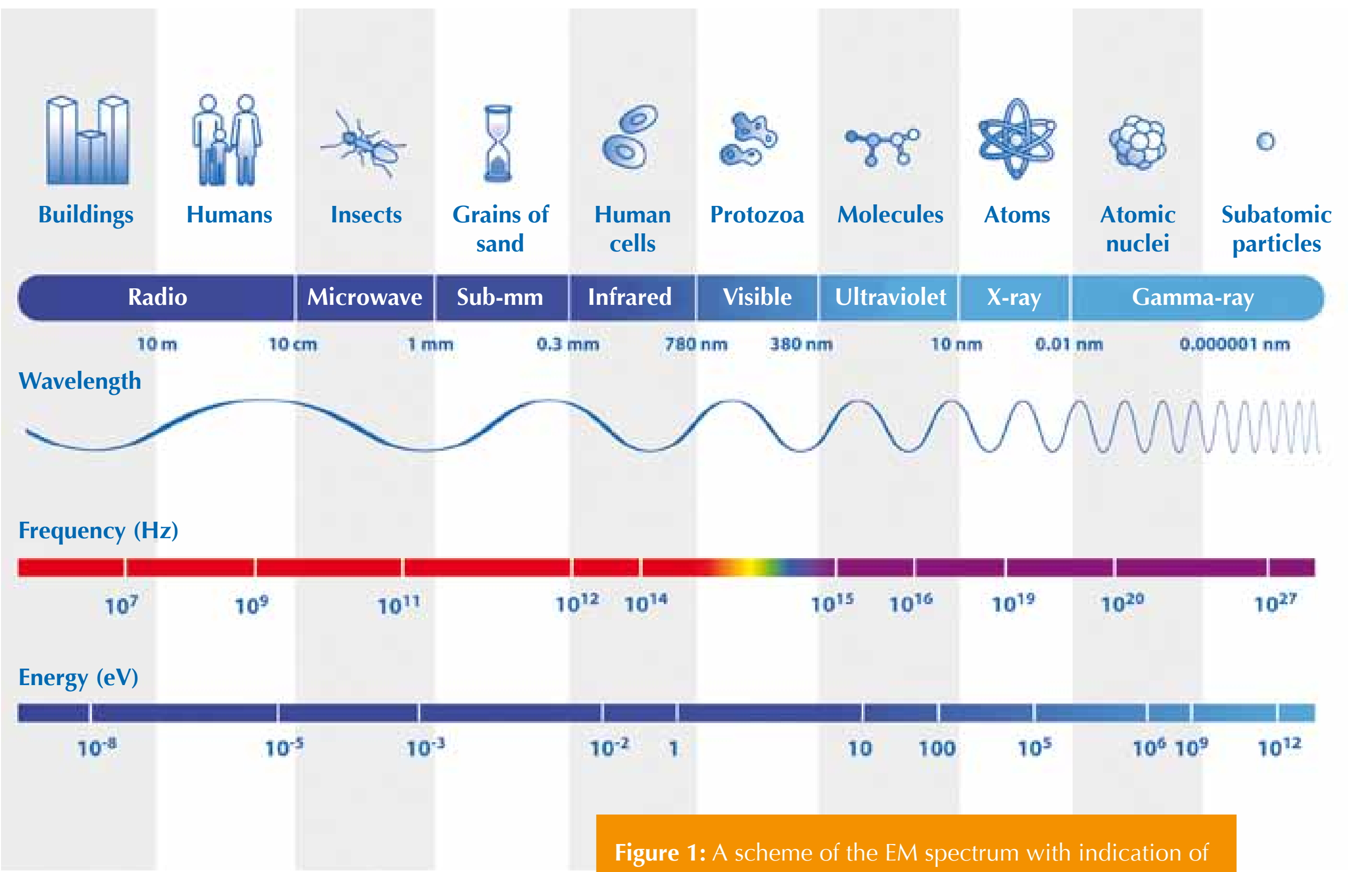


Figure 1: A scheme of the EM spectrum with indication of wavelengths, frequencies and energies

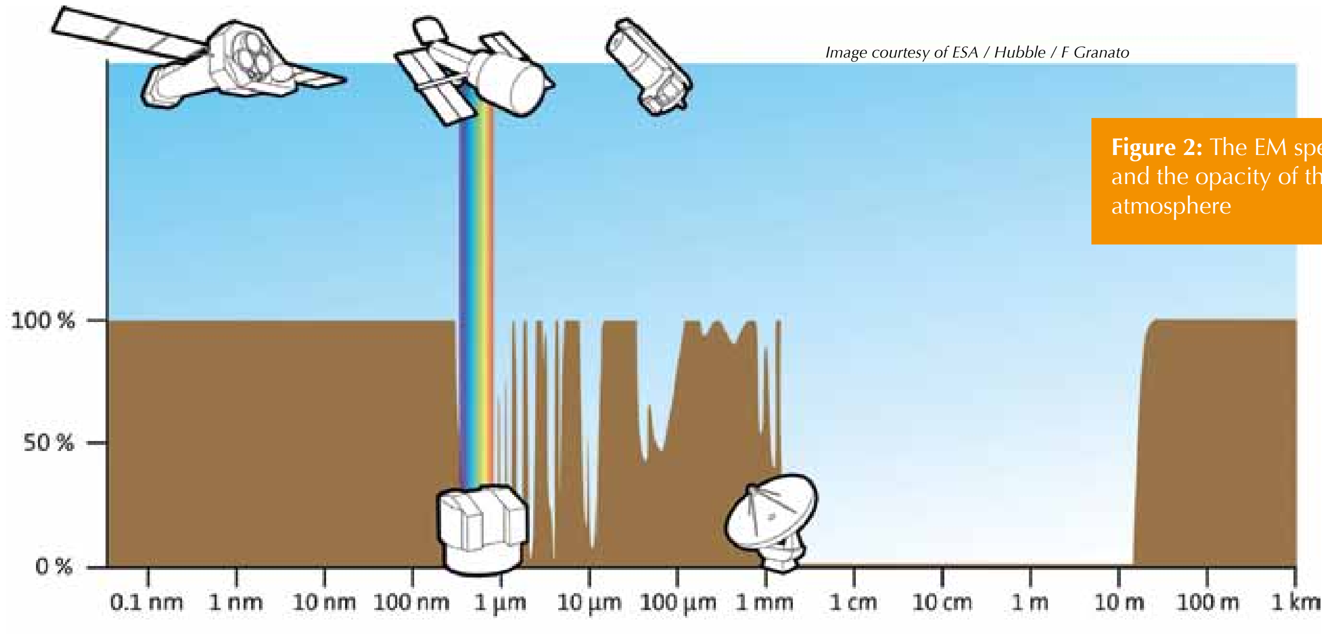


Figure 2: The EM spectrum and the opacity of the atmosphere

Gamma-rays, X-rays and UV light are blocked by the upper atmosphere (best observed from space)

Visible light is observable from Earth, with some atmospheric distortion

Most of the IR spectrum is absorbed by the atmosphere (best observed from space)

Sub-mm and microwaves can be observed from the ground at high altitudes in particularly dry climates

Mid-wavelength radio waves can easily be observed from the ground, but wavelengths over 10 m are absorbed by the atmosphere

ways – which is why, for example, UV light and radio waves have different applications in everyday life.

Towards the end of the 19th century, scientists began to investigate how this radiation from the cosmos could be captured to 'see' astronomical objects, such as stars and galaxies, in wavelengths beyond the visible range. First, however, they had to overcome the barrier of Earth's atmosphere.

The atmosphere is, of course, transparent to visible light – this is why many animals evolved eyes that are sensitive to this part of the spectrum. However, very little of the rest of the EM spectrum can penetrate the thick layers of our atmosphere (Figure 2).

- Highly energetic gamma- and X-rays, with wavelengths as small as or smaller than atoms, are absorbed by oxygen and nitrogen in the upper atmosphere. This protects life on Earth from lethal radiation but makes the radiation difficult for astronomers to detect.
- Most but not all UV radiation is absorbed by oxygen and ozone in the upper atmosphere and stratosphere. To exploit what UV radiation does reach Earth, some animals have evolved eyes that can detect it[w1].

More about ESA

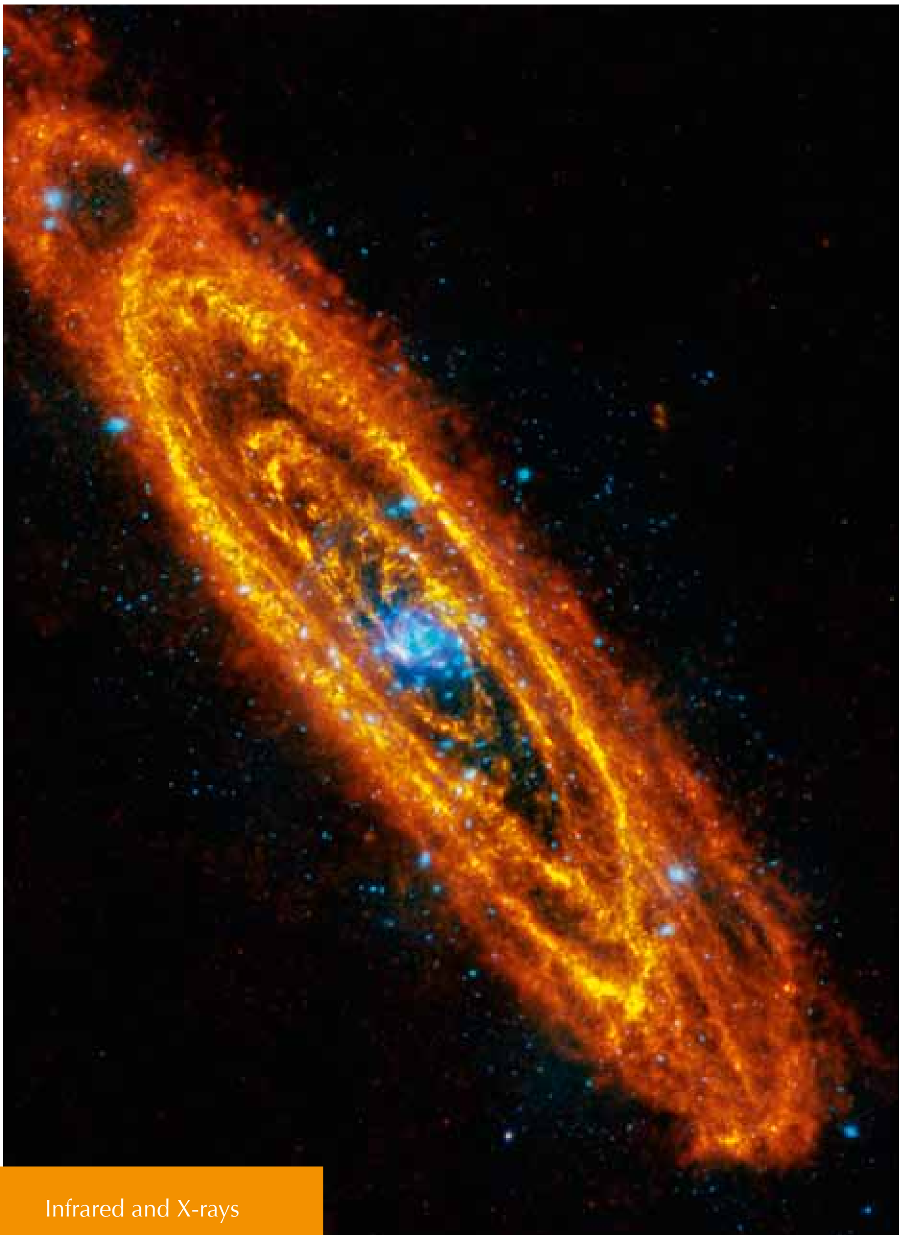
The European Space Agency (ESA)[w2] is Europe's gateway to space, organising programmes to find out more about Earth, its immediate space environment, our Solar System and the Universe, as well as to co-operate in the human exploration of space, develop satellite-based technologies and services, and to promote European industries.

The Directorate of Science and Robotic Exploration is devoted to ESA's space science programme and to the robotic exploration of the Solar System. In the quest to understand the Universe, the stars and planets and the origins of life itself, ESA space science satellites peer into the depths of the cosmos and look at the furthest galaxies, study the Sun in unprecedented detail, and explore our planetary neighbours.

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

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

Images courtesy of Robert Gendler (visible light); ESA / Herschel / PACS / SPIRE / J Fritz, U Gent (infrared); ESA / XMM-Newton / EPIC / W Pietsch, MPE (X-rays)



Infrared and X-rays

Figure 3:
Images of the Andromeda Galaxy
The Andromeda Galaxy, the nearest major galaxy to the Milky Way, seen at different wavelengths. Observations of visible light, with a ground-based telescope, show the several hundred billion stars that make up the galaxy. Observations at far-infrared wavelengths, by the Herschel space observatory, reveal the mixture of (mostly) gas and dust from which new stars will be born. X-ray observations, by the XMM-Newton space observatory, show the glow emitted by stars close to the end of their life cycle or by remnants of stars that have already died

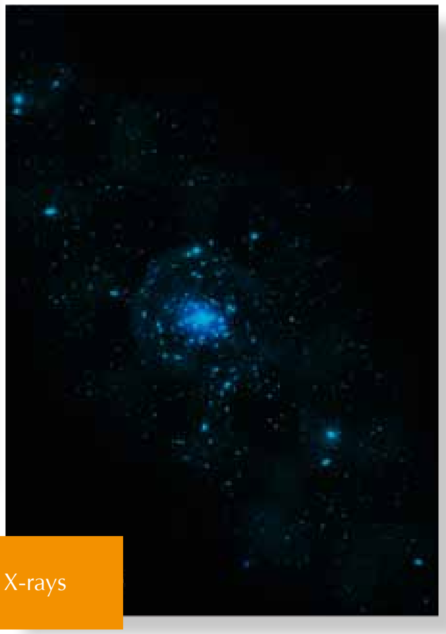
Infrared

- The shorter wavelengths of IR radiation can penetrate the atmosphere, but as its wavelength reaches one micrometre, IR radiation tends to be absorbed by water vapour and other molecules in the atmosphere.
- The same happens to sub-millimetre radiation – radio waves with wavelengths from a few hundred micrometres to about 1 millimetre – and to microwaves. They can be observed using ground-based facilities located in areas at high altitude with a particularly dry climate (as described by Mignone & Pierce-Price, 2010), or with balloon- and space-borne experiments.
- The atmosphere is transparent to mid-wavelength radio waves, which can easily be observed from the ground, but it blocks radio waves with wavelengths longer than ten metres.

The opacity of the atmosphere is not the only challenge it poses for astronomers; its turbulence also impairs the quality of astronomical observations even at wavelengths that reach the ground, such as visible light. Faced with these problems, in the second half of the 20th century, following the birth of the space age, astronomers began to launch their telescopes beyond the atmosphere, into space. This started a revolution in astronomy comparable to the invention of the first telescope just over 400 years ago.

Because different physical processes emit radiation at different wave-


Visible light


X-rays


Composite

@ EIROforum

Looking to the heavens: ground-based astronomy

Complementary to ESA's space telescopes are the ground-based telescopes of the European Southern Observatory (ESO)[w4]. To minimise distortion of the results by Earth's atmosphere, ESO operates telescopes at sites in northern Chile, which are among the best locations in the southern hemisphere for astronomical observations because of their high altitude and dry atmosphere.

Like ESA, ESO makes observations in different parts of the EM spectrum. ESO's Very Large Telescope (VLT) is the world's most advanced visible-light and infrared telescope, consisting of four 8.2 m diameter telescopes and four smaller telescopes, which can work together as an interferometer to enable observations in even greater detail. Still being built in the Atacama desert is ALMA, the largest ground-based astronomy project in existence. The result of a collaboration between ESO and international partners, ALMA will detect millimetre and sub-millimetre radiation, allowing astronomers to observe some of the coldest and most distant objects in the Universe with much better resolution and sensitivity than is presently possible (Mignone & Pierce-Price, 2010).

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

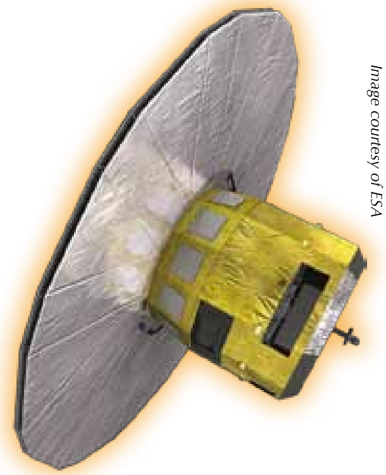


Image courtesy of ESA

lengths, cosmic sources shine brightly in one or more portions of the EM spectrum. By exploiting both ground- and space-based telescopes, therefore, astronomers today can combine observations from across the spectrum, which has produced a previously hidden and extremely captivating picture of the Universe (Figures 3 and 4). Observations in the IR range, for instance, show the otherwise invisible mixture of dust and gas that fills interstellar spaces and from which

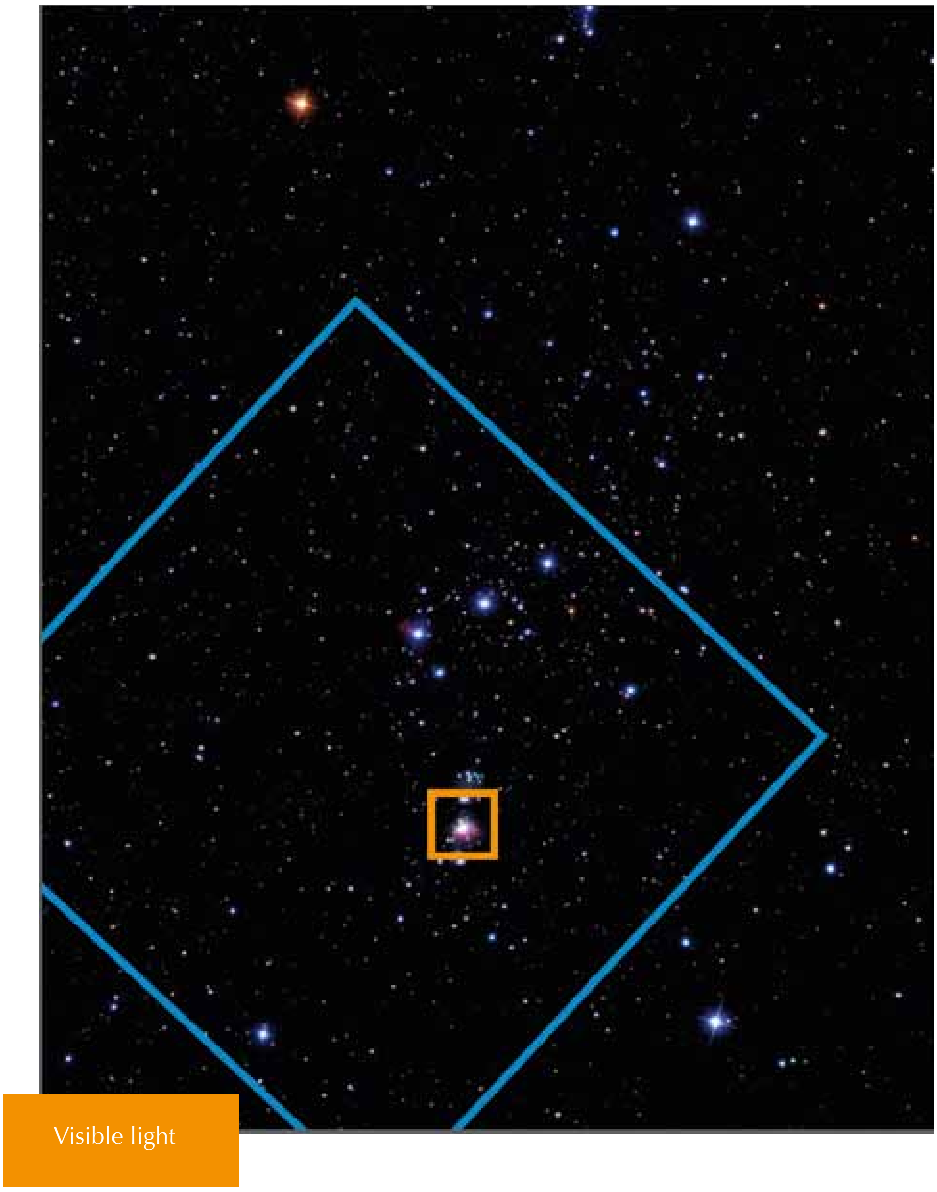


Image courtesy of ESA

new stars are born. By detecting gamma- and X-rays, astronomers can observe the most powerful phenomena in the Universe, such as black holes devouring matter and supernova explosions.

Probing the cosmos across the EM spectrum is one of the scientific objectives of the European Space Agency (ESA)[w2], which currently has five missions in operation that are dedicated to astronomy (see Figure 5, page 58). In order of increasing energies, they are Planck (sub-millimetre and microwaves), Herschel (IR), Hubble Space Telescope (visible, as well as some IR and UV wavelengths), XMM-Newton (X-rays), and INTEGRAL (gamma and X-rays)[w3].

In future *Science in School* articles, we will explore the EM spectrum in greater detail with help from ESA's fleet of past and present space telescopes, which have contributed to reshaping our understanding of the Universe.

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 – Unlike humans, some animals are able to see UV light.

To learn how researchers at the University of Bristol, UK, are investigating how birds can see UV light, and what evolutionary benefits it offers

Figure 4:
The Orion Nebula, an iconic cosmic 'nursery', seen at different wavelengths. The blue frame zooms in on part of the Orion constellation, and the orange frame zooms further in, showing the Orion Nebula in greater detail. This region, where thousands of stars are forming, looks very different across the EM spectrum. Observations in visible light, from ground-based observatories, show mostly stars, while observations at longer wavelengths (near- and mid-infrared, (sub)millimetre and microwave) reveal the intricate mixture of cold gas and dust from which stars are born. In contrast, X-ray observations show the extremely hot gas ejected by young, massive stars

Images courtesy of ESA / AOES Medialab (overall composition); Kosmas Gazeas (visible light, large image); STScI-DSS (visible light, small image); ESA, LFI & HFI Consortia (microwave and (sub)millimetre); AAAS / Science, ESA XMM-Newton and NASA Spitzer data (mid-infrared and X-rays); NASA, ESA, M Robberto (Space Telescope Science Institute / ESA) and the Hubble Space Telescope Orion Treasury Project Team (visible and near-infrared)

them, see: www.bristol.ac.uk/biology/research/behaviour/vision/4d.html

Pickrell J (2003) Urine vision? How rodents communicate with UV light. *National Geographic News*. See: http://news.nationalgeographic.com or use the direct link: http://tinyurl.com/urinevision

Bats scan the rainforest with UV-eyes. *Science Daily*. See: www.sciencedaily.com/releases/2003/10/031017073642.htm

How does a bee perceive flowers? See: www.naturfotograf.com/UV_flowers_list.html

w2 – For more information about ESA, see: www.esa.int

To learn more about the activities of ESA's Directorate of Science and Robotic Exploration, visit: www.esa.int/esaSC

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

w3 – For a spectacular view of the many different 'colours' of the Andromeda galaxy, as probed across the EM spectrum by various ESA missions, see: www.esa.int/export/esaSC/SEM5IUYGRMG_index_0.html

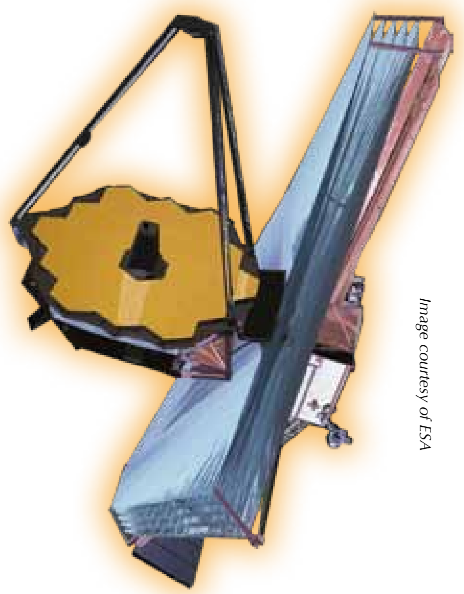


Image courtesy of ESA

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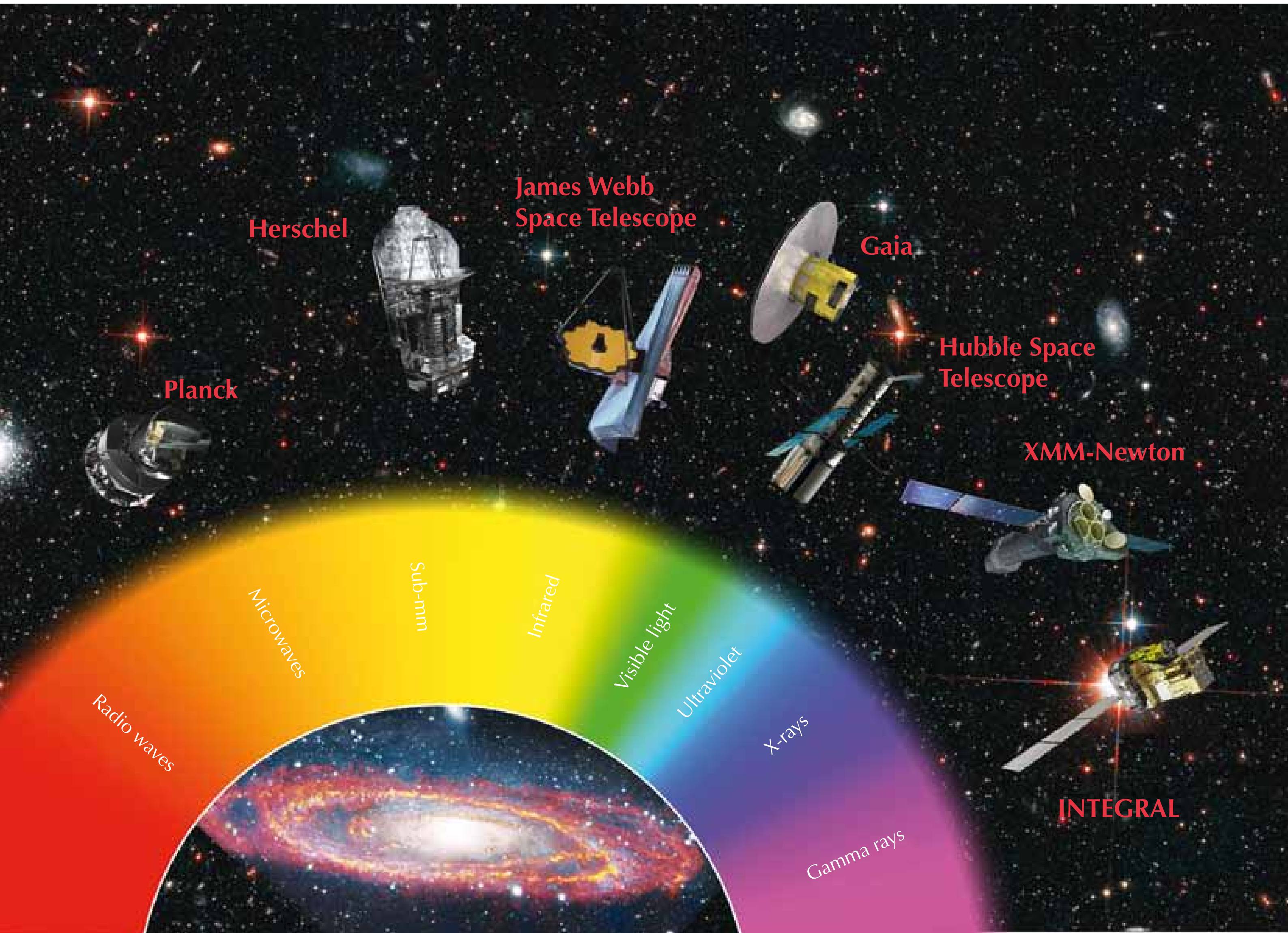

Figure 5: The current and future fleet of ESA missions probing the Universe across the EM spectrum

w4 – ESO is the world's most productive astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. To learn more about ESO, the VLT, ALMA and other ESO facilities, see: www.eso.org

For *Science in School* articles about the VLT and ALMA observatories, as well as recent astronomy research at ESO, see: www.scienceinschool.org/eso

w5 – To find out more about EIROforum, see: www.eiroforum.org

Resources

The Science@ESA vodcasts explore our Universe through the eyes of ESA's fleet of science spacecraft. Episode 1 ('The full spectrum') examines why we need to send telescopes into space and what they can tell us about the Universe. See: http://sci.esa.int/vodcast

To learn more about Earth's atmosphere and the role – and loss – of ozone, see:

Harrison T, Shallcross D (2010) A hole in the sky. *Science in School* **17**: 46-53. www.scienceinschool.org/2010/issue17/ozone

To see how physics teacher Alessio Bernadelli inspired his students about the EM spectrum by getting them to produce their own TV show on the subject, see Alessio's blog (http://alessiobernardelli.wordpress.com) or use the direct link: http://tinyurl.com/42ow4a9

To find out how the wavelength at which a celestial object emits most of its light is related to the object's

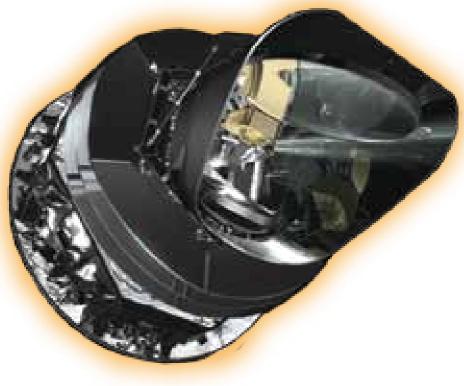

Image courtesy of ESA

temperature, see: http://sci.esa.int/jump.cfm?oid=48986

ESA has produced a wide range of freely available educational ma terials to support teachers in the classroom, which include printed materials, DVDs and online videos, teaching kits and websites. To see the full list, visit: www.esa.int/educationmaterials

To find out about all ESA education activities, see: www.esa.int/education

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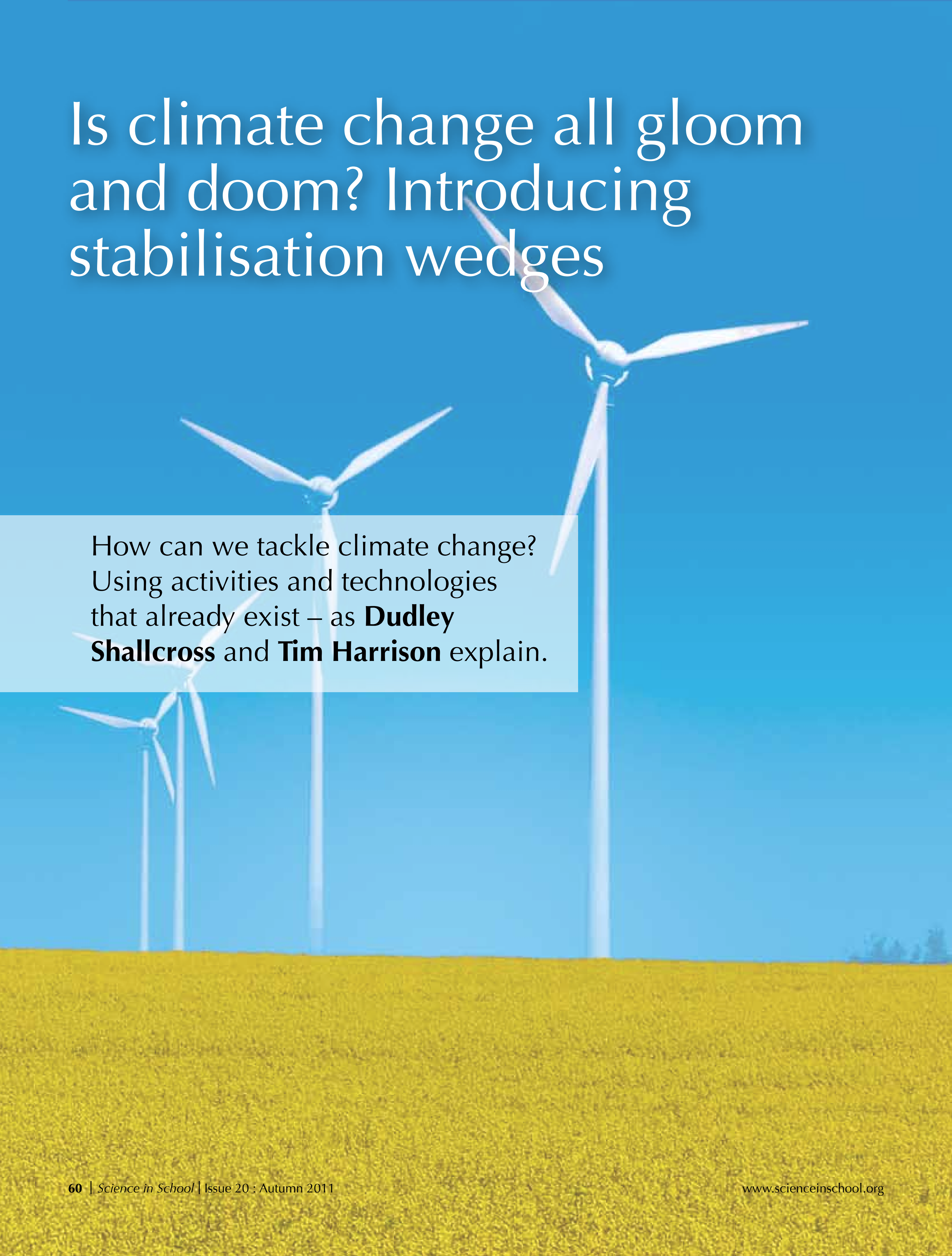
To learn how to use this code, see page 65.

Image courtesy of Kellermeister / pixelio.de



Is climate change all gloom and doom? Introducing stabilisation wedges

How can we tackle climate change? Using activities and technologies that already exist – as **Dudley Shallcross** and **Tim Harrison** explain.

When learning about climate change, students and the general public can easily become despondent: if the global catastrophe is inevitable, why even discuss ways to avert it? But they should not despair: there are ways to tackle one of the most important contributors to climate change: carbon dioxide (CO_2). In this article, we draw on the ideas of two leading climate scientists (Pacala & Socolow, 2004; Socolow & Pacala, 2006) for stabilising carbon dioxide emissions using technologies that already exist. We then offer some ideas on how to use the topic at school.

The challenge

Figure 1 (below) shows how global carbon dioxide emissions have increased over the past 50 years and how they are predicted (based largely on changes in population) to change in the next 50 years. Carbon dioxide emissions are quantified as the mass of carbon that is emitted as CO_2. If we take no action, by 2055, it is predicted that global annual carbon emissions will double to 14 gigatonnes of carbon (GtC; 1 Gt = 10^9 t). This will give a level of carbon dioxide in the atmosphere three times higher than that observed before the Industrial Revolution. Our planet has not had such a high level (around 850 ppm) for 30 million years, and it is predicted to cause a rise in Earth's average surface temperature of 1 to 5 °C.

Is this unavoidable? Pacala and Socolow believe not. They suggest that we try to maintain carbon emissions at their current levels of 7 GtC per year and because no one method will achieve this, they have devised the idea of stabilisation wedges.

A wedge represents an activity or technology that reduces carbon emissions to the atmosphere; the reduction starts at zero today and increases linearly until, in 50 years time, it accounts for a reduction in predicted emissions of 1 GtC per year (Figure 2, page 62). Over 50 years, the cumulative total of one wedge is therefore a reduction in predicted emissions of 25 GtC. A combination of seven wedges would achieve Pacala and Socolow's aim: annual emissions of 7 GtC in 2055 rather than the predicted 14 GtC.

Because the model assumes a starting year of 2005, there are now fewer

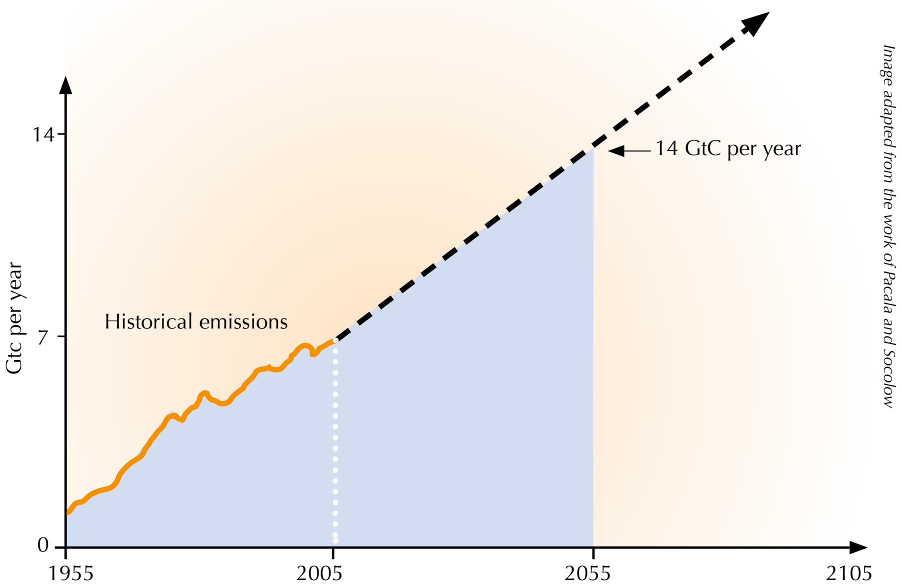


Figure 1: Historical, current and predicted levels of carbon emissions (modelled in 2005)

REVIEW

- Physics
- Chemistry
- Earth science
- Biology
- Environmental education
- Social studies
- Ages 10-19

Anthropogenic carbon dioxide production and climate change are common topics in science and environmental curricula in Europe and beyond, so the novelty of this article is the proposed approach, inspired by the Carbon Mitigation Initiative at Princeton University, USA[w1]. Teachers can introduce their students to the concept of stabilisation wedges, ways to reduce carbon dioxide production with present-day technologies, with the help of the proposed activities or a board game. It could also motivate students (and their families) to save energy and reduce carbon dioxide production in everyday life.

This article could be used to address many topics: greenhouse effect and climate change, atmospheric chemistry, natural resources, energy production and management, ecology, active citizenship and many others. The links to many different subjects make this article a potential starting point for interdisciplinary activities.

Giulia Realdon, Italy

Image adapted from the work of Pacala and Socolow

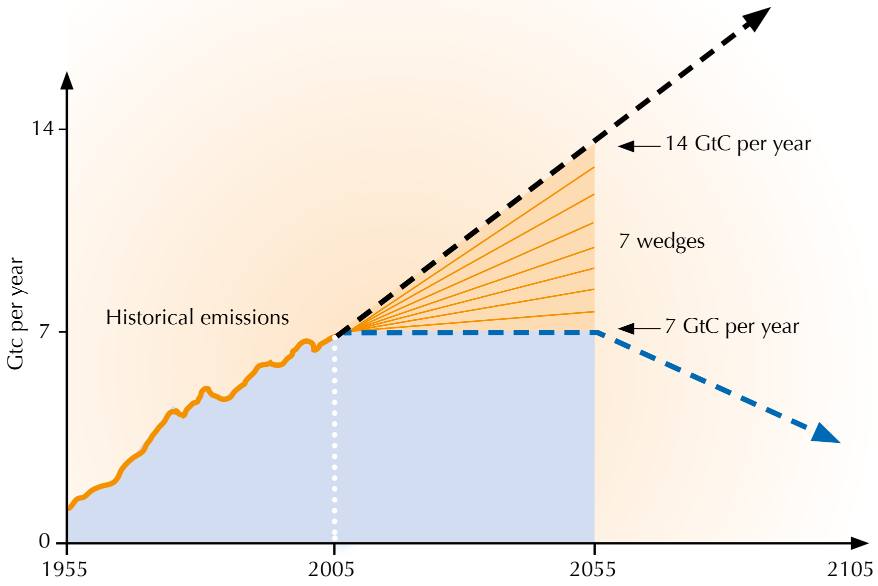


Figure 2: How stabilisation wedges could maintain carbon emissions at current levels

Image courtesy of sassi / pixelio.de

than 50 years to achieve the reductions, but the concepts are just as valid.

How could we save a wedge?

1. More efficient cars. It is predicted that in 2055, there will be 2 billion (2×10^9) cars in use, four times the number today. If they averaged 16 000 km per year (as they do today) but operated at 4.7 l per 100 km of fuel instead of 9.4 l per 100 km (the current value), this could save one wedge of carbon.
2. Reduced car use: by 2055, assuming 2 billion cars and no improvement in car efficiency, one wedge could be saved if the distance travelled per year was halved, from 16 000 km to 8000 km.

Both of these options could save more than one wedge if the number of cars in use by 2055 has been over-predicted. For example, more use of telecommunication (such as web conferencing and home working) and public transport would reduce the number of cars needed.

3. More efficient buildings: many savings can be made. For example, replacing all the world's incandescent light bulbs with compact fluorescent lights would save ¼ wedge. Even larger savings are possible with heating and cooling. To save a whole wedge, we would need to reduce carbon emissions from buildings by 25%.

Image courtesy of Wendell; image source: Flickr

Image courtesy of Timo Newton-Syms; image source: Flickr

Image courtesy of designritter / pixelio.de

4. Improved power plant efficiency: coal-powered plants currently operate at about 32% efficiency and are responsible for about 25% of all carbon emissions. Improving plant efficiency to 60%, e.g. with fuel cells or better turbines, would save half a wedge if the quantity of coal-based electricity were unchanged.
5. Decarbonisation of electricity and fuels: for example, per unit of electricity, carbon emissions from natural-gas power plants are half those of coal-based power plants. One wedge could be saved if, by 2055, 1400 GW that is currently produced from coal were instead produced from gas.
6. Increased use of renewable, non-fossil, energy sources including nuclear fission, wind electricity, photovoltaic electricity and biofuels.

- A wind-electricity wedge would require a wind farm with a combined land area the size of Germany.
- A photovoltaic electricity wedge would need an array of photovoltaic panels with a combined area about 12 times that of metropolitan London, UK.
- One wedge of first-generation biofuels would require planting an area the size of India with biofuel crops.

All these options are based on current technologies, and therefore some may provide even more savings as technology improves. There are also conservation options for saving wedges that do not involve modern technology:

7. Deforestation: eliminating clear-cutting of primary tropical forest over the next 50 years would save half a wedge. A further half a wedge would be saved if 250 million hectares of tropical land were reforested, or 400 million hectares of temperate land (areas of tropical and temperate forests are 1500 and 700 million hectares, respectively) over 50 years.
8. Soil management: conversion of forest or natural grassland to cropland aerates the soil through annual tilling, accelerating the decomposition of stored carbon and releasing it back into the atmosphere. It is believed that, historically, 55 GtC (2 wedges worth) have been released in this way. Currently, of a total of 1600 million hectares of cropland worldwide, only 110 million hectares undergo conservation tilling, whereby the soil is not disrupted. Examples of conservation tilling include soil-erosion control, planting of cover crops, and drilling of seeds without ploughing. Conservation tilling of all croplands could save from a half to one whole wedge. More vegetarianism and thus reduced levels of meat farming would also reduce carbon (and methane) emissions.

Classroom activities

Carbon dioxide emissions and the measures taken to reduce them will affect the young more than their teachers or the authors, so this is an important topic for schools. It could be used for a number of individual, group or class activities.

- Choose a carbon-saving activity or technology and either produce a poster or give a presentation to the rest of the class explaining how it works and how it could decrease atmospheric carbon.
- Investigate how you would save the requisite seven wedges. Which solutions would you use? What consequences would they have for people?
- If only three carbon-saving activities or technologies could be implemented, which would you choose and why?
- One carbon-reducing method could be to forbid cars to be driven by people under 24 years of age. Discuss the advantages and disadvantages.
- Identify the effects on ecosystems of any one of the carbon-saving technologies.
- Which carbon-saving solutions could be introduced at school and at home? Investigate the cost of powering your school by various methods (e.g. electricity, natural gas, butane, propane and fuel oil) and the savings made by any alternative-energy methods employed by your school.
- Should citizens of all countries be required to save carbon equally? Should developed and developing countries be treated differently?
- What do you think about the concept of stabilisation wedges? Is it sufficient to aim to keep carbon dioxide emissions at their current levels by 2055 or do we need to reduce them even further? Is that manageable? If so, how?
- Write a 250-word essay to your grandparents, explaining why the reduction of carbon is necessary and what they could do about it.

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Pacala S, Socolow R (2004) Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* **305(5686)**: 968-972. doi: 10.1126/science.1100103

Socolow RH, Pacala SW (2006) A plan to keep carbon in check. *Scientific American* **September 2006**: 28-35. www.scientificamerican.com/article.cfm?id=a-plan-to-keep-carbon-in

Web reference

w1 – For further details about Stephen Pacala and Robert Socolow's work, see the website of the Carbon Mitigation Initiative at Princeton University, USA: http://cmi.princeton.edu

In particular, a free board game and supporting materials can be downloaded here: http://cmi.princeton.edu/wedges

Resources

The *Scientific American* website offers a slide show about 'The World's 10 Largest Renewable Energy Projects'. See www.scientificamerican.com or use the direct link: http://tinyurl.com/3qr2mpc

To read more about stabilisation wedges and introducing them into your life, see:

Biello B (2007) 10 solutions for climate change: ten possibilities for staving off catastrophic climate change. *Scientific American*. See www.scientificamerican.com or use the direct link: http://tinyurl.com/3p9h22r

Calculate your own carbon footprint on The Nature Conservancy website: www.nature.org/greenliving/carboncalculator or the website of Conservation International: www.conservation.org/act/live_green/carboncalc

To introduce primary-school children to carbon dioxide, see:

Rau M (2011) Fizzy fun: CO_2 in primary school science. *Science in School* **20**: 24-29. www.scienceinschool.org/2011/issue20/co2

Find out more about the sustainable use of energy and how to teach it:

Haubold B (2011) Review of *Sustainable Energy – without the hot air*. *Science in School* **20**. www.scienceinschool.org/2011/issue20/sustain

You may also enjoy the other climate-change related articles in *Science in School*, including several by the current authors. See: www.scienceinschool.org/climatechange

To browse the series of energy-related articles in *Science in School*, see: www.scienceinschool.org/energy

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Dudley Shallcross is a professor of atmospheric chemistry and Tim Harrison is the director of outreach and school teacher fellow at Bristol ChemLabS, University of Bristol, UK.

Image courtesy of Paul-Georg Meister / pixelio.de

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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.jet.efda.org

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 fifteen 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 and ILL

The European Synchrotron Radiation Facility (ESRF) and the Institut Laue-Langevin (ILL) are European research centres where every year some 10 000 scientists from around the world conduct experiments. The centres put at the disposal of these scientists powerful beams of neutrons and X-rays, which are complementary probes for the study of matter at the atomic scale.
X-rays and neutrons penetrate deep into materials and make it possible to resolve their microstructure and composition in three dimensions. They are used in every scientific discipline that studies objects at the nano- or atomic scale. The 1800 experiments performed every year at ILL and ESRF address fundamental and applied research, and also industrial applications. Located on the same campus in Grenoble, France, ESRF and ILL are the most powerful sources of X-ray and neutron beams in the world.
See: www.esrf.eu and www.ill.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

Image courtesy of Sense About Science

Warrior against pseudoscience: Daniella Muallem

Image courtesy of Shirley Shalev

Daniella Muallem

Daniella Muallem tells **Eleanor Hayes** about challenging misleading 'scientific' claims.

How does a biophysicist get involved in the battle against pseudoscience? "I was like a lot of young scientists," recalls Daniella Muallem. "I was passionate about my science, passionate about research, but I didn't know how to use it to make a more immediate impact on society. I'd see misinformation about science or a product claim that seemed ridiculous, I'd complain to my colleagues and we'd all moan about it but we wouldn't do anything about it."

Until, that is, she joined Voice of Young Science (VOYS, pronounced 'voice')[w1]. Co-ordinated by the UK charity Sense About Science[w2], VOYS is a network of early-career scientists who want to stand up for science in public, investigating product claims and correcting misinformation in the media. "One of the things I've learned through working with VOYS is that even at an early stage in your career, you really are an expert in the scientific process, so you're in a great position to confront bad science and pseudoscience in the public arena."

Pseudoscience: a collection of beliefs or practices mistakenly regarded as being based on scientific method.

Daniella entered the battle when she and other members of VOYS decided to challenge the claims about many 'detox' products. "The word sounds scientific but it's used to describe a really wide range of products. For example, there are detox footpads that you're supposed to stick on your feet at night and they will supposedly remove toxins while you sleep. Detox hair straighteners, detox face washes, detox body brushes – there is a whole range of products."

The young scientists approached the companies producing these detox products, asking "What do you mean by detox?", "Which toxins are you removing?" and "Do you have any evidence to support the claims that you're making?".

To Daniella's surprise, the companies were totally unprepared for these questions. "They had no materials prepared; if we asked to speak to their scientific departments, these departments didn't exist; and in some cases the customer representatives even ended up agreeing with us: the products didn't really do anything different from a non-detox product. Other people simply refused to answer us."

Image courtesy of UNAIDS; data source: UNAIDS

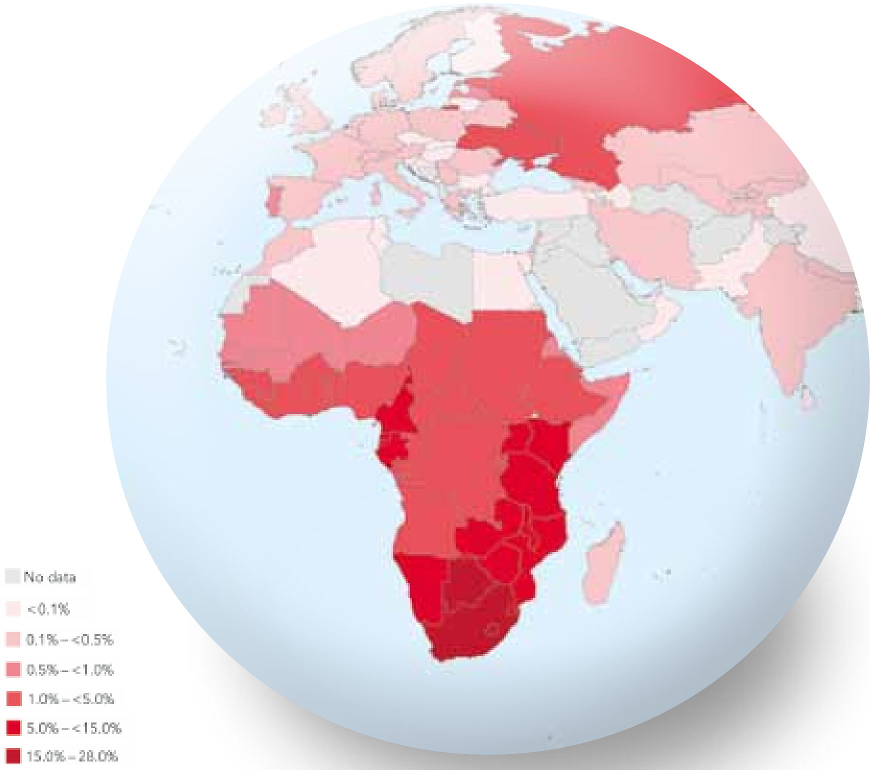

Image courtesy of ChristianHeldt; image source: Wikimedia Commons

Daniella and the other VOYS scientists drew their conclusions: "It was clear that detox has no scientific meaning and it's just a pseudoscientific marketing slogan." They released their report, including transcripts of the interviews with the companies, just after Christmas, "when everyone is obsessed with detox". The media coverage was enormous, and the young scientists were asked to give many interviews.

But doesn't everyone already know that these and similar scientific-sounding claims are rubbish? Daniella thinks not: "Our experience showed that people may not be sure, but they don't know how to make the judgement."

So some of the public benefited – but so too did Daniella. "The best thing about working with VOYS was being able to use my experience and knowledge for the general public. It also gave me the chance to really be

REVIEW

All sciences

Ages 15-18

This article addresses the importance of alerting the public to the fact that not everything that sounds scientific is actually science, making scientific literacy – and science education – vital.

Reading the article would be an excellent starting point for an interdisciplinary project with secondary-school students in grades 10-12 (ages 15-18). For example, biology and chemistry teachers could work together with their students to investigate 'scientific' slogans that are used to advertise products (e.g. in the cosmetic and food industry).

The article could also be used to start a discussion. For example:

Daniella Muallem says "You don't have to be a scientist to ask for explanations. By asking the right questions we can all get involved in the battle against pseudoscience. If you see something that seems wrong, ask!" Do you agree? Justify your position.

This should encourage students to realise that we need a certain level of knowledge to detect incorrect claims. Thus even people who do not enter a scientific career should (have the opportunity to) be scientifically literate.

Daniella Muallem states that "science affects everyday life and everyday people" and can benefit "human health and the environment". List and explain some examples to corroborate this statement; try to choose examples from different scientific areas.

Betina da Silva Lopes, Portugal

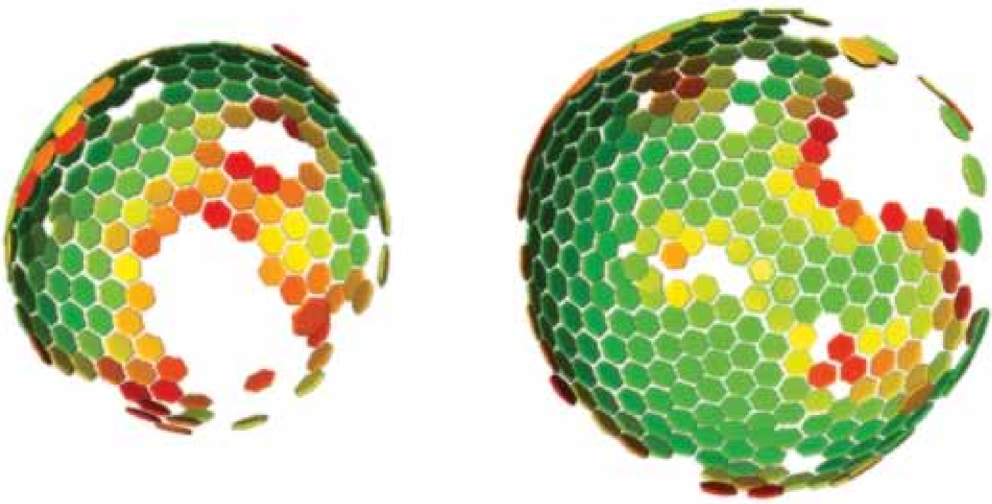

Image courtesy of John Briggs / EMBL

Lattice maps for immature HIV particles. The 3D computer reconstruction shows the immature Gag lattice of HIV that matures to form the protein shell of the infectious virus

Image courtesy of Kasiam / iStockphoto

part of a team, which is sometimes missing in research."

Alongside her postdoctoral research into biophysics, Daniella continued her involvement with VOYS. When they heard of a conference about using homeopathy to treat HIV, AIDS, malaria and other life-threatening illnesses in Africa, she and some other VOYS scientists discovered that several organisations were promoting homeopathy as the cheap, effective, side-effect-free alternative (not complement) to conventional medicine. They were particularly appalled by the stance of the World Health Organization (WHO): "Hidden away in all their information, they said 'the downside of homeopathy is that it doesn't really work' but also 'the advantage of homeopathy is that it's really cheap'."

With the help of Sense About Science, they involved medics who were working in Africa and experts in the fields of HIV and malaria, wrote a letter to the WHO and simultaneously released it to the media. "The response from the WHO wasn't quite as quick as we'd have liked but after weeks of pushing, we finally got a response: the WHO made a clear statement that homeopathy is not ap-

Image courtesy of icefront / iStockphoto

propriate for treating life-threatening illnesses in Africa. We got huge global coverage for this."

Inspired by these experiences, Daniella became more involved in science communication. "I loved the creative aspects of research, the feeling of excitement when my ideas turned out to be good ones and being absorbed in my own project, but the nature of academic research means you have to focus on a small scientific area. It can also sometimes feel quite disconnected from the everyday world. My experience with VOYS made me realise that although I loved research, I wanted to be more connected with how science affects everyday life and everyday people. I also realised how much I enjoyed interacting with a range of different people."

In 2010, she took the plunge, changing career, country and even continent – and now lives in Israel, working as a research analyst in the clean technology sector. This involves researching and reporting on companies that develop technologies to improve the environment, such as renewable energies and energy efficiency.

It may sound a long way from the lab, but Daniella would disagree. "I am using all the skills and knowledge I developed in my science career,

The *Anopheles albimanus* mosquito, a vector of malaria

Image courtesy of James Gathany / Public Health Image Library

such as research methods, analysing information, writing and presenting my findings. I am also drawing on my biology and physics background to understand the technologies and science in new areas of biotech and cleantech. These jobs are bringing me closer to the interface of where science meets technology and the implications of science for the benefit of human health and the environment."

Despite the geographical distance, Daniella remains in contact with VOYS. The network encourages young professional scientists – PhD students and postdocs – to challenge dubious-sounding scientific claims but, as Daniella says, "You don't have to be a scientist to ask for explanations. By asking the right questions

Image courtesy of Sense About Science


Image courtesy of Yuri Arcurs / iStockphoto

we can all get involved in the battle against pseudoscience. If you see something that seems wrong, ask!"

Daniella's advice to school students would be to work as a group, as, in her experience, it's more motivating that way. And even if you don't end up on TV, there's still plenty you can do. "If you can get your school interested in challenging pseudoscience and understanding the importance of evidence, that's already a big step. You could suggest holding a class discussion, or get outside speakers to come to your school and try writing about your experiences for the school magazine or the local newspaper."

We at *Science in School* look forward to hearing what you and your students have done.

So what does Daniella plan to do next? "The simple answer is I don't know. Having a science background keeps a lot of doors open, and there are so many different directions possible, it is sometimes hard to make a choice."

Web references

w1 – To find out more about the Voice of Young Science (VOYS), see: www.senseaboutscience.org.uk/voys

To learn more about the 'detox dossier', the homeopathy investigations and the media coverage they received, visit the Sense About Science website[w2] or use the direct link: http://tinyurl.com/3hlvmah

These and other investigations by VOYS are compiled in *There Goes the Science Bit: A Guide to Standing up for Science*, which can be downloaded from the Sense About Science website[w2] or via the direct link: http://tinyurl.com/3vryo3x

w2 – Sense About Science is a charity that works with scientists and civic groups to respond to the misrepresentation of science and scientific evidence on issues that matter to society. To find out more or get involved, visit: www.senseaboutscience.org.uk

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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, initially for a bioinformatics company and then for a learned society. In 2005, she moved to the European Molecular Biology Laboratory to launch *Science in School*.

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

The Technology, Entertainment and Design (TED) website

Reviewed by Colin Johnson

TED (Technology, Entertainment and Design) is a non-profit organisation that began as a conference to share "ideas worth spreading". The first of its annual conferences was held in 1984 and since then, the programme has spread to include regional and local events across the world (see the website's 'TEDx Events' section for local events).

There are now two major conferences held each year: the TED Conference in Long Beach and Palm Springs, both California, USA, and the TED Global conference in Edinburgh, UK. The registration fees are very hefty, yet the conferences are so popular that they are sold out up to a year in advance.

TEDTalks is the name given to speeches from the conferences that were released online and it now forms the focus of the TED website. With the headline 'Riveting talks by remarkable people, free to the world', the talks from the past five years have been openly available under a Creative Commons licence. There are now more than 700, covering a wide range of disciplines, making this an amazingly rich resource. To take just a few of the big-name speakers: mathematician Marcus du Sautoy (on symmetry), neurologist Oliver Sacks (on hallucinations), architect Frank Gehry (on how he went from blowing up his house to being a world-renowned architect) and virtuoso percussionist Evelyn Glennie (on listening to music with your whole body). The site has a good search facility and the videos play smoothly.

Thanks to the TED Open Translation Project, which, like *Science in School*[w1], is supported by volunteer translators worldwide, talks are now available with subtitles in 89 languages.

In addition, a TEDPrize is awarded annually to an exceptional individual with a "wish to change the world", leading to collaborative initiatives with far-reaching impact. You can also apply for the TED Fellows programme, supporting young innovators from across the globe who form a diverse and fascinating community. Interaction with them via the website is encouraged.

The TED site is not intended to support curriculum needs directly. Instead, it is about opening your own mind (as a teacher) and those of your students to the boundless excitement of science and technology. These are some of the world's most eloquent advocates for the world of science. The knowledge and inspiration you gain from them will be invaluable to your teaching, as well as to your students.

Details

URL: www.ted.com

Web reference

w1 – For more information on becoming a volunteer translator for *Science in School*, to help teachers in your mother tongue read our articles, see: www.scienceinschool.org/submissions/translators

Resource

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

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

Sustainable Energy – without the hot air

By David MacKay

Reviewed by Bernhard Haubold, Germany

Have you ever wondered how best to make students aware of the issues surrounding our current fossil-fuel-intensive lifestyle? After all, they stand a good chance of seeing fossil fuels perhaps not run out but become unaffordable in their lifetime. *Sustainable Energy – without the hot air*, by Cambridge professor of physics David MacKay, is an exemplary blueprint for engaging curious minds in the energy debate (it is also freely available online[w1]). Because fossil fuels are not only guaranteed to run out, but in so doing also lead to a potentially catastrophic increase in atmospheric carbon dioxide concentrations, MacKay's refreshingly radical aim is to live 'without fossil fuels'.

Whether or not this is an attainable aim is a matter of numbers: how much energy do we need and how much can we extract from various sources? Because raw numbers tend to be mind-numbing, MacKay presents the pertinent facts in many beautiful graphics, and as memorable number games. His back-of-the-envelope calculations are based on a single unit for measuring all energy consumption and production: the kilowatt-hour per day, which we can all relate to by reading the electricity meters in our homes.

The book is divided into four parts, the first two of which carry the main argument. Part I asks whether we can generate enough renewable energy to replace fossil fuels without making other adjustments. The somewhat disillusioning answer is, almost certainly not. So in Part II, alternative scenarios for weaning ourselves off fossil fuels are explored, such as electrifying transport. Part III supplements Part I by giving more rigorous calculations on the energy balance of cars, bicycles, planes, windmills, tides, and so forth. This part contains ideal material for teaching various elementary topics in physics, including car travel, plane flight, and heat transmission. Finally, Part IV consists of useful data for extending MacKay's UK-centric calculations to any country in the world.

Part I is structured as a clever race between energy consumption and energy production. Cars are the first consuming device considered, and MacKay asks: How many kilowatt-hours per day do we use by driving to school? Part of the answer is found by looking up the nutritional value of butter or margarine in your fridge and estimating the energy content of a litre of fuel from that. This exercise is then repeated for all of our well-known energy-consuming activities, including air travel, heating and lighting, but also for the traditional renewable energy sources centered on wind, sun, water and geothermal heat.

The conclusion from this race is that in the UK, renewable energy sources cannot nearly cover current energy consumption, so Part II explores new approaches to balancing demand and supply. MacKay emphasises *big* measures here, as the problem cannot simply be solved by disconnecting the phone charger. One such big measure would be to use bicycles whenever they can replace cars, which consume at least an astonishing 25 times more energy per kilometre travelled. Where is the cycle-lane building programme to reflect this fact?

Although most of us are aware that the bikes ridden by our students are more efficient than the cars we drive, this part of the book also contained surprises for me. For example, electrical heat pumps for heating houses are more efficient than condensing boilers, even if the heat pumps are powered by electricity generated from burning fossil fuels. Why is this fact not embodied in standards for new buildings?

MacKay is clearly aware of the politics of energy production and consumption when, for instance, he deftly compares the cost to the USA of the war in Iraq as estimated by Nobel Prize-winning economist Josef Stieglitz (USD 2000 million million) to his own estimated cost of converting the UK to sustainable energy production

(GBP 870 million million, the equivalent of about USD 1400 million million at the current exchange rate). However, in most of his book, MacKay steers clear of such considerations, while insisting that we should make an energy plan that actually adds up. For this we need to understand a lot of science, as shown throughout his book. But this is part of the fun of reading *Sustainable Energy*: the author is convinced that "simplification is a key to understanding" and thus allows his audience to grasp so much more than they might initially expect.

The intended audience for the book is the intelligent layperson. Although not specifically written for students, the book's engaging style and colourful illustrations make it suitable for anyone aged 14 and above. The chapters on the quantitative aspects of energy consumption and production would make excellent source material for secondary-level physics classes, the discussion of CO_2 emissions in rich versus poor countries would add spice to a geography class, the computation of the energy content of a kilo of margarine could enliven a biology class, and there is plenty more science for schools to be discovered in the book. If you are curious but wary of its full 384 pages, take a look at the 10-page synopsis posted on the book's web page[w1]. You will find a brilliant example of the power of simple scientific reasoning – exactly what science teaching should be about.

Details

Publisher: UIT Cambridge
Publication year: 2008
ISBN: 9780954452933

Web reference

w1 – *Sustainable Energy – without the hot air* is freely available online at: www.withouthotair.com

Resource

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

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

Translations – from today's science to tomorrow's medicine in Berlin-Buch

By Russ Hodge

Reviewed by Marie Walsh, Ireland

Campus Berlin-Buch is a science, health and biotechnology park in Berlin, Germany, with a focus on biomedicine. The Campus provides a unique environment for scientific exchange and research collaboration, facilitated by the close physical proximity of the research institutes, clinics and biotechnology companies. Major areas of activity include the study of the molecular causes of cancer, cardiovascular and neurodegenerative diseases, as well as interdisciplinary basic research to develop new drugs, patient-oriented clinical research and the commercial realisation of biomedical insights. Investments of more than 200 million Euros from the federal government, state government and the EU have made the tradition-rich Campus Berlin-Buch into an innovative location.

Translations is a celebration of just some of the research being carried out at Campus Berlin-Buch. Author Russ Hodge suggests that Berlin-Buch is a microcosm of current trends in experimental and clinical research in laboratories all around the world, and that the aim of the book is to open a window to the much larger international context of developing biomedicine.

This is a large (coffee-table type) book which would be a welcome addition to school libraries. The photography by Maj Britt Hansen and design by Nicola Graf (who is also responsible for the layout of the *Science in School* print edition) make it a very attractive book to browse. The literary style of the author also makes it an attractive book to read. For anyone with an interest in current research and development, and for teachers of life sciences who wish to take their students beyond the constraints of the syllabus and show the real-life applications of theory, this is a marvellous book. It certainly is not a textbook, but it is very relevant for contextualising the role of research in advancing medicinal science. The book can be ordered (free) in print or downloaded as a PDF[w1].

The book is introduced by the author's description of being driven from the train station in Berlin to the campus at Berlin-Buch where he was starting as a new staff member. This fantastic research facility is put in context with descriptions of Berlin's scientific development throughout history, and the author's attempt to give a glimpse of what the Campus is likely to produce in the future. Incidentally, German schoolchildren have the opportunity to tour the Campus teaching facility (the Transparent Laboratory, *Gläsernes Labor*), and many more visit during Berlin's 'Long Night of the Sciences'. This book will whet the appetite to visit!

The 300-page book is divided into four parts, each ending with an interlude or interviews. It finishes with a list of further reading – references to research articles relevant to the work on the Campus. All of the state-of-the-art areas of research in molecular biology are touched upon, including stem cells, genetics, information technology, learning from microscopic organisms, biomarkers and so on. The text is built around profiles of the people and places on the Campus, including their links to the outside community and the ideas that they have brought to the Campus from their work in other countries and disciplines.

One would have no hesitation in recommending this book for school libraries – with the caveat that students should be given an incentive to read it – build it into project or assignment work. It is not a book to be read in one sitting (although the style might encourage that), but it is certainly a very interesting insight into the cutting-edge research that is taking place in the field of biomedicine.

Details

Publisher: Max Delbrück Center for Molecular Medicine, Berlin-Buch (MDC)
Publication year: 2008
ISBN: 9783938833322

Web reference

w1 –The book can be downloaded free of charge in PDF format from the MDC website (www.mdc-berlin.de) or via the direct link: http://tinyurl.com/3gkcyne

Free print copies can be ordered from:

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Science Writer
Max Delbrück Center for
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Robert Rössle Str. 10
13125 Berlin-Buch
Germany

Resource

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

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

The Rough Guide to the Brain

By Barry J Gibb

Reviewed by Sam Hollis, UK

The Rough Guide to the Brain is a thoroughly readable, interesting and informative book. It was so compelling that I read it in a very short space of time (having two small children, this is no mean feat!). As a non-biologist, I felt that the book was very accessible, benefiting from a lack of jargon. I suspect this will make it valuable to teachers whose first language is not English.

The author covers a wide range of topics, which include evolution, the development of brain science, how the brain and nervous system work, memory, consciousness, intelligence and mechanical brains. The book explores these areas in quite some detail, while remaining easy to read. Although clearly aimed at a lay audience, the book covers the relevant parts of the UK's syllabuses for 14- to 18-year-olds. I would recommend that the decision to use the book as a teaching tool or as student reading material is made according to age group: a 14-year-old would find the content understandable and engaging, although it is probably aimed above the level of the average 18-year-old.

In the past, I have taught several aspects of the brain to my 14- to 16-year-old students. Had I read *The Rough Guide to the Brain* first, I would not only have been far more knowledgeable of the subject area, but also able to retell some of the book's interesting and sometimes rather dramatic anecdotes about brain injuries that have affected people's behaviour. Such as that of Phineas Gage, who while working on the railroad in the USA survived having a 3-cm-wide metal rod penetrate his skull and come out the other side! He became foul-mouthed and erratic, giving a clue as to the area of the brain that was destroyed – that concerned with higher thinking.

The Rough Guide to the Brain should be read and referred to by all of those teaching about the brain to students aged 14 and upwards. This book could make a real difference to your teaching, understanding and enjoyment of this important topic in today's secondary-school science syllabus.

Details

Publisher: Rough Guides
Publication year: 2007. A new edition is due to be published in May 2012
ISBN: 9781843536642

Resource

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

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

Globesity: A planet out of control?

By Francis Delpeuch, Bernard Maire, Emmanuel Monnier and Michelle Holdsworth

Reviewed by Michalis Hadjimarcou, Cyprus

For someone interested in learning about obesity, *Globesity: A planet out of control?* is an excellent book to start with and, unless preparing for a doctorate thesis, possibly to finish with. The authors analyse obesity using a variety of approaches to give a detailed account of this frequently misunderstood phenomenon, which has in the past few decades affected people all over the world at an alarming rate.

Anybody can benefit from reading *Globesity.* The book is ideal for individuals who seek a trustworthy source to satisfy their curiosity about the subject, because the information it contains is based on numerous peer-reviewed publications. Teachers from any discipline wishing to gather obesity-related material for use in their classroom will also find the book valuable. *Globesity* covers not only the characteristics of and potential hazards associated with obesity, but also the socio-cultural, physical, psychological, medical and even economic factors involved in its appearance. The only thing that may limit the usefulness of the book is the complexity of the language. The use of extensive vocabulary may make the book difficult to understand for readers who are not fluent in English.

Assuming that the book can be easily understood, it will have unlimited use in both the science and non-science classroom for a wide range of ages. Biology teachers, for example, can focus on the authors' discussion about how bad nutritional habits and possibly genetic factors can lead to obesity. Biology students will find the book a useful resource for projects linking obesity to diseases such as diabetes, or, surprisingly, to climate change – or to report on attempts to develop drugs and other methods to fight obesity.

Economics teachers and students may concentrate on how multinational companies employed in the production, distribution and sale of food have an important role in the way our body is shaped. Alternatively, they can investigate the potential economic value to employers of investing in reducing the prevalence of obesity among their employees.

Obesity is an ideal topic for interdisciplinary lessons linking biology, chemistry, physical education, human geography, economics and sociology to debate various 'hot' issues, such as whether fast food is responsible for obesity, or whether prevention is better than cure (weight loss).

On a more practical note, the authors discuss specific solutions to the obesity problem that can be found through action taken at both an individual and a national level, and provide examples of strategies that have already worked.

Details

Publisher: Earthscan
Publication year: 2009
ISBN: 9781844076673

Resources

For ideas on a teaching project about obesity, based on a science article published in *Science in School*, see:

Krotschek F (2010) Using cutting-edge science within the curriculum: balancing body weight. *Science in School* **16**: 19-26. www.scienceinschool.org/2010/issue16/obesity

If you enjoyed reading this review, why not take a look at the full list of biology-related articles published in *Science in School*? See: www.scienceinschool.org/biology

For a full list of resource reviews in *Science in School*, see: www.scienceinschool.org/reviews

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