Autumn 2012 Issue 24

SCIENCE in SCHOOL

The European journal for science teachers

In this issue:

Indigo: recreating Pharaoh's dye

Also:

Cracking down on wildlife trafficking

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Editorial

As I write this, the children in my village have been back at school for two weeks. The school just down the road, however, doesn't start again for another two weeks. If school holidays – and indeed school types, curricula and teacher training – differ so much within Germany, how much variation must there be across Europe?

Nonetheless, some of the challenges for science teachers are the same wherever you are in the world. How to inspire your students? How to share the fascination of science? And how to keep yourself up to date with the latest scientific developments?

Supporting you in these challenges is what *Science in School* is all about. In this issue, for example, we have suggestions to motivate even the least enthusiastic students. They could synthesise indigo – treasured by the Egyptian pharaohs and still used to dye jeans (page 40) – or investigate how we trick our brains into perceiving 2D pictures as 3D (page 29). Drinking wine at school is probably not a good idea, but producing and analysing it introduces a wide range of chemistry topics (page 47). And if you teach younger children, they can discover for themselves how materials change when we heat them (page 23).

Whether you are looking for cutting-edge science for your lessons or simply feeding your own thirst for knowledge, *Science in School* has plenty to offer. Did you know, for example, that genetic analysis is used to combat the illegal wildlife trade in Brazil (page 6)? Or are you puzzled by the behaviour of an autistic student (page 17)? Next time you teach the electromagnetic spectrum, you could show how radiation is used to monitor what goes on in a fusion reactor (page 12) and to investigate the mysteries of the distant Universe (page 53). And if you think you've already mastered all there is to know about crystal structure, maybe it's time to think again (page 59)?

Colleagues can be a source of inspiration – but they don't have to be the teachers down the corridor. Earlier this year, a group of teachers from Austria, Germany and Italy travelled to Spain to learn from a truly inspirational primary school (online article). Clearly, that's not possible for every teacher, which is why we regularly introduce you to inspiring European teachers: in this issue, find out how a Polish teacher rose to the challenge of teaching physics to disabled children (online article).

Finally, don't forget that many of our articles are available online in other European languages, thanks to volunteer translators across Europe. To view all the articles in your language, just click on the relevant flag on our website. And if you'd like to translate our articles into your native language, we'd love to hear from you.

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

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Forthcoming events for schools: **www.scienceinschool.org/events**

To read the whole issue, see: **www.scienceinschool.org/2012/issue24**

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

Image courtesy of EFDA-JET

Bigger, faster, hotter

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

CERN:
The masters of the Internet – and you can be one, too!

Although a lot of people know that the World Wide Web was invented at CERN, not many know that the organisation has also played a central role in developing the Internet in Europe. In 1988, CERN convened the historic meeting that led to the creation of the RIPE (*Réseaux IP Européens*), which still allocates IP addresses in Europe. In the early 1990s, CERN was the largest Internet hub in Europe, managing more than 80 % of the international bandwidth available on the continent. It was also one of the founding members of the Internet Society, a global organisation dedicated to ensuring that the Internet stays open, transparent and defined by its users. The society celebrated its first 20 years at a conference held in Geneva, Switzerland, from 22 to 24 April 2012, with CERN as a special guest.

To mark the occasion, the Internet Society established a website where people can share their ideas and wishes on how the Internet should evolve: http://wishingtree.internetsociety.org

Get involved, and make the Internet your place, too!

To find out more about the Internet Society, see: www.internetsociety.org

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

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

CERN's director general (third from right) participating in a round-table discussion at the INET 2012 forum in Geneva

Image courtesy of CERN

EFDA-JET:
Refurbished JET – clean, hot and safe

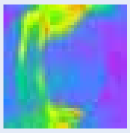


Image courtesy of EFDA-JET

An infrared image of the inside of the JET vessel shows hot spots (reddish) during a plasma disruption

Fusion energy researchers at the Joint European Torus (JET) continue to reap rewards from the 2009-2011 upgrade. The new metallic walls in the reactor have led to much cleaner plasma, without the undesirable radiation caused by contaminants from the previous carbon wall. In addition, the new heating systems can deliver 40 % more power to the plasma in 50 % longer pulses.

Nonetheless, turbulent events known as disruptions – in which the energy of the plasma escapes its magnetic cage in one spot and hits the wall – still occur occasionally. Because the new wall has a lower melting point than the previous one and higher plasma temperatures are now being used, a protection system had to be developed before the full heating power could be applied. This will mitigate disruptions because the associated heat levels and magnetic forces can be extremely high.

Recent tests have shown that the protection system successfully detects disruptions and then quickly puffs argon gas into the vessel. The argon rapidly 'contaminates' the plasma, radiating energy in all directions, thereby diffusing the hot spot. The JET team now has the confidence to turn the new system up to record power levels in the coming months.

To find out how hot spots and other potential problems are monitored within the JET reactor, see:

Dooley P (2012) Seeing the light: monitoring fusion experiments. *Science in School* **24**: 12-16. www.scienceinschool.org/2012/issue24/fusion

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

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

Composite image of Faulkes Telescope North and the Milky Way

EMBL: Filming life in the fast lane

Scientists at the European Molecular Biology Laboratory (EMBL) have filmed the development of a fruit fly embryo from when it is about 2.5 hours old until it crawls away from the microscope as a larva, 20 hours later. In the video, you can watch as cells on the embryo's belly dive in to form what's known as the ventral furrow. Other cells can then be seen moving around the embryo's rear end to its back, in a process called convergent extension. Later, when an opening appears in the embryo's back, you can see the surrounding cells close the gap in a process known as dorsal closure.

To obtain the video, the scientists developed a new microscope called multi-view SPIM, which enables them to image rapid biological processes in thick samples in unprecedented detail. They can obtain a high-quality 3D image of a fruit fly embryo in just a few seconds. Using such fast imaging, the movements of every nucleus in the early embryo can be recorded.

In the future, the scientists would like to use their new microscope to investigate how organs and tissues form, not only in the fruit fly but also in other organisms.

To watch the video and for more information about the microscope, see the press release on the EMBL website (www.embl.org) or use the direct link: http://tinyurl.com/muvispim

To watch other EMBL videos, see the EMBL Youtube channel: www.youtube.com/user/emblmedia

The original publication is:

Krzic U et al. (2012) Multi-view selective-plane illumination microscope for rapid 3D imaging of developmental processes with sub-cellular resolution. *Nature Methods* **9**: 730-733. doi: 10.1038/NMETH.2064

For an earlier *Science in School* article about how embryo development is observed at EMBL, see:

Furtado S (2010) Watching it grow: developing a digital embryo. *Science in School* **15**: 18-22. www.scienceinschool.org/2010/issue15/zebrafish

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

Foreground: early *Drosophila* embryo with the cell nuclei marked. Background: an unrolled image of a *Drosophila* embryo with the cell membranes marked (the alternating green / magenta colour represents different views from the microscope)

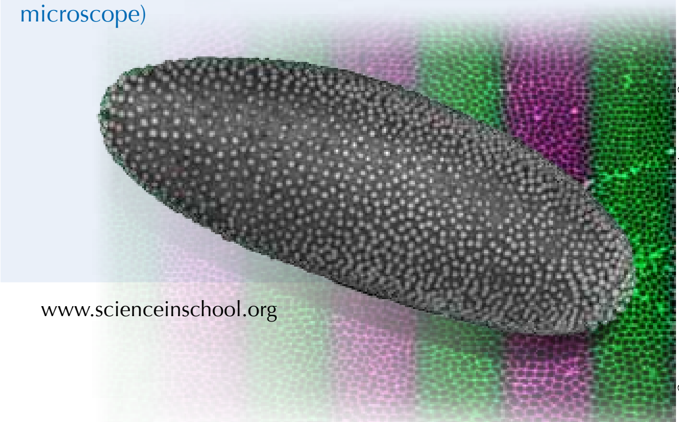


Image courtesy of Uroš Krzič / EMBL Heidelberg

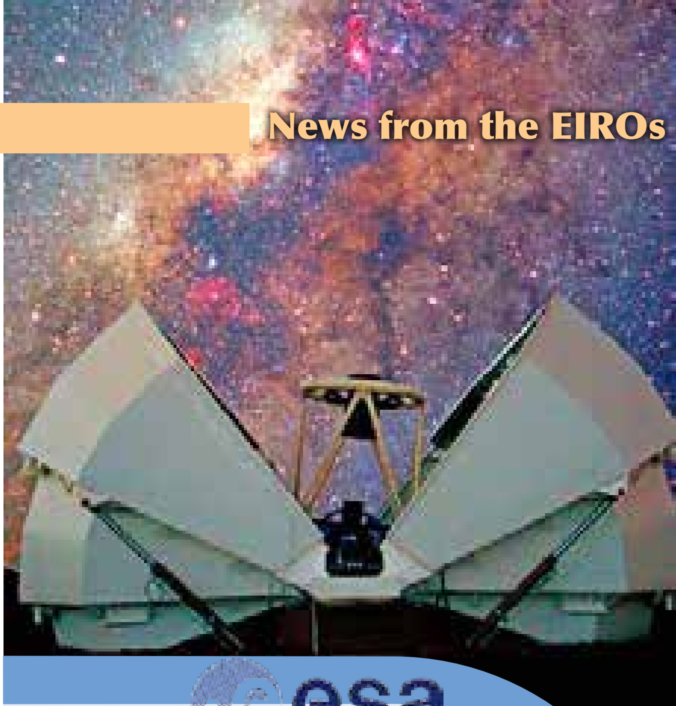


Image courtesy of Nik Szymanek / FT / LCOGT

ESA: Join the asteroid hunt

The European Space Agency (ESA) has recently joined forces with the UK's Faulkes Telescope Project to allow students to support the Agency's Space Situational Awareness (SSA) programme. This programme keeps watch over space hazards, including disruptive space weather, debris objects in Earth orbit and asteroids that pass close enough to Earth to cause concern.

Any attempt to survey and catalogue hazardous asteroids faces a number of difficulties. They are often jet black or at least very dark, can approach rather too close before anyone sees them, and are often spotted only once and then disappear before the discovery can be confirmed.

So ESA is turning to amateur astronomers to 'crowd-source' observations as part of Europe's contribution to the global asteroid hunt. These efforts will greatly enhance asteroid-spotting for the SSA programme, enabling detection of fainter objects and tracking from a global telescope network.

The Faulkes Telescope Project offers free access to robotic telescopes and a fully supported education programme to encourage teachers and students to engage in research-based science education. Supporting ESA's SSA programme is just one of the many possible astronomy projects that schools can engage in.

Go to the Faulkes Telescopes website to join the hunt: www.faulkes-telescope.com

To learn more about using the Faulkes Telescopes at school, see:

Dodds R (2007) The Faulkes Telescopes: real-time, remote-control astronomy for schools. *Science in School* **4**: 42-45. www.scienceinschool.org/2007/issue4/faulkestelescope

For another asteroid-hunt teaching activity, see:

Newsam A, Leigh C (2011) Hunting for asteroids. *Science in School* **20**: 30-35. www.scienceinschool.org/2011/issue20/asteroids

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

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

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

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

ESO:
World's biggest eye on the sky

The European Southern Observatory (ESO) is to build the largest optical / infrared telescope in the world. The ESO council approved the European Extremely Large Telescope (E-ELT) programme at its meeting in Summer 2012, pending confirmation of four *ad referendum* votes. The E-ELT will be a 39.3 m segmented-mirror telescope sited on Cerro Armazones in northern Chile, close to ESO's Paranal Observatory. Operations are planned to start early in the next decade, and the E-ELT will tackle some of the biggest scientific challenges of our time. "The E-ELT will keep ESO in a leading position for decades to come, and lead to an extraordinary harvest of exciting science," said ESO council president, Xavier Barcons.

For more information, see the press release: www.eso.org/public/news/eso1225

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

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

Artist's impression of E-ELT in its enclosure on Cerro Armazones, a 3060 m mountaintop in Chile's Atacama Desert

Image courtesy of ESO / L Calçada

ESRF:
When insects first became pollinators

Image courtesy of ESRF

Synchrotron tomography image of a specimen of *Gymnospollisthrips* minor covered with pollen grains (yellow). These grains are minuscule and exhibit adherent features so that insects can transport them

Insect pollination of plants is a relatively recent event in Earth's history – water and wind did the job before the little creepy-crawlies arrived. But once they did, a mutual evolutionary success story started: today, by far the majority of flowering plant species are pollinated by insects, which transport the pollen from male to female plant parts. But how did it all begin?

Flowering plants are a comparatively recent group, evolving from gymnosperms. These 'naked seed' plants have cones instead of flowers, and include today's conifers and *Ginkgo*. Although most gymnosperms used wind pollination, some already used insects as pollinators – well before the evolution of the first flower.

Two pieces of amber some 110 million years old from northern Spain revealed the oldest record of insect pollination, when scientists used X-rays at the European Synchrotron Radiation Facility (ESRF) to produce detailed images of two newly described species of tiny insects covered with pollen grains. *Gymnopollisthrips minor* and *Gymnopollisthrips maior* are thrips (Thysanoptera), minute insects that feed on a variety of plant and animal sources, including pollen. These particular thrips are thought to have fed on the pollen of *Cycadopites*, a now extinct genus of gymnosperm that related to cycads – the plants that look like a giant cross between palm and fern trees and make up the 'forests' in dinosaur films.

To learn more, see the news item on the ESRF website (www.esrf.eu), use the direct link (http://tinyurl.com/thrips), or read the research paper:

E Peñalver et al. (2012) Thrips pollination of Mesozoic gymnosperms. *Proceedings of the National Academy of Sciences of the United States of America* **109(22)**: 8623-8628. doi: 10.1073/pnas.1120499109

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

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

European XFEL:
The diggers are done

European XFEL has reached an important milestone. The construction of the network of tunnels, totalling nearly 5.8 km in length and extending 3.4 km from Hamburg-Bahrenfeld to Schenefeld in Schleswig-Holstein, Germany, is now finished.

As Professor Massimo Altarelli, managing director of European XFEL, commented, "The tunnel construction is one of the most difficult building phases. We are glad that this task could be completed according to plan, and that we could keep costs within the tight budget we set at the time the contract was awarded."

Tunnel construction began in July 2010. In January 2011, a second boring machine started to excavate the five photon tunnels leading into the experiment hall. On 14 June 2012, more than 400 people – including guests from politics and science as well as staff from collaborating companies – celebrated the completion of the tunnel construction.

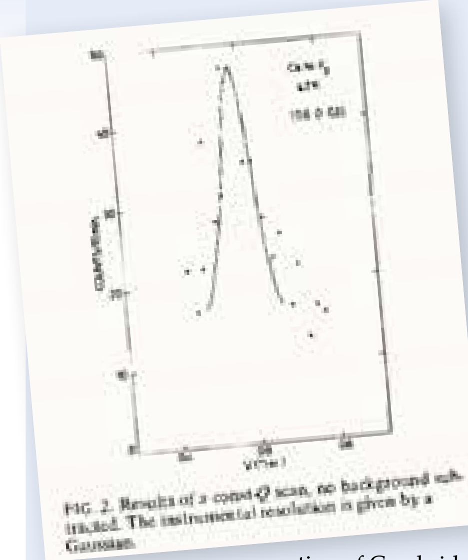
European XFEL is a research facility currently under construction in the Hamburg area in Germany. It will generate extremely intense X-ray flashes for use by researchers from all over the world. To learn more, see: www.xfel.eu

For a list of *Science in School* articles relating to European XFEL, see: www.scienceinschool.org/xfel

Celebrating the arrival of the tunnel-boring machine AMELI in the final reception shaft on 4 June 2012

Image courtesy of European XFEL

ILL:
Celebrating the neutron's 80th birthday



First published results from ILL, submitted in 1972

Steiner & Dorner (1973)

This year, the world's flagship neutron science facility marks the 80th anniversary of James Chadwick's famous discovery. On 1 June 2012, it will be 80 years since the publication of Cambridge physicist James Chadwick's famous Nobel Prize-winning paper, which proved the existence of the neutron. Chadwick's discovery led to the development of neutron research, which continues to make breakthroughs across the sciences. This year also marks the 40th anniversary of the use of Chadwick's famous particles at the Institute Laue-Langevin (ILL).

As Professor Andrew Harrison, director general of the institute, explains: "Thanks to Chadwick's discovery and the technology developments that have taken place since, ILL can use neutrons as if they were super X-rays, to understand the world at the atomic level and make discoveries that improve our lives. The neutrons we produce and the world-leading instruments that detect them are delivering impact in areas as varied as health care, the environment and engineering, as well as improving our fundamental knowledge of how the world works."

See the research paper describing the first published results from ILL:

Steiner M, Dorner B (1973) Spin wave measurements in the one-dimensional ferromagnet $CsNiF_3$. *Solid State Communications* **12(6)**: 537-540. doi: 10.1016/0038-1098(73)90652-2

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

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

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

Image courtesy of SteveD.; image source: Flickr

Turtle shells are traded illegally in Brazil

Image courtesy of B.K. Dewey; image source: Flickr

Cracking down on wildlife trafficking

Biologist Juliana Machado Ferreira is using science to combat wildlife traffickers in Brazil.

By Nina Notman

The illegal wildlife trade in Brazil is one of the main threats to the country's fauna, explains biologist Juliana Machado Ferreira. It is estimated that each year 38 million animals, mainly birds, are removed from their natural habitats in Brazil to be sold for a variety of different purposes[w1]. This illegal market is estimated to be worth US$2 billion per year.

"There are four main categories of illegal wildlife trade in Brazil," explains Juliana. The first is for products and souvenirs: for example, items made with turtle shells, teeth, claws, feathers, fur and skin. The second category is for use in traditional medicines. "People think that the craziest things will cure them or even make them more sexually active," says Juliana. "For instance, in Brazil, the genitalia of river dolphins are very sought after, because people think that they will attract love."

The third is bio-piracy: the unfair exploitation of Brazil's biodiversity and local knowledge. "Local people may know which kinds of plants or animals will cure them of an inflam-

The genitalia of river dolphins are highly prized in Brazil, as they are believed to have aphrodisiac properties

Image courtesy of Joachim S. Müller; image source: Flickr

Macaw feathers are a valuable commodity in the Brazilian illegal wildlife trade

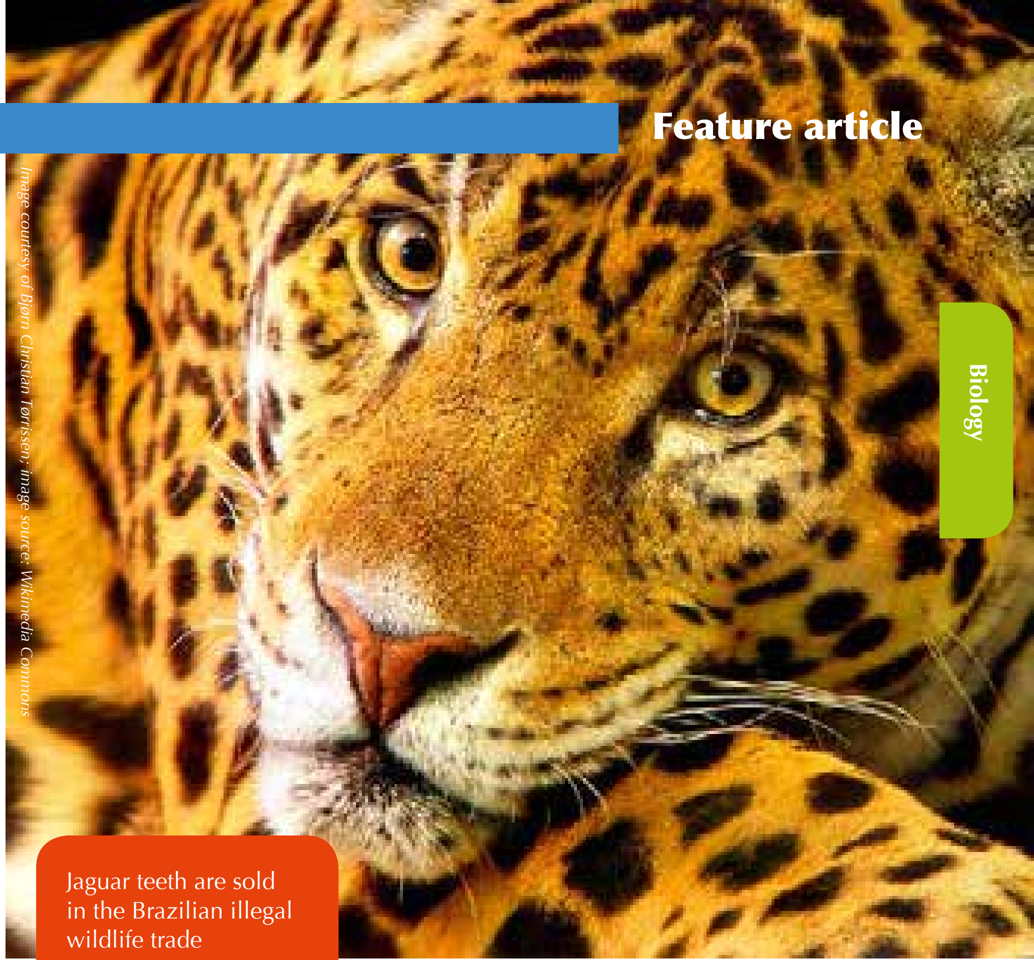


Image courtesy of Bjørn Christian Tørrissen; image source: Wikimedia Commons

Jaguar teeth are sold in the Brazilian illegal wildlife trade

mation or other health problem," she explains. "Pharmaceutical and cosmetic companies sometimes exploit this knowledge, and once they have learned that traditional people use, for example, a frog's poison to treat an inflammation, they smuggle the frog or the poison back to the lab." There, attempts are made to identify and then synthesise the active molecule – the molecule responsible for the anti-inflammatory activity. "They then patent it and sell the very, very expensive results back to us as medicine." Such practices contravene the 2010 agreement in Nagoya, Japan, by the Convention on Biological Diversity, which states that the benefits arising from the use of genetic resources should be shared in a fair and equitable way[w2] (Rau, 2010).

The fourth and largest category of illegal wildlife trade in Brazil is to supply the pet market. "In Brazil, birds are the most sought-after group because it's part of our culture to have song birds, macaws and parrots in cages at home," she says. Other animals stolen for this purpose include fish, reptiles, amphibians, spiders and small mammals. Some species of pet can be purchased legally from commercial breeders, but the illegal market is still extremely large. "One reason is that animals

REVIEW

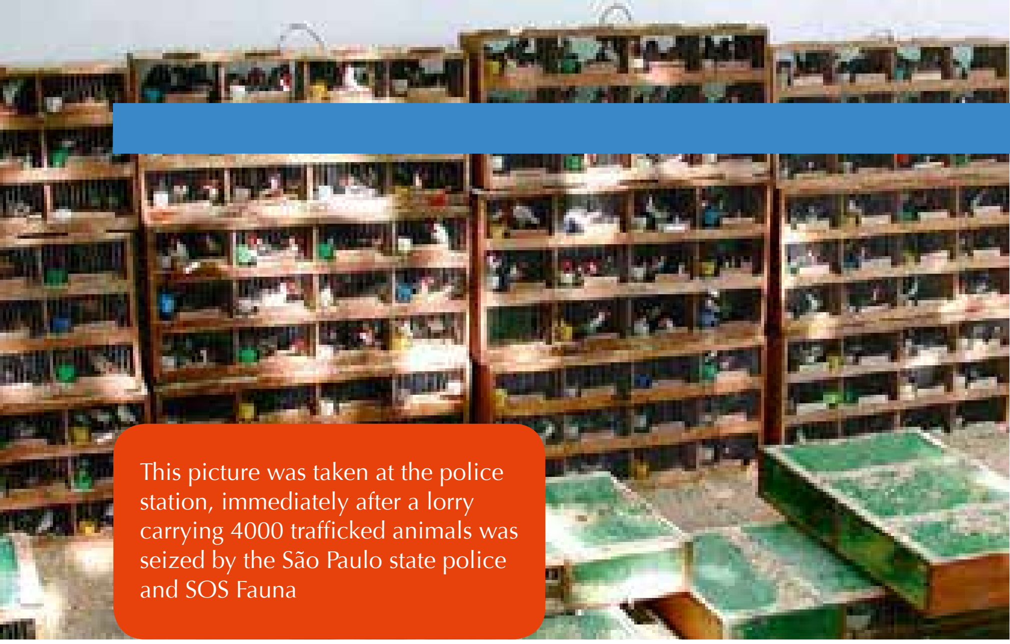
Biology
Ethics
Ages 11-19

This article about the battle against illegal wildlife trafficking addresses a topic of social and political importance, involving many biological aspects such as ecology, molecular biology, genetic fingerprinting and population dynamics. It raises important questions about the exploitation of indigenous knowledge by pharmaceutical companies. At an everyday level, it can be related to the wish of many children to own a pet or to bring souvenirs back from their holidays.

Based on the article, class discussions could cover the politics of Brazil, the rights of local people, the impact of the wildlife trade, and how to control it. The text can also be used as an excellent example of how molecular biology is being applied to the conservation of endangered species.

1. What are the four main categories of wildlife trafficking in Brazil?
2. What solutions are offered in the article to combat wildlife trafficking?
3. Which methods did Juliana use to discover the origin of the captured birds?
4. Why may it be important to return rescued animals to the area they originated from?
5. Describe the steps of Juliana's work to investigate the genetics of the captured birds.

Friedlinde Krotscheck, Austria



This picture was taken at the police station, immediately after a lorry carrying 4000 trafficked animals was seized by the São Paulo state police and SOS Fauna

Images courtesy of SOS Fauna

One of the birds rescued by the São Paulo state police and SOS Fauna, still in the box it had been trafficked in

bred in captivity are always more expensive than ones caught from nature," Juliana explains. The animals are captured all over Brazil and sold mainly in large cities such as Rio de Janeiro and São Paulo.

The other reason why the problem is particularly large in Brazil, says Juliana, is because of weak environmental legislation. It can be hard for the authorities to prove that animals are illegal, and traffickers only have to pay small fines if they are caught.

Even when the police do seize illegally trafficked animals, the question remains of what to do with them. There are government assessment and rehabilitation centres, but the scale of the problem – in 2002 alone, 45 000 animals (of which 37 000 were birds) were received by these centres – means they are very costly to run. Currently, the 'solution' proposed by the Brazilian Ornithological Society is to euthanise all animals from non-endangered species, which Juliana strongly opposes. The alternative to mass euthanasia or keeping the animals in centres for the rest of their lives is to return them to the wild. In the past this has been deemed too risky, for both the released animal and the natural habitat. But the work of Juliana and her peers shows that re-release is possible. This isn't a new idea globally, notes Juliana, but in Brazil it is still a big issue.

Where should the rescued birds be released, though? Is it important (or even possible) to return individual birds to the area that they came from, or could they be released into any suitable habitat? The answer depends on the ecology, behaviour and genetics of the species, in particular on how isolated and differentiated the populations of that species are.

When populations are isolated from each other and their environments differ, they can evolve significant local adaptations. For example, chicks need to hatch at a time when food is plentiful, so in colder regions they will normally hatch later in the year than in warmer regions. The populations may also evolve what are known as *co-adapted gene complexes*: groups of gene variants that work well together, but not as well when mixed with other variants of the same genes.

If rescued birds from one isolated population are released to breed with individuals from another population, the result may be *outbreeding depression* in subsequent generations. This can result either from a disruption in biological cycles (e.g. the chicks hatching before there is enough food available) or from the co-adapted gene complexes being broken up during genetic recombination. Either of these outcomes will make the birds less able to survive in their environment.

In contrast, if populations of a species are not isolated and their behaviour, ecology and genetics are very similar, releasing individuals into the 'wrong' population is unlikely to cause genetic problems.

During her recently completed PhD, Juliana investigated the genetic similarity between populations – and thus the likelihood of outbreeding depression if individuals are released into the wrong population – of two exploited bird species: *Paroaria dominicana* (the red-cowled cardinal) and *Saltator similis* (the green-winged saltator). She travelled all over Brazil to collect blood samples from birds in different areas and then studied their genomes to see if an individual bird's origin could be identified. Instead of

Blue-fronted Amazon parrots that were seized by the São Paulo highway patrol in 2006 and arrived at SOS Fauna as chicks. The parrots are now fully rehabilitated and were taken to the release site in July 2012. They will stay in acclimation for a month and should be released in mid-August 2012

Image courtesy of SOS Fauna

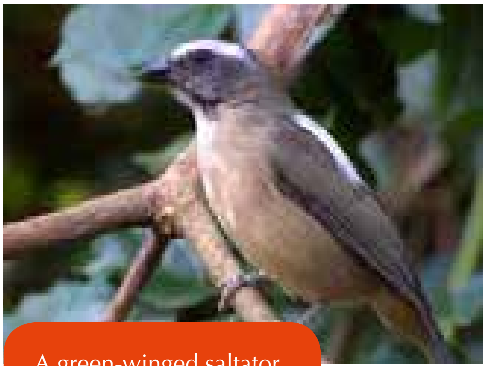


Image courtesy of Dario Sanches; image source: Flickr

A green-winged saltator

Image courtesy of Dilson Santos; image source: Flickr

A red-cowled cardinal

Image courtesy of Erica Pacifico

After trapping a bird, Juliana measures it, attaches a leg band for identification, takes a tiny blood sample, disinfects the puncture site, rehydrates the bird and then releases it

looking at the whole genome (which would largely be the same for every bird sampled), Juliana focused on sections of the genome that are highly variable and evolving very quickly.

Her first task was to identify these highly variable regions. "I had to find these hypervariable regions in each species' genome," Juliana explains. She did this by breaking up the genomes of the birds into small pieces and placing them in bacteria. She then 'fished' for highly variable regions using probes of complimentary DNA strands. But how did Juliana know what type of genetic sequence to fish for in the first place? "One of the characteristics of these variable regions is that they have repetitive units," she explains. "So we used probes that are repetitive as well, for example blocks of AGAGAGAG or GATAGATAGATA." Once the highly variable sections had been identified, new probes that are more specific (called primers) could be designed so that these sections could be directly targeted in the future. (To learn more about the technique, see Müller & Göllner-Heibült, 2012.)

Next, Juliana needed to collect blood samples from the two species of birds from all across Brazil to work out if the differences between the gene sequences in these highly variable sections of the genome were sufficient to allow a bird's origin to be identified. To find the birds in each region, she would trek for miles playing a recording of a male bird's song. "When a bird hears the song of the same species but coming from another individual, it goes crazy, as it needs to defend its territory," she says. The bird is then captured using very fine nets, and tiny – microlitre sized – blood samples are taken, after which the puncture site is disinfected and the bird rehydrated before being returned to the wild. In total, Juliana collected samples from 10 different birds in each sample site and also received donations of museum tissue samples and blood samples from other researchers – from more than 500 birds in total.

Once her collection was complete, Juliana returned to the lab to analyse the samples. "I went through a period of very intensive lab work during which I had to extract DNA from the blood samples, clean it and quantify it, and then – using a technique called the polymerase chain reaction (PCR), which mimics DNA replication – I increased the amount of only those fragments I was interested in," Juliana explains. For the PCR, Juliana used the primers she had identified earlier to allow the correct part of the genome to be replicated.

Next, she looked for any differences between these specific sections of DNA in the individual birds. This process is called genotyping. The differences Juliana was looking for were variations in the number of repeating units. As mentioned previously, these highly variable sections are blocks of

Image courtesy of Marcos Antonio Melo

Juliana with a green-winged saltator (*Saltator similis*), which she is about to release repetitive units such as AGAGAGAG. "One person has $(AG)_3$ while another may have $(AG)_7$," Juliana explains.

Once each bird had been genotyped, Juliana used statistics to analyse the variation in the population across the whole of Brazil. "Some of the questions that could be answered were: how many different genetic groups are there in this sampling? Are they correlated to geography? How different are they? Are they isolated from each other? What is the within-group variability compared to the total variability?" she says.

On the basis of this information, Juliana was not able to tell where individuals of *S. similis* had come from. This means that her genetic analysis cannot be used to assign captured birds to their home population, but it also means that returning birds to the 'wrong' population should not cause genetic problems.

The situation for *P. dominicana* was a little different. Juliana was able to identify three major genetic groups that were correlated to distinct geographical areas. Although these groups were recognisable, they were not isolated: there were high levels of gene flow between them. So even though it is possible to tell roughly where captured birds had come from, there would be little likelihood of outbreeding depression if they were released elsewhere.

During her PhD, Juliana was able to apply her research directly to the battle against illegal wildlife trafficking. "I was able to track the origin of 49 *P. dominicana* individuals seized in São Paulo; they were all part of the same genetic cluster," she says. "This information corroborates what the police think is the most exploited region for this species." As well as helping the authorities decide where to return the birds to, knowing the areas that are the most exploited allows efforts to be made there to prevent exploitation.

Examples of possible actions include road blocks to check for traffickers leaving the area with wildlife, more environmental legislation and social work with the local communities, she explains.

It is these sorts of applications that first encouraged Juliana to enter conservation research, after she had spent years volunteering with the non-government organisation (NGO) SOS Fauna[w3], working closely with its president, Marcelo Pavlenco Rocha. Through SOS Fauna, she attends raids to assist the police in identifying which species are legal to own, helps with release projects, and is a spokesperson against animal trafficking. More recently, she has established another NGO called Freeland Brasil. Through this organisation, Juliana is involved in making public policy, in projects to train people from different sectors on how they can combat wildlife trafficking, and in seeking funding to establish an independent wildlife forensics lab in Brazil.

Juliana's story demonstrates just how much one determined young person can achieve, with a great deal of devotion and effort. But surely we too can help to end wildlife trafficking? Juliana has two requests to all of us. First, remember that wild animals are not pets; if you want a pet, keep a domestic animal. Second, make sure you know the sources of the things that you buy, whether pets or wildlife-based products. "If you really need to have an animal or if you really need to buy that comb, find out whether it is from a legal breeder or a legal source," she says. "Ask whether it is okay for them to be selling this tortoise-shell comb or that red coral necklace."

Acknowledgement

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

Juliana would like to thank her PhD advisor, Dr Joao Morgante, the US Fish and Wildlife National Forensics Laboratory and São Paulo State Police for their support. She is also grateful for the research funding from the Brazilian federal research funding agencies CAPES and FAPESP.

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Müller S, Göllner-Heibült H (2012) Genetic fingerprinting: a look inside. *Science in School* **22**: 49-56. www.scienceinschool.org/2012/issue22/fingerprinting

To learn about the lead-up to COP 10, the 10th meeting of the Convention on Biological Diversity, at which the Nagoya Protocol was agreed, see:

Rau M (2010) Homo sapiens – an endangered species? *Science in School* **15**. www.scienceinschool.org/2010/issue15/biodiversity

Web references

w1 – The extent of the illegal wildlife trade in Brazil was estimated by the NGO RENCTAS, the Brazilian national network to fight the trafficking of wild animals. www.renctas.org.br

w2 – Adopted in October 2010, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity is an international agreement which covers appropriate access to genetic resources and transfer of relevant technologies, taking into account all rights over those resources and to technologies. See: www.cbd.int/abs

A night-time skyline in São Paulo – areas of which are hot spots for illegal wildlife trafficking

Image courtesy of Diego3336; image source: Flickr w3 – SOS Fauna is a non-governmental, non-profit organisation that works to defend and conserve the wildlife of Brazil. See: www.sosfauna.org/index-en.php

Resources

The Freeland Foundation is an international organisation dedicated to stopping human and wildlife trafficking. See: www.freeland.org

Inspired by the Freeland Foundation, Freeland Brasil is dedicated to preserving Brazil's unique and important biodiversity. See: www.freelandbrasil.org.br

Traffic, the wildlife trade monitoring network, works to ensure that trade in wild plants and animals is not a threat to the conservation of nature. See: www.traffic.org

In 2010, Juliana Machado Ferreira gave an online lecture about her work to save birds and other animal stolen from the wild in Brazil. See: www.ted.com/talks/juliana_machado_ferreira.html

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments to ensure that the international trade in specimens of wild animals and plants does not threaten their survival. See: www.cites.org

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

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

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

Seeing the light: monitoring fusion experiments

Finding out what is going on in the core of a fusion experiment at 100 million degrees Celsius is no easy matter, but there are clever ways to work it out.

By Phil Dooley, EFDA-JET

The Joint European Torus, JET, is the world's largest nuclear fusion experiment, just outside Oxford in the UK. As described in a previous article (Rüth, 2012), our scientists are developing a clean energy source for the future, involving the fusion of light atoms in a doughnut-shaped vessel nearly six metres across. This is not splitting the atom and there is no uranium involved – we fuse the hydrogen isotopes deuterium and tritium into the heavier element helium. Forcing the atoms to fuse takes a huge amount of energy, but the fusion process itself releases yet more energy.

Inside the experiment, the fuel (usually deuterium alone; the mixture with radioactive tritium is used only occasionally) is heated until the electrons are stripped off their nuclei. This ionised gas is called plasma and is the ideal environment for the colli-

The vessel in which the JET experiment takes place is shaped like a doughnut

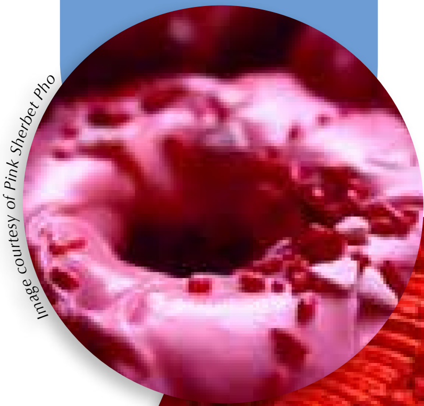


Image courtesy of Pink Sherbet Pho

Image courtesy of EFDA-JET

The inside of the JET vessel during a high-power pulse. The plasma core is transparent because the hydrogen isotopes are completely ionised, so there are no electron transitions providing visible radiation – except for a small visible wisp of cooler plasma on the inside lower edge

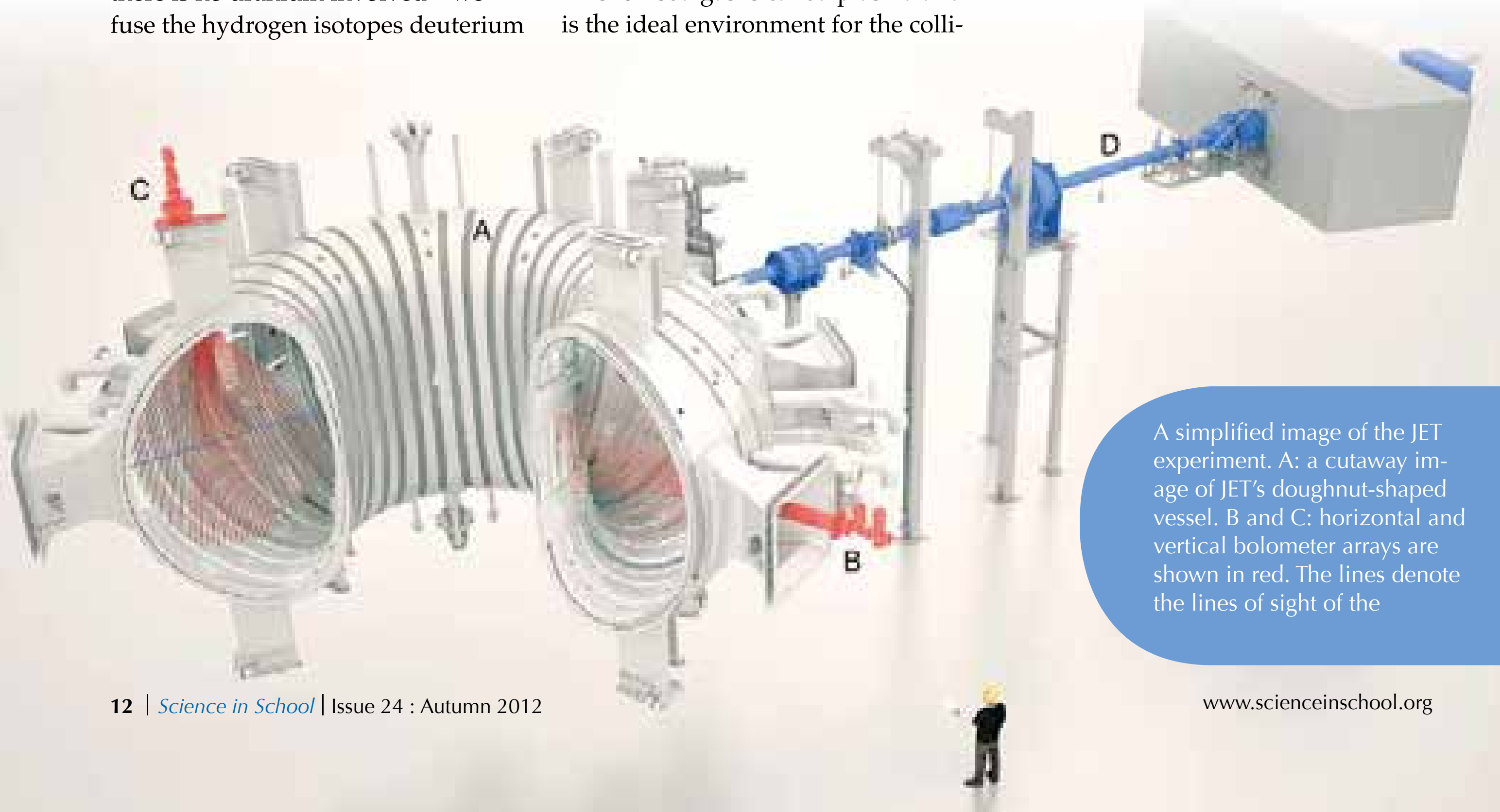


Image courtesy of EFDA-JET

A simplified image of the JET experiment. A: a cutaway image of JET's doughnut-shaped vessel. B and C: horizontal and vertical bolometer arrays are shown in red. The lines denote the lines of sight of the sions between nuclei that are required for fusion. The plasma is ten times hotter than the core of the Sun and races around the vessel, twisting and tumbling in an intricate magnetic cage woven by the scientists who control the machine.

Creating matter this hot is a major achievement, but keeping it confined long enough for a significant number of fusion reactions to happen is even more challenging – both because of the extremely turbulent nature of plasma this hot, and because of its tendency to pick up impurities from the components inside the vessel. Hence, sophisticated control mechanisms have been developed to monitor the plasma's every facet during operation, make adjustments to keep it stable and clean where possible, or terminate it if it gets too turbulent (see EIROforum, 2012).

But how do we know what is going on inside this sealed vessel at 100 million degrees Celsius? Any measuring device that you tried to put into the plasma would be destroyed – sublimed into plasma in seconds. Even looking at the experiment through the sealed windows of the vessel is less informative than you might expect, as the hot plasma is almost transparent. This is because the core of the plasma is so hot that all the electrons have been stripped off their nuclei, so no electron transitions – the source of visible light – are possible.

However, there are many other ways to find out what is happening in the plasma. Our understanding of this jumble of high-speed particles comes from about one hundred *diagnostics*: cameras, sensors, detectors, lasers, ion beams and coils – to name a few. We will discuss some of these systems in this article.

bolometers. D: the horizontal gamma-ray detection system is shown in blue, channelling the radiation away from the vessel through the surrounding thick concrete walls to the detector system, which is in a separate hall

REVIEW

- **Physics**
- **Chemistry**
- **Nuclear energy**
- **Ages 15-18**

Following on from a previous article (Rüth, 2012), this article gives a clear picture of some of the wealth of detectors used in nuclear fusion research. Teachers can use this article to provide information about how fusion can be monitored, and what difficulties and challenges scientists face when working at such high temperatures.

Suitable comprehension and discussion questions include:

- Why is a high amount of energy required for fusion to occur?
- What type of material has to be used for the chamber walls? Why?
- Which devices are used to monitor what is happening inside the plasma?
- How is the plasma confined within the walls and kept at a safe distance from them?
- How can leakage of energy be detected?

The discussion with students could then be taken further by addressing environmental impacts, sustainability and the importance of such experiments.

Catherine Cutajar, Malta

We have fusion! Gamma rays

The main product of a fusion reaction is fast neutrons. As well as measuring the number of neutrons, we always cross-check the number of fusion reactions with a second measure, the number of gamma rays. In addition to the main reaction between deuterium and tritium, during fusion, many other reactions occur in small proportions in the hot plasma, some of which leave the nuclei themselves in excited energy states. Just like electrons in excited energy levels, these nuclei then release their energy in the form of electromagnetic radiation. Because nuclear energy levels are very energetic, gamma rays are released rather than the visible or UV light emitted by electrons.

JET's gamma-ray detector works in a similar way to a Geiger counter, shown here. A Geiger counter is used to measure various forms of ionising radiation, including gamma rays

Image courtesy of Radioactive Rosca; image source: Flickr

Physics

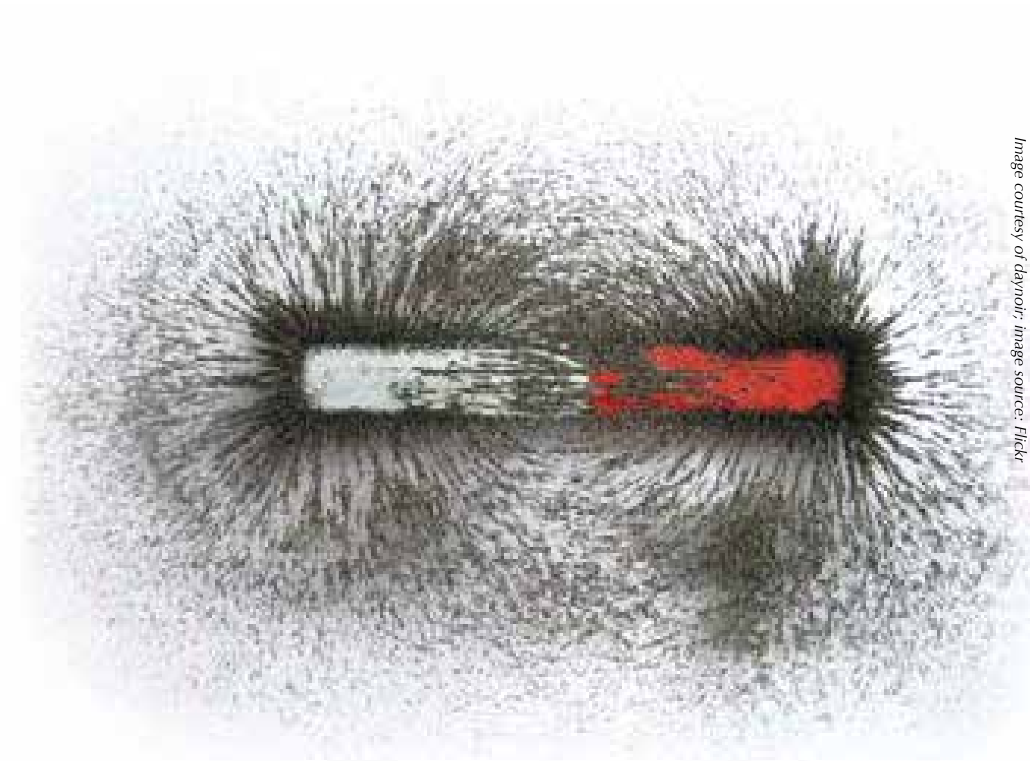


Image courtesy of daynoir; image source: Flickr

Magnetic fields keep the immensely hot plasma away from the vessel wall. These fields are many times larger than those of this bar magnet, made visible by iron filings

Gamma rays pass straight through most cameras, so a specialised detection system is needed. The experiment is surrounded by 2 m thick concrete walls to contain the radiation, but a long pipe channels some radiation through the walls to the detection laboratory. Here, we use a system similar to a Geiger counter, which generates an electric current when gamma rays pass through a small chamber, ionising the gas inside. We count the electrical pulses from two systems – one with a vertical view of the chamber, the other horizontal – which tells us how many fusion reactions have occurred, and where in the chamber they took place.

Measuring energy leakage: bolometry

One of the keys to a successful fusion experiment is confinement – preventing the energy from escaping from the plasma. Even if we keep the particles confined, significant amounts of energy can leak from the plasma in the form of electromagnetic radiation. Although it looks transparent, the plasma does give out a lot of radiation that we can't see. To measure this radiation leakage, we need a device that, unlike our eyes, can see radiation at all wavelengths. We use a bolometer, which is surprisingly simple – just a tiny strip of metal. Electromagnetic radiation of any sort – e.g. radio waves, UV radiation or gamma rays – heats the metal, and changes its resistance, which is easily measured.

One of the main causes of the radiation is impurities in the plasma, most of which originate from the walls of the vessel. It is important to find out where the impurities end up – on the edge of the plasma is not a big problem, but impurities in the hot core will deplete energy from the most important area. A single bolometer cannot distinguish between radiation from the core or the edge, but with a number of them, it is possible to build up a detailed 3D map of the radiation sources. This is achieved by putting each bolometer behind a couple of pinholes to narrow down their field of view. Then the results from all the different views – some through the middle, some just grazing the edge of the plasma, and so on – are combined with some clever processing to build up a 3D image. This construction of a 3D image from lots of individual measurements is a similar technique to that used in medical computed tomography (CT) scans, where a 3D image is compiled from many single X-rays taken from different angles.

Watching out for hot spots: cameras

It seems astonishing that a plasma at more than 100 million degrees Celsius can be contained within a metal vessel. Yet the huge magnetic fields created by the coils around JET succeed for the most part in keeping the plasma away from the vessel wall, which was recently refurbished with

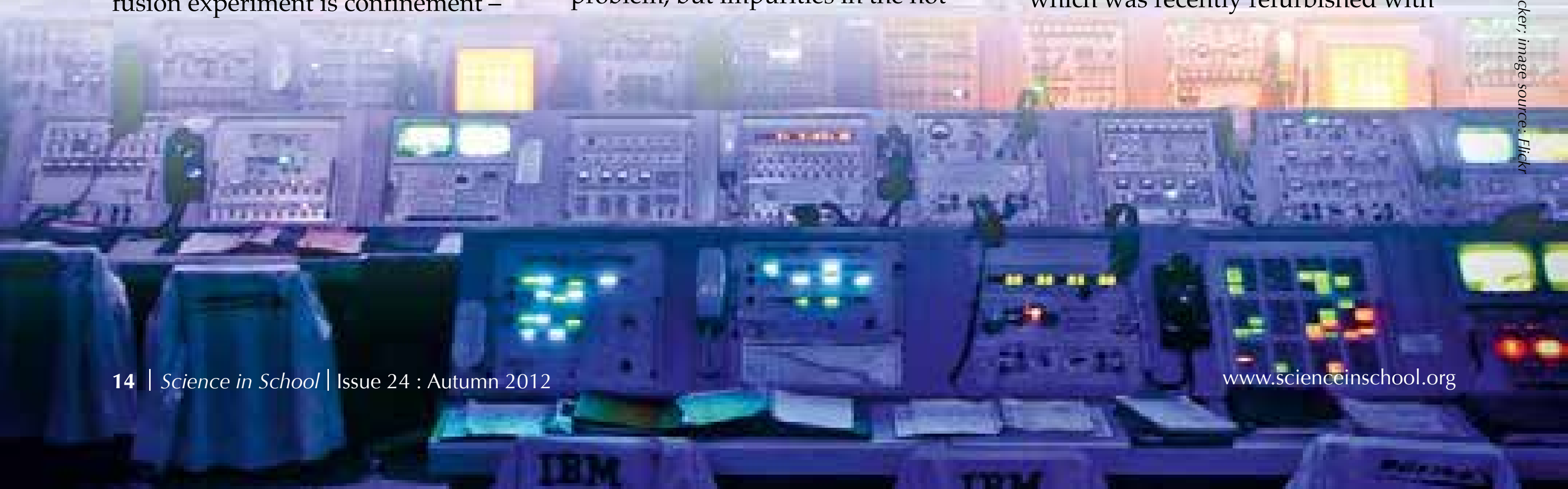
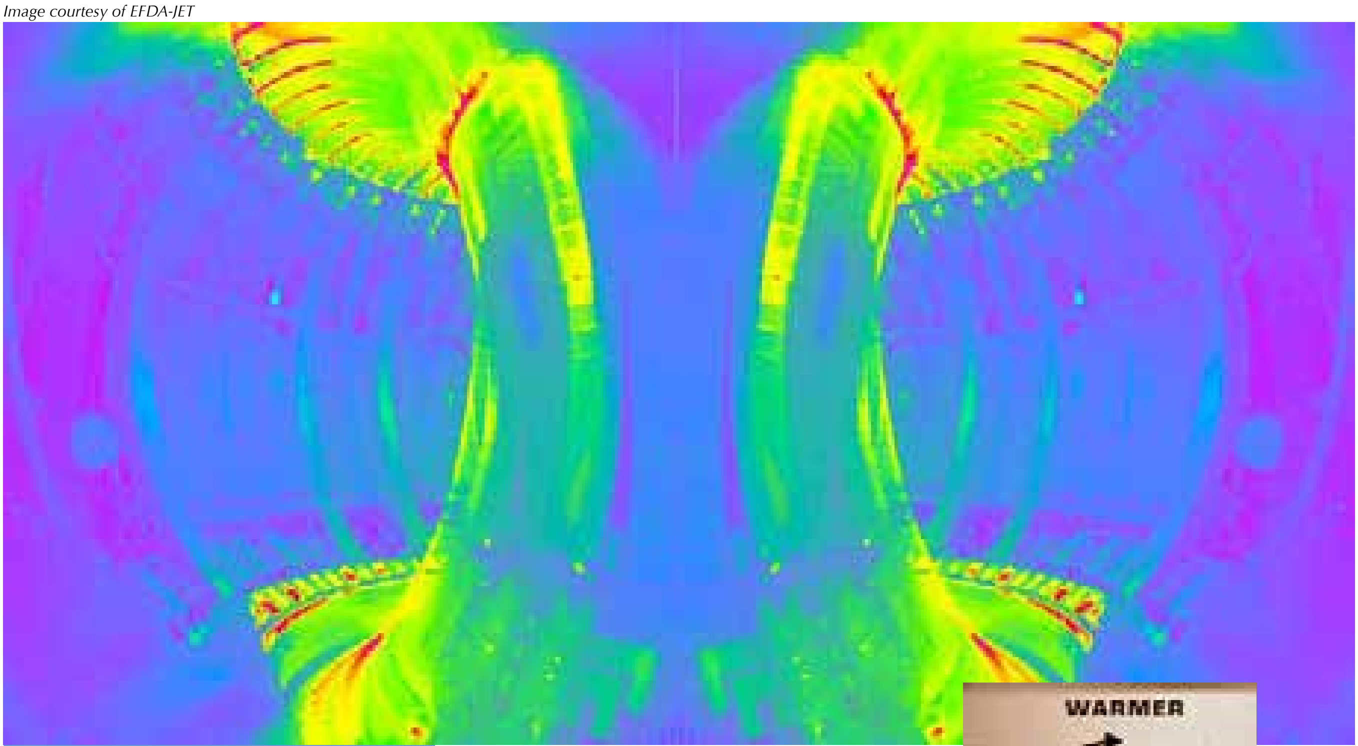


Image courtesy of Samantha Decker; image source: Flickr

Image courtesy of EFDA-JET



An infrared view of the JET vessel during an experiment, showing hot spots where the plasma is touching the wall

beryllium tiles that have a melting point of merely 1278 °C. One of the keys to the success of this set-up is an array of video cameras used to ensure that the plasma does not get too close to the vessel wall.

The indication that the plasma has moved too close is a hot spot on the wall, which gives out what is known as black body radiation. To the human eye, a hot spot would begin to glow red at around 500 °C, and would be orange by 1000 °C. However, it can be detected a lot earlier, because a hot spot will emit infrared radiation as soon as it becomes hotter than its

Image courtesy of Derek Jensen; image source: Wikimedia Commons

surroundings. Because most cameras can detect infrared radiation (using what is often called the night vision setting), a protection system has been developed that uses cameras to monitor for infrared hot spots. If one begins to develop, the plasma can be adjusted – for example by moving the magnetic field away from the wall or by turning down the power to reduce the temperature – before any damage is done.

Supporting activity: visualising infrared light

Most cameras are sensitive in the infrared – even those in mobile phones. Shine a TV remote control at a camera and you can see the infrared radiation signalling its special code for the TV.

Next, show that the wavelength of electromagnetic radiation determines

More about EFDA-JET

EIROforum

EFDA JET

As a joint venture, the Joint European Torus (JET)[w1] is collectively used by more than 40 European fusion laboratories. The European Fusion Development Agreement (EFDA) provides the platform to exploit JET, and more than 350 scientists and engineers from all over Europe currently contribute to the JET programme.

EFDA-JET is a member of EIROforum[w2], the publisher of *Science in School*.

See all EFDA-JET-related articles in *Science in School*.
www.scienceinschool.org/efdajet

Image courtesy of EFDA-JET

Unlike your eyes, a digital camera will register the infrared radiation from a TV remote control

Image courtesy of EFDA-JET

Although visible light from a torch is absorbed by cola, infrared radiation is not

how well it can pass through a material – which is why we need different types of detector to monitor the different types of radiation emitted by the reactor. Shine a torch through a glass of cola: the visible light from the torch is absorbed by the drink, which still appears brown. Then shine the remote control through the cola while watching with the camera: the infrared light travels through the liquid more or less unaffected.

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EIROforum (2012) Bigger, faster, hotter. *Science in School* **24**: 2-5. www.scienceinschool.org/2012/issue24/eiroforum

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

Web references

w1 – More information is available on the EFDA-JET website. See: www.efda.org/jet

w2 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. To learn more, see: www.eiroforum.org

Resources

Warrick C (2006) Fusion – ace in the energy pack? *Science in School* **1**: 52-55. www.scienceinschool.org/2006/issue1/fusion

Browse the whole series of *Science in School* articles about fusion in the Universe. www.scienceinschool.org/fusion

For an introduction to the electromagnetic spectrum and how it is used in astronomy, see:

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

If you enjoyed this article, why not browse the other cutting-edge science articles in *Science in School*? See: www.scienceinschool.org/cuttingedge

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Dr Phil Dooley is the news and education officer at EFDA-JET. He was born in Canberra, Australia, and completed a PhD in laser physics at the Australian National University. To escape academia he took a job in IT in Rarotonga, Cook Islands, for 18 months, before returning to Australia and working in software training. His love of science drew him back to physics, this time as a communicator, running the school outreach programme at the University of Sydney. In October 2011 Phil joined the EFDA-JET team in Oxfordshire, UK.

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

Image courtesy of EFDA-JET

Behind the autism spectrum

Image courtesy of Norma Desmond; image source: Flickr

The autism awareness ribbon. The jigsaw puzzle pattern symbolises the complexity of the autism spectrum

Image courtesy of Melesse; image source: Wikimedia Commons

Research into the genetics of the autism spectrum is increasing our understanding of these conditions, and may lead to better ways to diagnose and manage them.

By Andreas Chiocchetti

The first time I encountered autism was in the summer of 2004 while working as a children's camp counsellor. That year, one boy stood out. His name was Peter, but everyone called him 'the professor'. Peter knew a great deal and read a lot; to the others he seemed to be a genius. However, he didn't make friends easily and mainly played alone. Staff became concerned when they realised that Peter didn't laugh at jokes, avoided eye contact and grew angry if he couldn't sit in the same seat. The camp manager thought Peter might have autism. His parents then admitted that Peter had been diagnosed

REVIEW

Biology

Ages 16+

This informative article gives an insight into the autism spectrum disorders (ASD) and their distinguishing features. It is helpful as a source of information for any teachers who have students with ASD, for understanding the genetic mutations associated with ASD, and as an example of how genetics and environment can affect phenotype.

The article could be used in biology lessons about the brain or behaviour, or in discussions of synaptic plasticity. Suitable comprehension questions include:

1. How do studies show that autism is largely inherited?
2. What are the risk factors for autism?
3. What kind of genetic variations are linked to autism?

Shaista Shirazi, UK

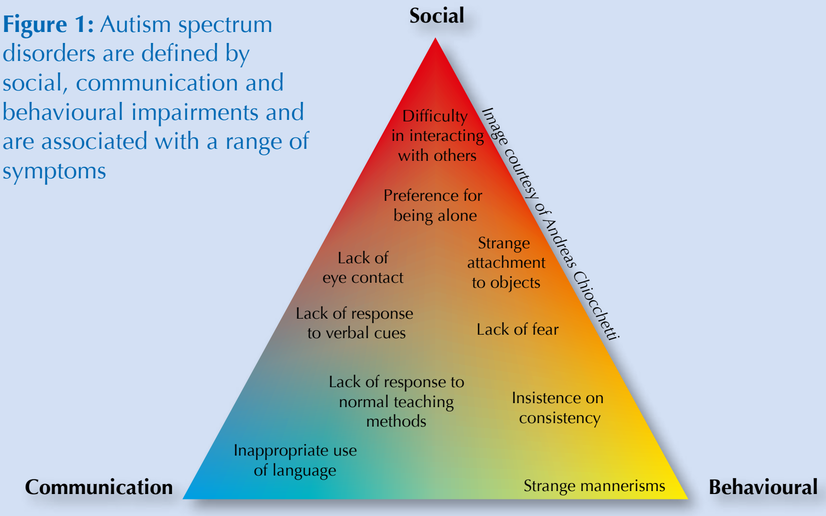


Figure 1: Autism spectrum disorders are defined by social, communication and behavioural impairments and are associated with a range of symptoms

with Asperger's syndrome but that they hadn't mentioned it because Peter was so keen to attend the camp. 'The professor' was able to stay until the end of the camp and we all learned a lot from him.

Asperger's syndrome is one of a group of similar disorders

My experiences with Peter made me want to understand and research the biological basis of Asperger's Syndrome. This is one of three disorders with similar, but distinct, symptoms (see box), which are classified as autism spectrum disorders (ASD). ASD

BACKGROUND

The autism spectrum disorders

Autism spectrum disorders (ASD) are defined by certain communication, social and behavioural difficulties (figure 1). ASD is a 'spectrum' because different people experience the symptoms differently, and with varying degrees of severity. There are three sub-types – Asperger's syndrome, early childhood (or classical) autism and pervasive developmental disorders not otherwise specified (PDD-NOS) – with varying symptoms and severity (figure 2 and table 1).

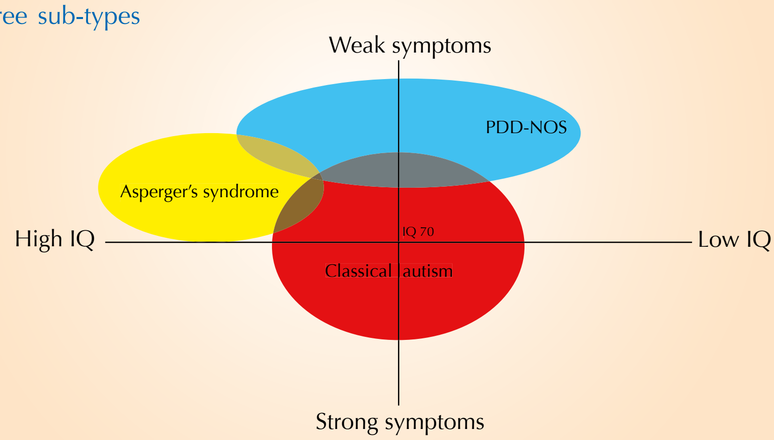


Figure 2: The three sub-types of ASD vary in the severity of their symptoms and mental impairment. People diagnosed with early childhood (classical) autism display a range of symptoms, such as those in figure 1. Asperger's syndrome has similar symptoms to early childhood autism, but with normal language development and IQ. PDD-NOS is the mildest form and is often referred to as atypical autism or sub-threshold autism

	Early childhood (or classical) autism	Asperger's syndrome	PDD-NOS
Onset	Early childhood	Usually later onset	Not specified
Social level	Impaired	Impaired	At least two of these three are affected
Language level	Impaired	Not impaired	
Behavioural level	Impaired	Impaired	
IQ	High functioning: IQ > 70; low functioning: IQ < 70	IQ > 70	IQ > 35

Table 1: Differences between the three sub-types of autism spectrum disorders

Image courtesy of paulaphoto / iStockphoto

Image courtesy of Norma Desmond; image source: Flickr

starts in early childhood and continues throughout adulthood. Sometimes people are not aware that they have it. Common symptoms include lack of eye contact and difficulties maintaining relationships, often combined with learning difficulties (figure 1). It can be hard for sufferers to integrate into society or to live independently.

ASD has both genetic and environmental causes

ASD prevalence in the general population is estimated at about 1 % and rising, mainly due to increased awareness and a broader diagnosis. It is estimated that up to 80 % of ASD has a genetic basis (see box). Geneticists believe that ASD is caused by a combination of different variations in several genes, rather than one single mutation or gene variant.

If 80 % of ASD is genetic, the other 20% must be explained by environmental factors. Only a few environmental factors have been proven to increase the risk of ASD, including parental age and rubella infection during pregnancy. Despite the widely publicised scare in the UK, however, there is no evidence to suggest that vaccines increase the risk of developing ASD[w1, w2].

BACKGROUND

ASD heritability

Twin studies have shown that the cause of ASD is largely genetic (up to 80 %). These studies analyse twins who have grown up together where at least one child has ASD. Monozygotic (identical) twins have the same genetic information, whereas dizygotic (non-identical) twins are more like normal siblings: they share around half of their genetic information but have experienced many of the same environmental factors (e.g. parents and home care).

If a disorder has a purely genetic basis, it will always affect both monozygotic twins. In dizygotic twins, if one has a genetic disorder there is a 50 % chance that the other twin will have it too. Studies have shown that if one twin has ASD, the chance of the other twin being affected is around 80 % for identical twins, and about 30 % for non-identical twins; these figures include both the genetic contribution and the effect of the environment that was shared by the twins. From these data, the average genetic contribution to ASD has been estimated to be 50-80 %. The remaining contribution is environmental, so to develop ASD, a person would usually need both a genetic predisposition and an environmental trigger.

Another risk factor for ASD is gender: boys are four times more likely to be diagnosed with ASD than girls. Perhaps some risk factors are carried on the X chromosome (of which males only have one copy, meaning they have no second, healthy, chromosome to compensate) or in genes that are activated during male development.

Some other disorders, such as fragile X syndrome, show similar symptoms to ASD: around 50 % of people with fragile X have autism-like symptoms. Fragile X patients have a known mutation in the *FMR1* gene, which alters a protein essential for normal brain function.

ASD is linked to synaptic plasticity, which is crucial for learning, memory, emotional recognition and use of language

ASD is linked to synaptic plasticity

Genetic research on ASD focuses on identifying variations linked to ASD. Researchers are genotyping ASD sufferers and their parents to identify the inheritance patterns of particular high-risk alleles. My collaborators and I are also comparing the DNA of healthy people with the DNA of people diagnosed with ASD.

Studies have identified several rare mutations and single nucleotide polymorphisms (SNPs, which are more common; see box) linked to ASD. Geneticists have also discovered that, in ASD sufferers, copy number variations (CNVs; see box) affect coding regions of DNA more often than in the general population.

By analysing the proteins that these genes encode, we have shown that they are important for energy metabolism, protein synthesis and signalling in neurons. It seems that these variations affect the ability of brain cells to make and maintain connections. This process, called synaptic plasticity, is crucial for learning, memory, emotional recognition and the use of language.

Genetic diagnosis provides hope for better treatment

Currently ASD is diagnosed by interviewing the parents and observing the ASD sufferer. The diagnosis can be influenced by the parents or the psychiatrist's personal bias. It is also a very time-consuming process. Therefore, a fast, objective and reliable diagnostic tool is needed.

Knowing which genes or genetic variations are responsible for ASD makes it possible to design new diagnostic tools. Understanding the molecular mechanisms involved might also enable new medications or treatments to be developed. Personally, my main reason for doing this research is to explain the biological basis of ASD to both ASD sufferers and the general public to help reduce the stigma associated with the condition.

Dr Andreas Chiocchetti was born in South Tyrol, Italy, and is head of the molecular genetics laboratory at the University Hospital for Child and Adolescent Psychiatry, Psychosomatics and Psychotherapy in Frankfurt, Germany. There, his research focuses on the characterisation of genetic variations in children and families with psychiatric disorders such as attention deficit / hyperactivity disorder and ASD. In 2007, he graduated in biotechnology and genetics from the University of Salzburg, Austria, and then gained a PhD in proteomic biomarkers in ASD at the German Cancer Research Center in Heidelberg, Germany.

Web references

w1 – Wikipedia offers a good overview of the controversy surrounding the combined measles, mumps and rubella (MMR) vaccine. See http://en.wikipedia.org/wiki/MMR_vaccine_controversy

w2 – The British medical community also responded to the MMR scare. See: www.bmj.com/content/342/bmj.c7452

Resources

This novel is told from the point of view of a boy with Asperger's syndrome:

Hadden M (2004) *The Curious Incident of the Dog in the Night-Time*.

BACKGROUND

Genetic variation

Each of us carries many genetic variations. These variations include single nucleotide polymorphisms (SNPs) and copy number variations (CNVs), as well as rare mutations. Mutations are alterations in the genetic code, including deletions and insertions or nucleotide replacements. SNPs occur when one single DNA nucleotide is different, e.g. at a particular place in the genome, one person might have an adenine (A), whereas another person might have a guanine (G) nucleotide.

Most people have two copies of each gene, one from each parent. However, some people have CNVs: these people might have more than or fewer than two copies of a gene, or might even be missing a sequence entirely.

SNPs and CNVs are normal, fairly common (particularly in non-coding DNA) and do not usually cause problems. However, some variations, if they are found in or near an important gene, can cause illness. Certain damaging SNPs, CNVs and rare mutations are associated with ASD (figure 3).

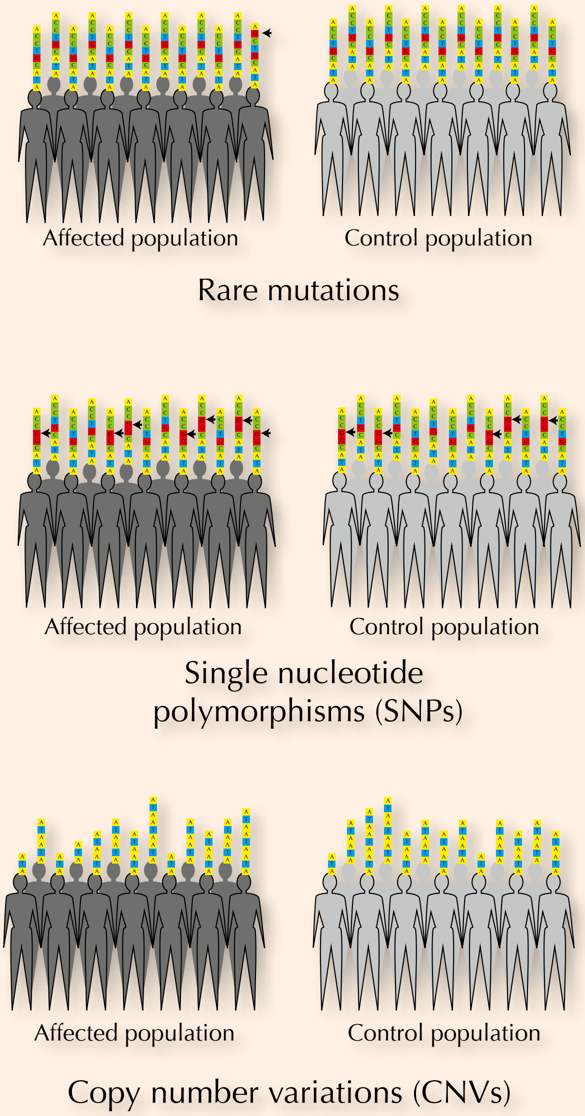


Image courtesy of Andreas Chiocchetti

Figure 3: Genetic variations and ASD research. Researchers are investigating three types of genetic variation – SNPs, CNVs and rare mutations – to assess whether they increase the risk of ASD. This figure shows how certain variations, which may also be present within the general (control) population, are more common in people diagnosed with ASD. Some variations are very common and associated with a low risk of ASD, whereas others are very rare and considered high risk. The more risk factors (genetic and environmental) a person is exposed to, the more likely they are to be affected by ASD

London, UK: Random House. ISBN: 9781400032716

Fans of Jane Austen's novels will find this a fascinating and enlightening study:

Ferguson Bottomer P (2007) *So Odd a Mixture: Along the Autistic Spectrum in 'Pride and Prejudice'*. London, UK: Jessica Kingsley. ISBN: 9781843104995

ASD from the perspective of a special education teacher:

Rich L (2005) *Casey's Wall: A Novel*. Bloomington, IN, USA: iUniverse, Inc. ISBN: 9780595378579

Chapter 16 of *Bad Science* covers the MMR scare in the UK:

Goldacre B (2008) *Bad Science*. London, UK: Harper Collins. ISBN: 9780007240197

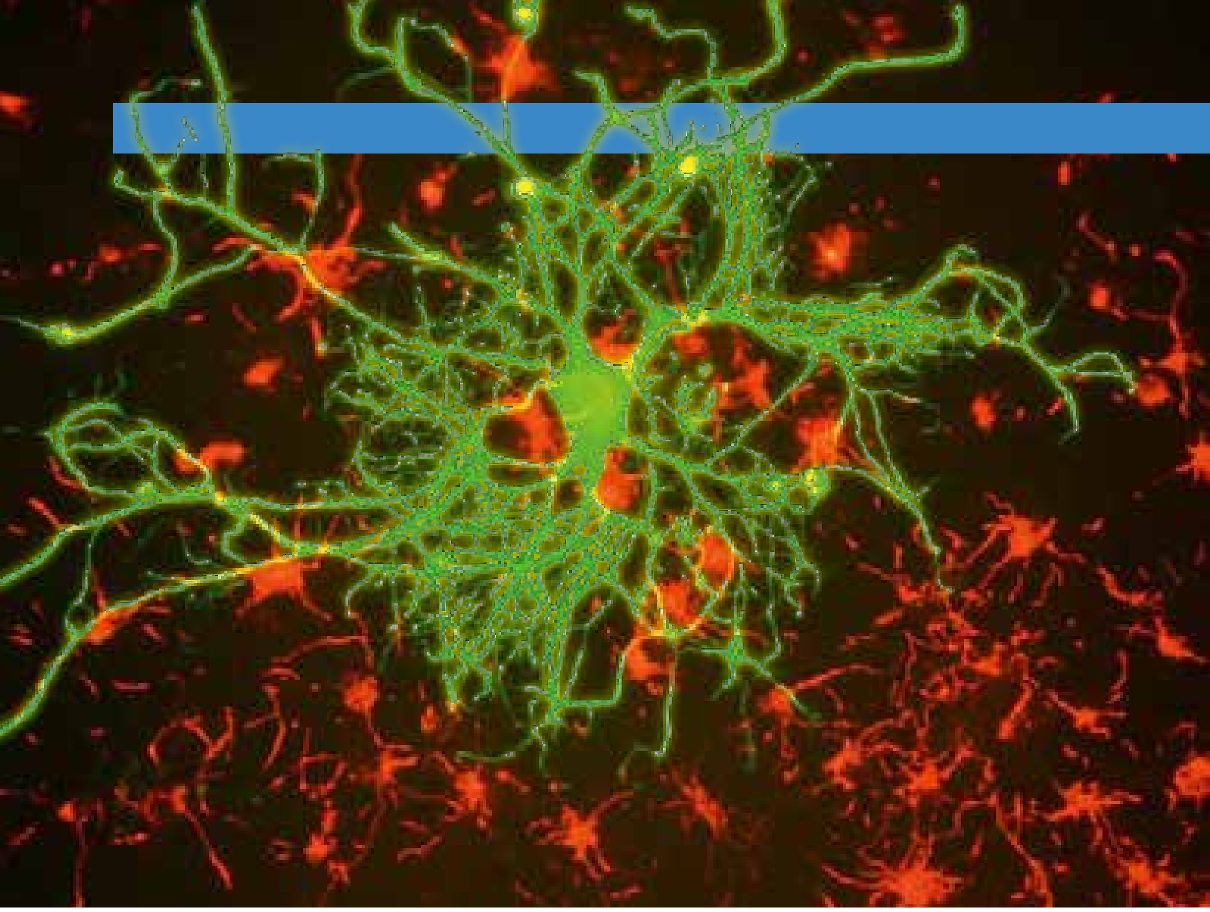
The animated film *Mary and Max* (2009; Director: Adam Elliot; Australia) tells the curious and touching story of two unlikely pen pals, Mary and the autistic Max.

The character of Raymond, the autistic central figure in the 1988 film *Rain Man* is based on a real person.

If you have concerns about a pupil, family member or friend, it is advisable to speak to a doctor or psychiatrist. You should not rely on self-diagnosis or web-based diagnostic tools, as there is a lot of misleading information on the Internet.

The following websites, however, may be helpful:

The UK's National Autistic Society provides information and support



A neuron (stained in green) in tissue culture. Mutations linked to ASD appear to affect the brain's ability to make and maintain connections

Image courtesy of GerryShaw; image source: Wikimedia Commons

for people with ASD, and also for their families. See: www.autism.org.uk

Autism Speaks is the USA's largest autism science and advocacy organisation. See: www.autismspeaks.org

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

Readers who are interested in consulting the primary literature may find the following articles useful:

Chiocchetti A et al. (2011) Mutation and expression analyses of the ribosomal protein gene RPL10 in an extended German sample of patients with autism spectrum disorder. *American Journal of Medical Genetics Part A* **155(6)**: 1472-1475. doi: 10.1002/ajmg.a.33977

Freitag CM et al. (2010) Genetics of autistic disorders: review and clinical implications. *European Child & Adolescent Psychiatry* **19(3)**: 169-178. doi: 10.1007/s00787-009-0076-x

Hallmayer J et al. (2011) Genetic heritability and shared environmental factors among twin pairs with autism. *Archives of General Psychiatry* **68(11)**: 1095-1102. doi: 10.1001/archgenpsychiatry.2011.76

Holt R et al. (2010) Linkage and candidate gene studies of autism spectrum disorders in European populations. *European Journal of Human Genetics* **18(9)**: 1013-1019. doi: 10.1038/ejhg.2010.69

Leblond CS et al. (2012) Genetic and functional analyses of SHANK2 mutations suggest a multiple hit model of autism spectrum disorders. *PLoS Genetics* **8(2)**: e1002521. doi: 10.1371/journal.pgen.1002521

PLoS Genetics is an open-access journal, so this article is freely available.

Lichtenstein P et al. (2010) The genetics of autism spectrum disorders and related neuropsychiatric disorders in childhood. *American Journal of Psychiatry*. **167(11)**: 1357-1363. doi: 10.1176/appi.ajp.2010.10020223

Liu XQ et al. (2008) Genome-wide linkage analyses of quantitative and categorical autism subphenotypes. *Biological Psychiatry* **64(7)**: 561-570. doi: 10.1016/j.biopsych.2008.05.023

Pagnamenta AT et al. (2010) Characterization of a family with rare deletions in *CNTNAP5* and *DOCK4* suggests novel risk loci for autism and dyslexia. *Biological Psychiatry* **68(4)**: 320-328. doi: 10.1016/j.biopsych.2010.02.002

Pinto D et al. (2010) Functional impact of global rare copy number variation in autism spectrum disorders. *Nature* **466(7304)**: 368-372. doi: 10.1038/nature09146

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Weiss LA et al. (2009) A genome-wide linkage and association scan reveals novel loci for autism. *Nature* **461(7265)**: 802-808. doi: 10.1038/nature08490

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

Image courtesy of videophoto / iStockphoto

Image courtesy of dem10 / iStockphoto

Mercury and liquid nitrogen. To familiarise students with the differences between solids, liquids and gases, use examples of materials that exist in an unexpected state of matter, such as mercury or liquid nitrogen. This helps to challenge misconceptions such as 'all metals are solids'. Also point out that air is not the only gas (another common misconception), and that it is in fact a mixture of gases

The effect of heat: simple experiments with solids, liquids and gases

From a homemade thermometer to knitting needles that grow: here are some simple but fun experiments for primary-school pupils to investigate what happens to solids, liquids and gases when we heat them.

By Erland Andersen and Andrew Brown

Why do elephants squirt water onto their backs? How does fog form? And why do trains make a 'clickety clack' noise? Your students will have answers to all of these questions once they have understood how heat affects solids, liquids and gases. In this small collection of experiments, we begin by investigating how heat alters the properties of the three states of matter. We then examine how heat can convert gases,

REVIEW

- Primary
- Science
- Physics
- Ages 10-13*

The main strength of this article is that it presents a group of activities in an order that makes sense as a whole. Even though the activities are likely to be known by many teachers, the suggested sequence and questions will help teachers approach some rather difficult concepts, such as heat transfer, evaporation and condensation. The activities also help teachers to examine the reversibility of some of these processes. Another important advantage of this article is that it uses feasible and easy experiments, which can be carried out using standard school equipment and cheap materials.

Christiana Nicolaou, Cyprus

*Note that the authors suggested using the activities with younger students, aged 7-11.

Physics

Primary


Image courtesy of Andrew Brown

The home-made thermometer

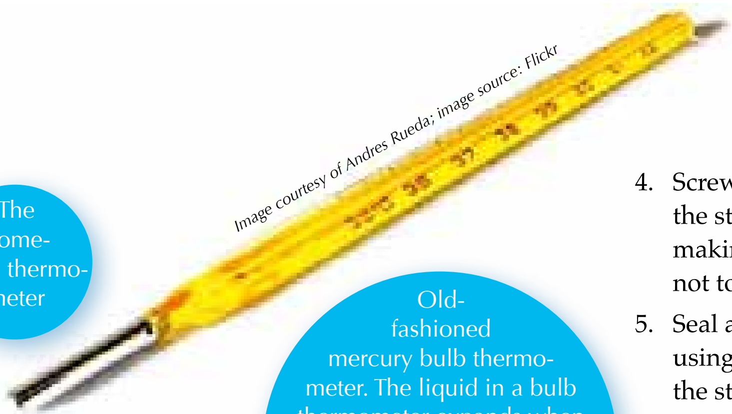


Image courtesy of Andres Rueda; image source: Flickr

Old-fashioned mercury bulb thermometer. The liquid in a bulb thermometer expands when heated, causing it to rise up the narrow glass tube. The thermometer in experiment 1 relies on the expansion of gas, not liquid

liquids and solids from one to another. After each experiment, in the manner of true scientists, we question our results and think about how we could improve our experimental design.

Each of the five experiments relies on simple materials and is suitable for pupils aged 7-11 (although note that the reviewer suggested the article is suitable for pupils aged 10-13). When used together, they could occupy your class for a whole day, but they could also be split up and used in separate lessons. Before starting, ask your students to think about what solids, liquids and gases actually are, in terms of their appearance and properties[w1].

Changing properties

1) Make your own thermometer: gases expand when heated

This experiment introduces the idea that heat makes gases expand. Students will make their own thermometer based on this principle.

Safety note: teachers should perform the step involving scissors. See also the general *Science in School* safety note on page 65.

Materials

Per group of pupils:

- A rigid plastic bottle with a lid
- Play dough or modelling clay, e.g. Plasticine®
- A transparent plastic drinking straw
- A pair of scissors
- Food colouring (optional)
- Tap water

Procedure

1. Use a pair of scissors to make a hole in the top of the bottle lid, big enough for the drinking straw to fit through.
2. Fill the bottle halfway with cold water.
3. Add a few drops of food colouring and mix.
4. Screw on the bottle lid and insert the straw through it into the water, making sure that the straw does not touch the base of the bottle.
5. Seal around the hole in the lid using play dough, thereby fixing the straw in place. The seal must be completely airtight.
6. Place one hand on the upper part of the bottle. What happens to the liquid in the straw, and why?

What happens?

The heat from your hand warms the air inside the bottle. The air expands and pushes on the water, causing it to rise up the straw.

Questions for your pupils

1. Was it really heat that caused the liquid to rise up the straw, or could pressure from your hands be responsible?
2. How can we test this experimentally?

   Answers: the bottle was rigid and, assuming you didn't squeeze, the liquid rose up the straw due to heat, not pressure. You can test this by placing your hands close to but not on the bottle and seeing if the liquid still rises up the straw.


Image courtesy of Andrew Brown

Experiment 2: watching a knitting needle grow

2) Watch a knitting needle grow: solids also expand when heated

In the previous experiment, the heat from a pair of hands was sufficient to expand the gas in the bottle considerably. Solids, however, expand much less than gases for a given increase in temperature. In the following experiment, we will use a simple but sensitive device to observe the expansion of a knitting needle when heated by a candle.

Safety note: because naked flames and sharp objects are used in this experiment, it is advisable to perform it as a demonstration. See also the general *Science in School* safety note on page 65.

Materials

- A metal knitting needle
- Two empty glass bottles (wine bottle are suitable)
- A cork to fit one of the bottles
- A set of keys or other object (e.g. modelling clay) to weigh down one end of the knitting needle
- A pile of books (or other objects to support the apparatus)
- A sewing needle with a cylindrical shaft
- A drinking straw
- A tea light (short candle)
- Matches

Procedure

1. Push the cork halfway into one of the bottles.
2. Push the sharp end of the knitting needle into the side of the cork, so that the knitting needle is just above the rim of the bottle.
3. Lay the other end of the knitting needle across the mouth of the second bottle.
4. Stick the sewing needle through the drinking straw, one third of the way along the straw's length. The hole should be small enough that the straw does not turn loosely around the needle.
5. Place the sewing needle (with straw attached) across the mouth of the second bottle, underneath the knitting needle and at right angles to it.
6. Hang a weight (e.g. keys) on the free end of the knitting needle
7. Point the straw downwards.
8. Place a pile of books between the two bottles.
9. Place the candle on top of the pile of books. Adjust the height of the pile so that the top of the candle is approximately 3 cm from the knitting needle.
10. Light the candle. What happens to the straw? What causes this?

What happens?

The heat from the candle causes the knitting needle to expand. As it expands lengthways, it moves over and rolls the sewing needle. The straw magnifies the small movements of the sewing needle.

Questions for your pupils

1. We have seen that solids and gases expand when heated, but what about liquids?

   Answer: liquids are no exception – they too expand when heated.
2. What problems might heat-related expansion cause for bridges or railways?

   Answer: see the images below.

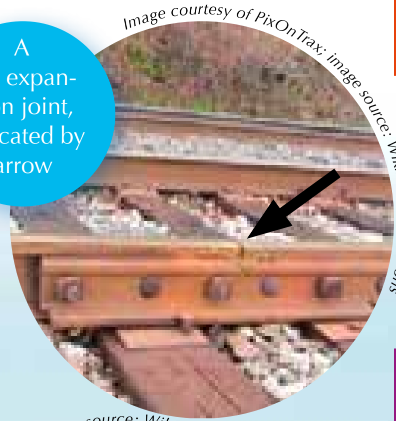

A rail expansion joint, indicated by arrow

Image courtesy of PixOnTrax; image source: Wikimedia Commons


A bridge expansion joint

Image courtesy of Ingolfson; image source: Wikimedia Commons

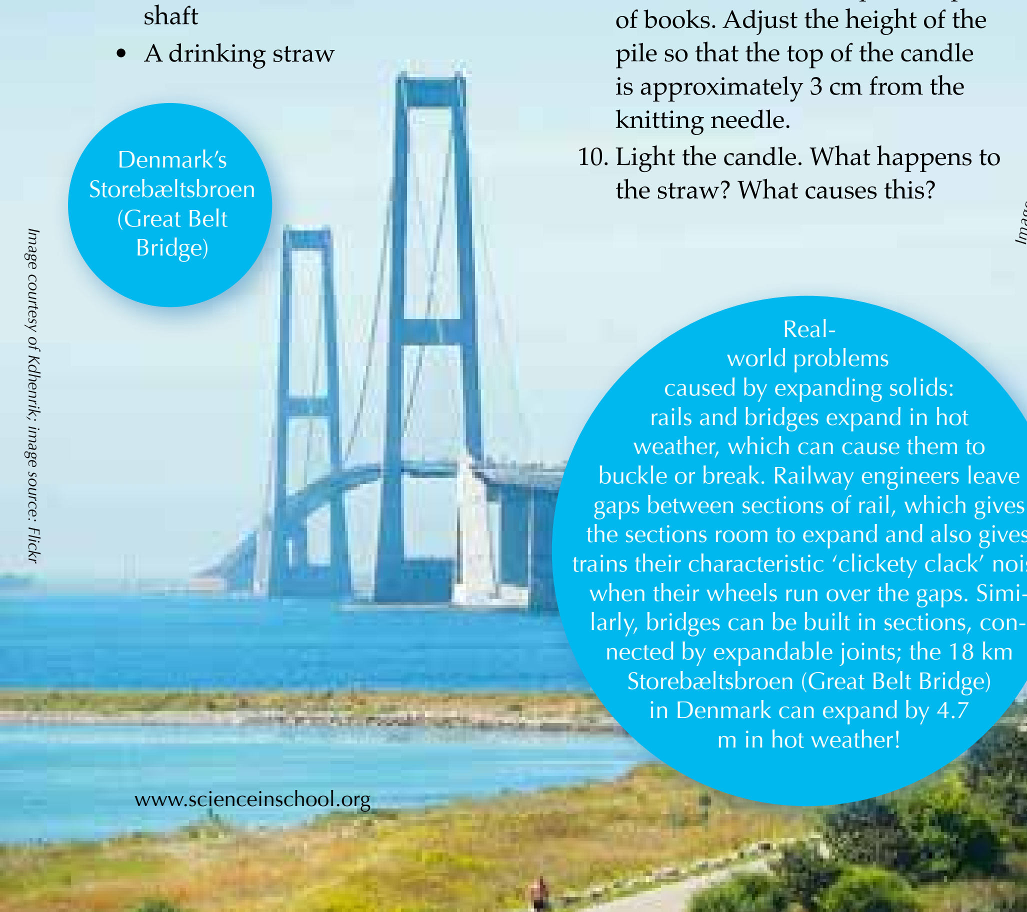

Denmark's Storebæltsbroen (Great Belt Bridge)

Image courtesy of Kdhenrik; image source: Flickr

Real-world problems caused by expanding solids: rails and bridges expand in hot weather, which can cause them to buckle or break. Railway engineers leave gaps between sections of rail, which gives the sections room to expand and also gives trains their characteristic 'clickety clack' noise when their wheels run over the gaps. Similarly, bridges can be built in sections, connected by expandable joints; the 18 km Storebæltsbroen (Great Belt Bridge) in Denmark can expand by 4.7 m in hot weather!

Physics

Primary

Images courtesy of k.landerholm, atomicshark and Vélocia; image source: Flickr

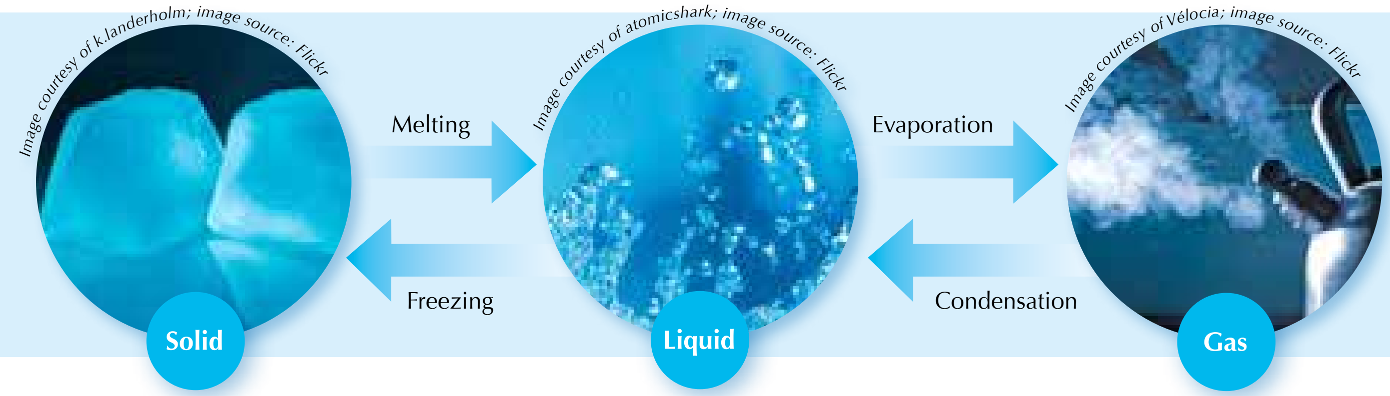


Figure 1: This diagram shows the processes responsible for converting the three states of matter from one to another. Changes in state are reversible

Changing states

So far, students have seen what happens when we heat solids and gases: they expand. You have also told your students that liquids do the same. But what happens when we heat substances even further (figure 1)? Ask your students to think about a bar of gold; it is solid at room temperature, at 100 °C, and even at 500 °C. But what happens when we raise the temperature even higher, to 1064 °C? At this temperature, something amazing happens: the solid gold becomes a liquid! Heat the liquid further still (to 2856 °C) and the liquid boils and turns into a gas.

Of course, this is a rather extreme example; most of us will never experience gold in its gaseous form. But everyone in the class will be familiar with water moving through the three states of matter: turning from solid ice to liquid water (0 °C), then to its gaseous form, water vapour (100 °C). So as well as expanding them, heat can also cause substances to change state. Different substances require different amounts of heat to do this: it takes more heat to boil gold than to boil water. But in theory at least, all substances can exist in the three states of matter.

In the following experiments, we will look at what happens when we turn liquid water to a gas – and back again.

The world's largest bar of gold is in a museum in Toi, Japan. It weighs 250 kg and at the time of writing is worth about US$12 million

Liquid gold being poured into a cast to make a gold bar

3) Liquid to gas: evaporation on your finger

Even before a liquid boils, some of it may start to turn into gas – ask your students to think of the wisps of steam that come off a pan of water long before it boils. In this experiment, students will see that that even our fingertips generate enough heat to make small amounts of water turn from a liquid to a gas. We call this process evaporation.

Materials

- A cup of water

Procedure

This experiment is best done outdoors or somewhere where there is a draft, such as near an open window.

1. Dip your index finger in the water, then hold it up.
2. What do you see and feel?

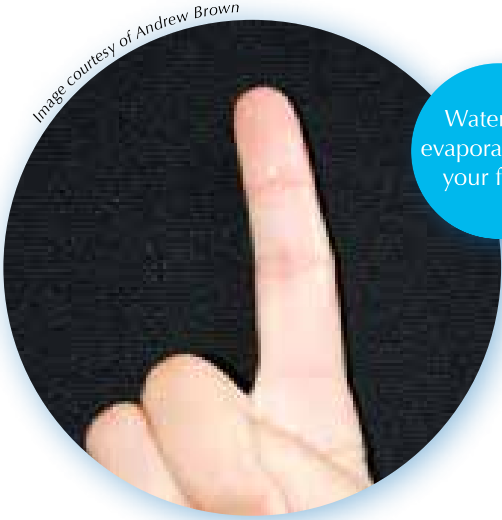
What happens?

The water evaporates from your finger, leaving it dry. Your finger also feels cold. This is because the heat from your body is transferred to the liquid water and carried away in water vapour.

Image courtesy of bratboy76; image source: Flickr

An elephant squirting water onto its back

Image courtesy of Andrew Brown



Water will evaporate from your finger

Questions for your pupils

1. In this experiment we heated liquid water, but what happens when we heat a solid? Think about what happens when you heat butter.
   Answer: solids melt when heated.
2. How could we improve our experiment?
   Answer: what if your finger felt cold not because of evaporation, but because the water was cold? To test this idea, we could use water at body temperature (37 °C). Try it – you should get the same result.
3. Using what you have learned, can you explain why elephants sometimes squirt water onto their backs?
   Answer: elephants do this to cool themselves down, by taking advantage of the cooling power of evaporation.

4) Gas to liquid: condensation in a bag

Students have seen that heating a liquid can turn it into a gas (evaporation), but this is a reversible process: cooling a gas sufficiently turns it into a liquid, in a process called condensation. In the following experiment, students will investigate condensation.

Materials

- A transparent plastic bag
- An elastic band
- A small cloth
- Water

Procedure

1. Run the cloth under a tap to make it wet and then squeeze it to remove the excess water.
2. Place the cloth inside a plastic bag. Trap some air inside the bag and seal it.
3. Leave the bag in a warm place, such as on a radiator or in direct sunlight, for one hour. What do you see?

What happens?

Water droplets form on the inside surface of the bag.

How? Water evaporates from the wet cloth so that the air inside the bag contains lots of water vapour. The inside surface of the bag is cool enough to change the water vapour back into liquid water.

Questions for your pupils

1. In this experiment we cooled a gas (water vapour), but what happens when we cool a liquid? Think about how you make ice cubes.
   Answer: when cooled, liquids freeze and become solid.
2. How could we modify our experiment to make the water droplets form faster?
   Answer: making the surface of the bag colder, for example by placing ice cubes next to it, will make condensation occur faster.
3. Which causes fog: evaporation or condensation?
   Answer: fog forms when water vapour cools and condenses into a cloud of small water droplets near the ground (like a cloud but lower down).

Image courtesy of Andrew Brown

Condensation in a plastic bag

Acknowledgement

The instructions on how to make a thermometer were adapted from the California Energy Commission's Energy Quest website. For this and other science projects, see: www.energyquest.ca.gov/projects

Web references

w1 – The BBC Bitesize website features concise, high-quality teaching resources for students. It includes an excellent section on the properties of solids, liquids and gases. See: www.bbc.co.uk/schools/ks2bitesize/science/materials or use the shorter link:/http://tinyurl.com/ceyt6te

w2 – To find out more about one of the authors, visit Erland Andersen's website (in Danish): www.naturfagskurser.dk

w3 – The small energy driving licence certificate and teacher's handbook (both in Danish) can be downloaded from the website of the Danish Electricity Association (Dansk El-Forbund; www.evu.dk) or via the direct link: http://tinyurl.com/energylicence

Resources

Watch a video of a simple experiment showing that gases expand when heated, involving nothing more than a refrigerated drink and a coin. www.metacafe.com/watch/333171/jumping_coin or use the shorter link: http://tinyurl.com/slgexp1

Watch a video showing solids expanding when heated and gases contracting when cooled (involves fire, liquid nitrogen and a balloon). http://youtu.be/tPJLFDekxZA

If you enjoyed reading this article, you can browse the full collection of *Science in School* articles for primary-school teachers. See: www.scienceinschool.org/primary

Erland Andersen is a former primary-school teacher from Denmark. He now provides training courses for science teachers[w2].

Erland developed the activities in this article as part of a 'small energy driving licence'[w3]. Pupils earn their licence by performing energy-related experiments in small groups. Erland encourages the pupils to explain and question their results, and to use what they have learned to explain real-world phenomena.

Andrew Brown is a molecular and cellular biology graduate of the University of Bath, UK. He currently works for *Science in School*, based at the European Molecular Biology Laboratory in Heidelberg, Germany.

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

Sable Island, off the coast of Nova Scotia, Canada, is known as the 'graveyard of the Atlantic'. The island is 36 km long and is located where warm, moist air from the Gulf Stream is cooled by air from the Arctic Ocean, causing frequent heavy fogs. This makes it is a dangerous place for ships: at least 350 vessels have been wrecked there

Image courtesy of archer10 (Dennis) OFF; image source: Flickr

Image courtesy of stock photos for free.com

Seeing is believing: 3D illusions

To make the two-dimensional images that we see in print and on screen appear more real, we can hijack our brains to create the illusion of a third dimension, depth. These activities explore the physics that make this possible.

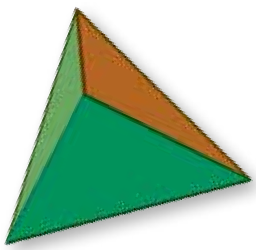


Image courtesy of DTR; images source: Wikimedia Commons

By Andrew Brown

Look around you. How many dimensions can you see? As a three-dimensional being living in a three-dimensional world, surely you see three dimensions: height, width and depth? Not so. In fact you see only two dimensions. This is because what we *see* is merely 2D images, even of 3D objects, projected onto the backs of our eyes. What we *perceive* is entirely different: our brains process those 2D images into something that appears to have not only height and width but also depth – three dimensions. Thus, the brain uses 2D images from the eyes to create an illusion of 3D.

The four activities in this article, suitable for 11- to 19-year-old physics students, investigate how we can hijack the workings of the brain to

- **Physics**
- **General science**
- **Biology**
- **Optics**
- **Ages 14-19***

The use of 3D illusions in the visual media is becoming increasingly popular. But how is it that we see a 2D picture in 3D? And how can we create our own 3D illusions? These questions and many more are answered in this novel article. The great thing is that it does not just give explanations, but also provides a number of activities to help the students understand what is going on. It is very useful as a way of linking theory to real-life applications.

Suitable for teachers of physics (optics) and general science, this article would also be good background reading for biology (vision) and art teachers.

Paul Xuereb, Malta

*Note that the activities were used by the IOP for students aged 11-19

REVIEW

make an object that is genuinely 2D to begin with – such as a drawing, painting or movie – appear 3D. Activities 1, 2 and 3 take about 20 minutes each, and activity 4 takes about 30 minutes. The materials required are inexpensive but will require sourcing in advance. Although this article mainly covers physics topics, it could also be adapted for use in biology lessons because it deals with vision and the brain.

Adding another dimension

First, how does the brain allow us to perceive truly 3D objects in three dimensions?

We use this ability every time we do something as simple as pouring a drink. Cover one eye, keep your head still and your eyes level with the top of the glass, then try to pour the water into the glass. It's difficult. Now open both eyes and try again. This time, your brain receives two slightly different images of the same objects, which it uses to perceive depth. As a result, you should be able to pour the water accurately into the glass.

We can exploit this ability of the brain in order to enhance the realism of a 2D picture. We do this by presenting each of our eyes with a slightly different image, mimicking what happens when we look at a 3D object. The brain combines these two images, convincing us that there is depth in what is actually a 2D picture.

Three strategies are used to create these 3D illusions. The first strategy (covered in activity 1) directs a different image into each eye using refraction, whereas the other two strategies (activities 2 and 3) use different types of special glasses. In activity 4, students use what they have learned to make their own 3D image.

Activity 1: 3D lenticular images

Your students may have seen designs on postcards, DVD covers or the cards you find in cereal packets that seem to have an amazing sense of depth. If so, they've already encountered 3D lenticular pictures. In the following activity we will investigate how they work.

Materials

Per student or pair of students:

- A 3D lenticular picture

Procedure

1. Cover your left eye and look at the picture. Then cover your right eye instead and look again.
2. Look at the picture with both eyes. What do you notice?

These anaglyphs (see activity 2) were created from images taken with a scanning electron microscope. Use your red / green glasses to view them.

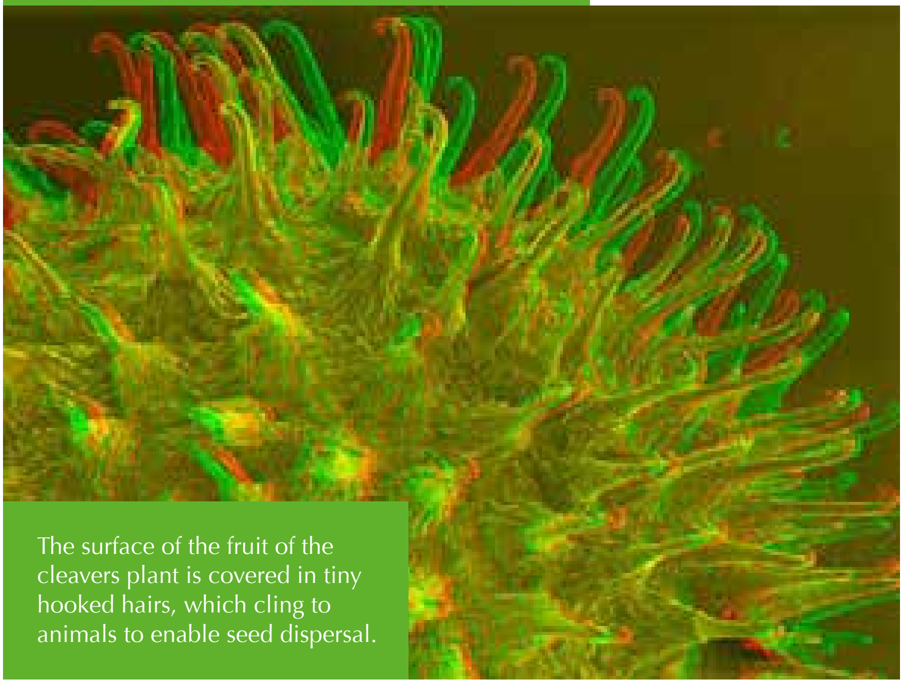


Image courtesy of Syngenta

The surface of the fruit of the cleavers plant is covered in tiny hooked hairs, which cling to animals to enable seed dispersal.

Image courtesy of Syngenta

Spores of a pathogenic fungus (wheat yellow rust) erupting through the surface of a wheat leaf.

What happens?

When you view the picture with both eyes it looks 3D, but when you view it with only one eye it looks 2D.

How does it work?

The simplest 3D lenticular pictures are created from two separate images, which are offset from one another laterally. Let's take as an example a composite picture made of picture A and picture B. Both pictures are cut into vertical strips and reassembled alternately into what is called an *interlaced image* (figure 1a), making the order of strips: A-B-A-B-A…. The interlaced image is printed onto paper and overlain by a sheet of lenticular plastic, which consists of a series of long, thin lenses (figure 1b). The lenses are aligned with the underlying strips in such a way that light reflected off strips of A will be sent in one direction, to the left eye, and light reflected from strips of B is sent in another direction, to the right eye (figure 1c).

In our experiment, your brain combines pictures A and B of the lenticular picture to give an illusion of depth. The illusion works because the two pictures are offset from one another, so the brain is combining two different images – just as it does when you look at a 3D object with two eyes. There is no such illusion of depth when you look through a single eye: either your left eye sees only picture A or your right eye sees only picture B.

Figure 1: 3D lenticular pictures: how they are made and how they work

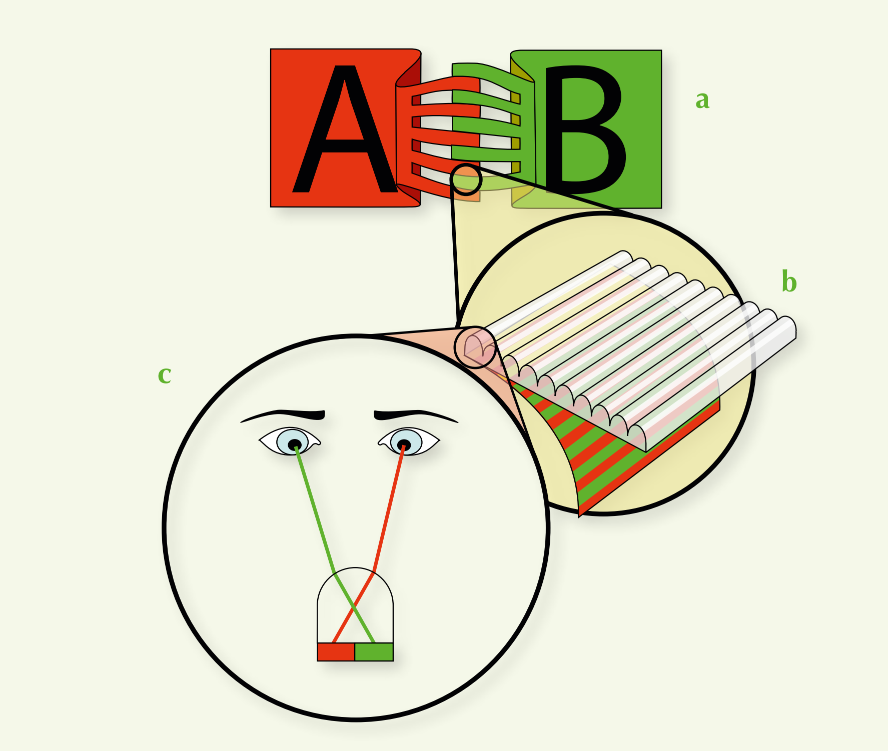


Image courtesy of Lenstar.org

a) Two separate images, A and B, are cut into strips and then reassembled alternately, to form an interlaced image. The images are also offset from one another laterally.
b) The interlaced image is printed onto paper and overlain by a sheet of lenticular plastic consisting of plastic lenses.
c) The lenses send light reflected from strips of A to one eye and from strips of B to the other eye. The brain combines the images to create the illusion of depth

Activity 2: anaglyphs

Whereas lenticular 3D pictures work when viewed with the naked eye, other ways of creating the illusion of depth require special glasses. Early 3D movies took advantage of colour to create the illusion of 3D. Watchers wore red / green glasses to view a projected picture composed of two offset pictures: one red and one green. Such pictures, called anaglyphs, are still used widely today in printed materials. In the following activity, your students will learn how anaglyphs work.

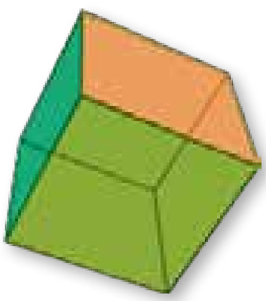


Image courtesy of DTR; images source: Wikimedia Commons

Materials

Per pair of students:

- A pair of red / green glasses

Procedure

1. Wear the red / green glasses with the red filter over your left eye and the green filter over your right eye
2. Look at one of the anaglyphs on page 30.

Red / green glasses

Image courtesy of Andrew Brown

What happens?

The anaglyph appears to have depth: it looks 3D.

How does it work?

We can filter light based on its colour (wavelength). The red filter in your glasses absorbs all wavelengths of light apart from red, whereas the green filter absorbs all wavelengths apart from green.

To make the anaglyph, each of the two component pictures was taken from a slightly different position before being coloured: one in red and one in green. When you look at the anaglyph with your red / green glasses on, your left eye receives the red image and your right eye, the green image. The illusion of depth is created when your brain combines the two offset images.

Activity 3: 3D polarising glasses

Most modern 3D movies use polarising glasses to achieve the illusion of depth. The following activity investigates how these glasses work.

Materials

Per pair of students:

- Two pairs of 3D polaroid glasses, such as those made by RealD™

Procedure

In pairs:

1. Wear your glasses and look at your partner.
2. Cover the left lens and look at your partner, who should have both lenses uncovered. What do you see?
3. Cover the right lens and look again. What has changed?

What happens?

When you look at your partner with both of your lenses uncovered, your partner's lenses look transparent. When you cover one of your lenses, one of your partner's lenses appears to darken. If you cover your other lens, your partner's other lens appears to darken.

How does it work?

To understand your observations, and how modern 3D movies work, we need to remember that light travels in waves. We can influence the orientation of the waves' oscillations by passing the light through a circular polarising filter, which makes the oscillations travel in spirals (figure 2). The lenses in your 3D glasses contain circular polarising filters: one polar-

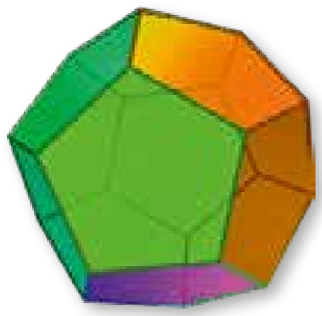
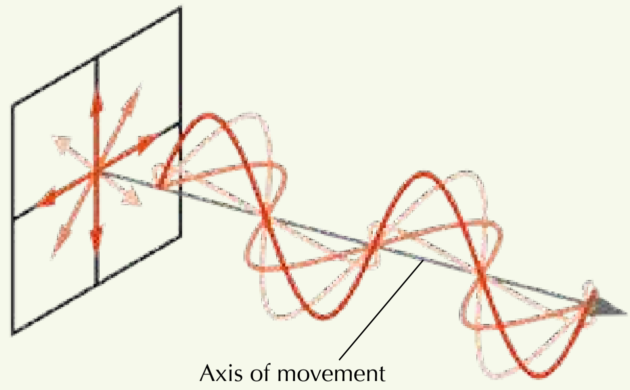


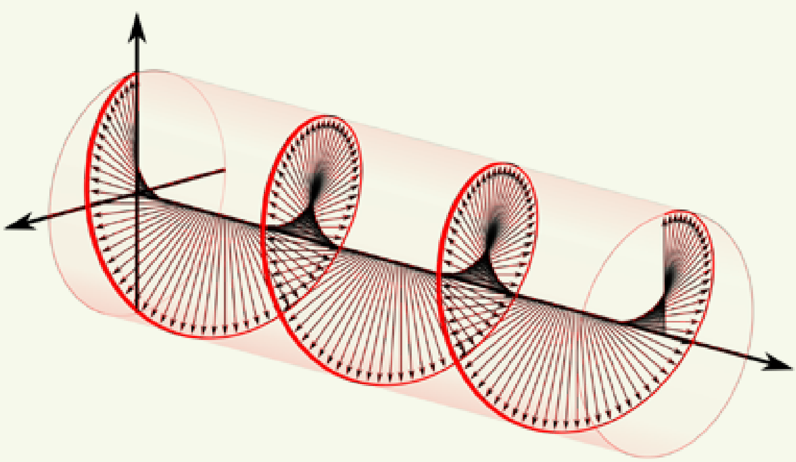
Image courtesy of DTR; images source: Wikimedia Commons

Figure 2: The way light travels in waves can be affected by polarising filters

Un-polarised light: normally, the peaks and troughs of a wave of light point in random orientations about the axis of its movement



Circularly polarised light: circular polarising filters cause the wave's oscillations to rotate about its axis of movement, in either a clockwise or an anti-clockwise direction, depending on what kind of filter is used. The wave shown here is polarised in a clockwise direction



Images courtesy of Bob Mellish (top) and Dave3457 (bottom); image source: Wikimedia Commons

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Image courtesy of libraryman; image source: Flickr

ises light in a clockwise direction and the other in an anticlockwise direction[w1].

Let's think about what happens when you look at your partner with both of your lenses uncovered (figure 3A). Your partner's lenses appear transparent, because you are able to see the light that has passed through them: clockwise polarised light from your partner's clockwise polarising lens reaches one of your eyes, while anticlockwise polarised light from your partner's anticlockwise polarising lens reaches your other eye.

Now think about what happens when you cover your clockwise polarising lens (figure 3B). Your partner's clockwise polarising lens appears darker, because you no longer receive the light that has passed though it. Why not? Because your anticlockwise polarising lens (the only lens through which you can now see) blocks the clockwise polarised light. When you cover your other lens (figure 3C), the situation is reversed and your partner's other lens appears darker.

The 3D movies for which your glasses were designed are filmed using two cameras mounted so that the distance between the cameras' lenses is roughly equal to that between the average pair of human eyes. During the movie, the two moving pictures are circularly polarised in opposite directions and projected onto a screen. Your 3D glasses ensure your

Figure 3: The darkening lens experiment. The blue lines indicate light passing through your partner's clockwise (CW) lens, while the red line indicates light passing through your partner's anticlockwise (ACW) lens.

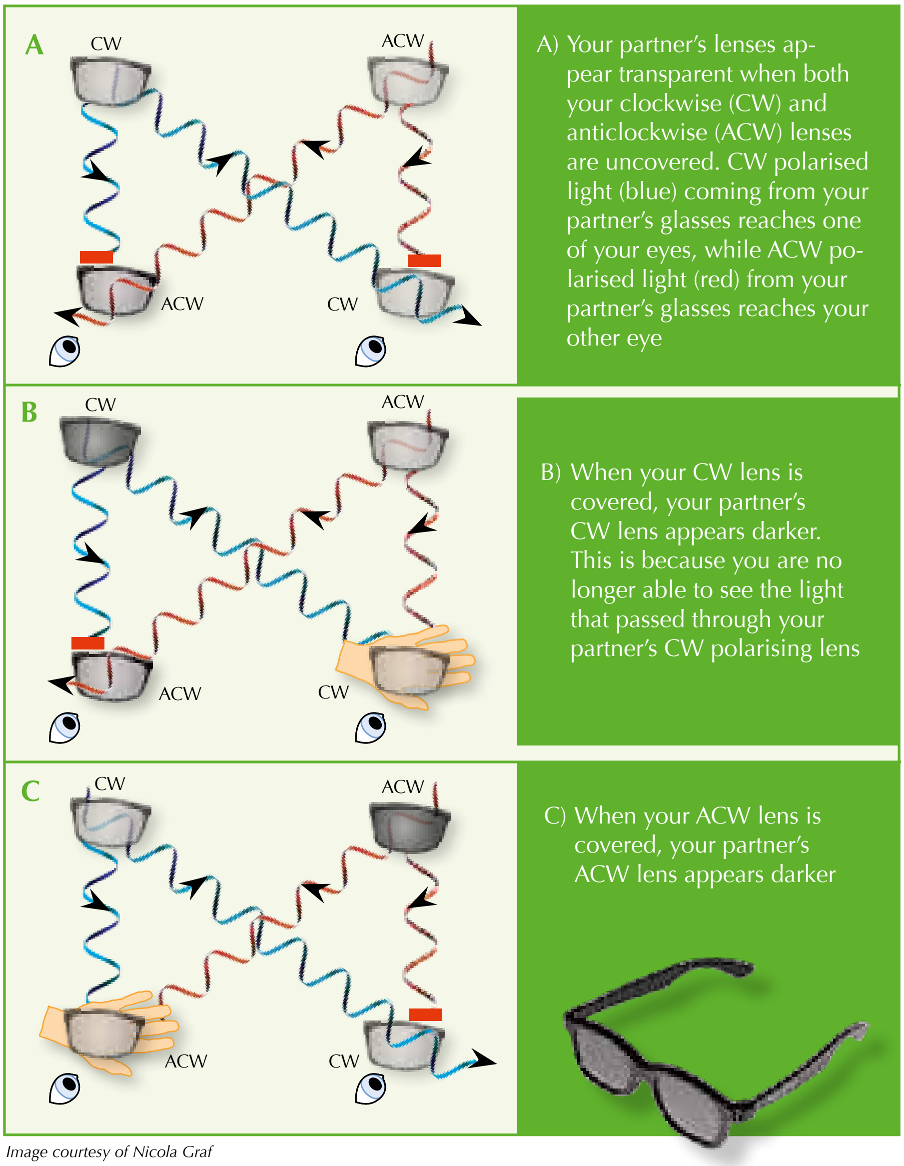


Image courtesy of Nicola Graf

left eye receives one image, and your right eye the other. The two moving pictures are displayed alternately at an imperceptibly fast rate of 144 times per second. The brain combines the images it receives from both eyes to create the illusion of depth.

Activity 4: making your own 3D image

Once your students have understood the principles of 3D imaging, they can make their own anaglyph using a digital camera and a computer (figure 4).

Materials

- A digital camera
- A tripod or other type of support for the camera (e.g. a pile of books)
- A pair of red / green glasses
- A piece of software that can make an anaglyph, such as Anaglyph Workshop[w2].

Procedure

1. Choose a stationary subject.
2. Take a photo.
3. Move to the right by about 6 cm (about the distance between our eyes), ensuring that the camera remains at the same level. Take a second photo.
4. Follow the instructions of your chosen software to colour and superimpose the two photographs. You now have an anaglyph.
5. Look at your anaglyph through your red / green glasses, either on a computer screen or a printout. You may need to repeat the procedure a few times, adjusting the distance you move before taking the second photo, to refine the 3D effect.

Note: if you have a smart phone, you can simplify the procedure by using an app (e.g. 3D Photo Maker) to make your anaglyph directly, using images taken with your phone's camera.

Image courtesy of Nicola Graf

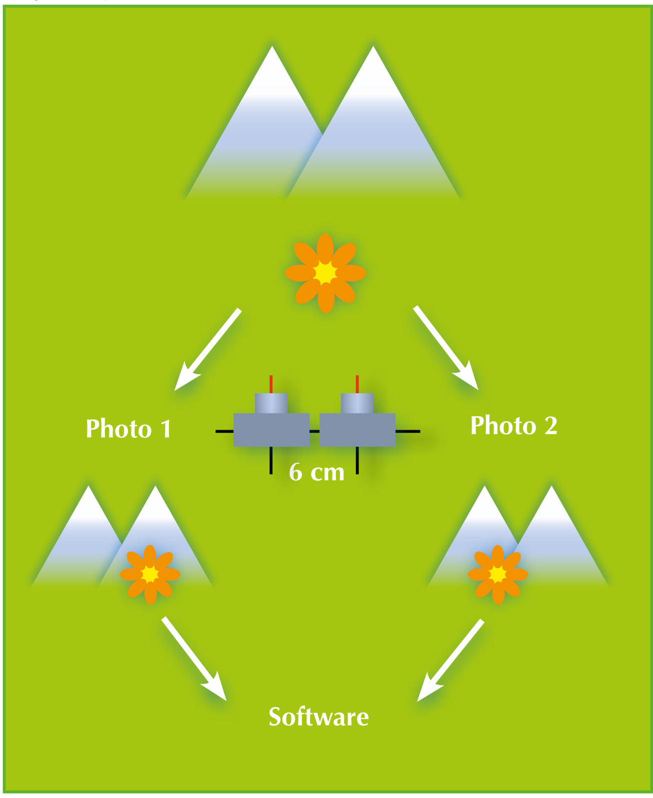


Figure 4: Making an anaglyph: photo 2 should be taken from a position slightly to the right of photo 1. The two images are made into an anaglyph using your chosen piece of software

Acknowledgements

The activities in this article were devised by Alison Alexander, Cerian Angharard, Frances Green and Ruth Wiltsher, who are all physics-teacher network co-ordinators for the UK's Institute of Physics (IOP)[w3]. These and other activities were originally part of a package of activities called 'Lights, cameras, images' that was used for a workshop for the IOP's teacher network.

The worksheets for all of the 'Lights, cameras, images' activities can be downloaded from the Talk Physics website[w2].

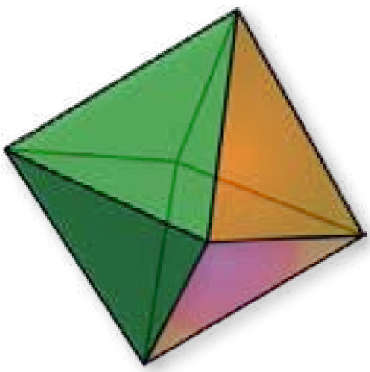


Image courtesy of DTR; images source: Wikimedia Commons

Web references

w1 – Circularly polarising 3D glasses are in fact slightly more complicated than described in this article, as they contain both a linearly and a circularly polarising filter. Read a more detailed explanation of how the glasses work: www.3dtvtechnology.org.uk/polarization

w2 – The Anaglyph workshop software for Windows or Mac is freely available to download. See: www.tabberer.com/sandyknoll/more/3dmaker/anaglyph-software.html, or use the shorter link: http://tinyurl.com/anaglyphmaker

w3 – The UK's Institute of Physics (IOP) teacher network provides support for physics teachers across Great Britain and Ireland. See: www.iop.org or use the direct link: http://tinyurl.com/iopnetwork

The IOP website has an extensive collection of resources for physics teachers. See: www.iop.org/education

The complete set of worksheets for the 'Lights, cameras, images' activities are available on the Talk Physics website (www.talkphysics.org), a resource from the IOP for teachers of physics and their supporters. Search for 'lights' or use the tinyurl: http://tinyurl.com/lcmworksheet. You need to register to use the website, but registration is free.

Resources

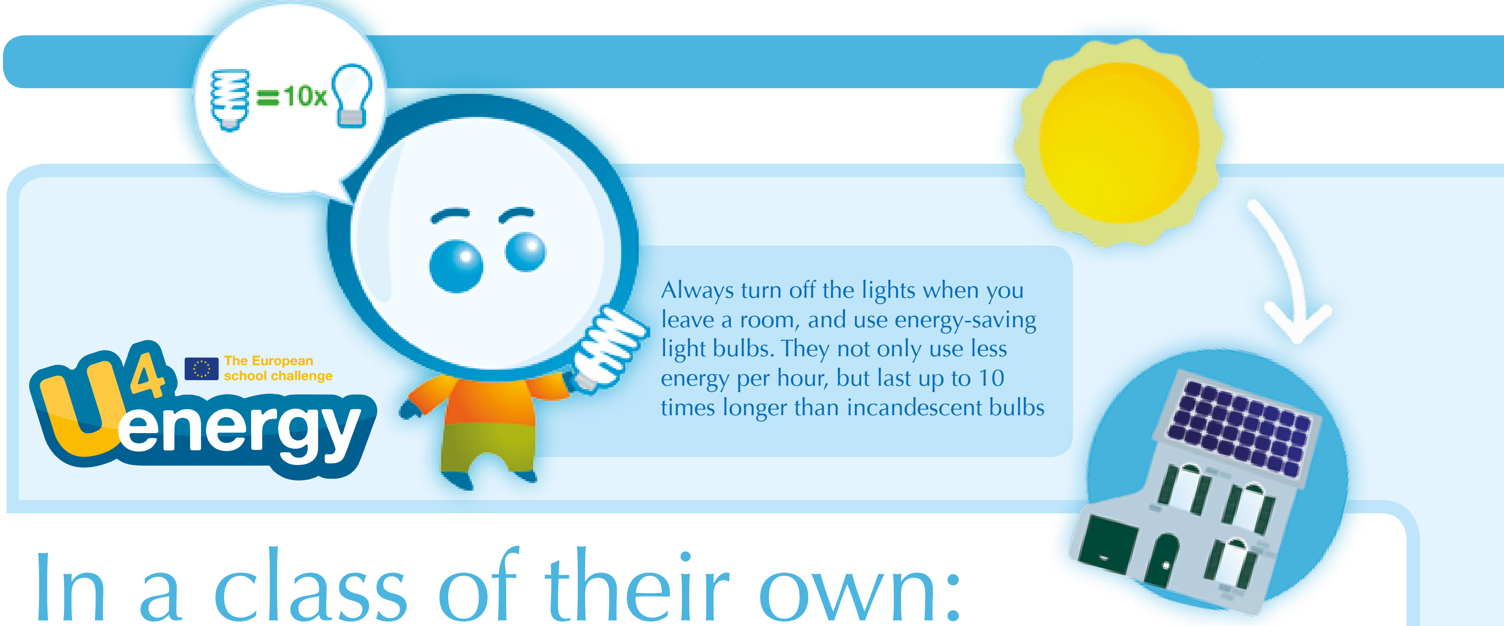
The highly praised animation 'Imagining the Tenth Dimension' includes an explanation of how to imagine the higher dimensions. See: http://tenthdimension.com/medialinks.php

If you enjoyed reading this article, you can browse the full collection of *Science in School* teaching activities. See: www.scienceinschool.org/teaching

Andrew Brown is a molecular and cellular biology graduate of the University of Bath, UK. He currently works for *Science in School*, based at the European Molecular Biology Laboratory in Heidelberg, Germany.

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

Image courtesy of Manuel Martín; image source: Wikimedia Commons



Images courtesy of the European Commission

In a class of their own: lessons in energy and education from European schools

"If we don't protect our environment, we won't have one," says Carolina, 13, from Portugal.

How far would you be willing to go to raise awareness amongst staff and students at your school of the need for sustainable energy?

You could get creative with the curricula. As a topic, energy efficiency lends itself to a host of disciplines, from easier fits like science, technology, engineering and mathematics (STEM subjects) right through to the humanities and arts: there are many approaches that teachers can be encouraged to take. Biology lessons could look at the effects of pollution on the environment. Religious education might tackle the ethics of sustainability. You could engage with children's creativity by producing journals, reports or works of art about sustainability.

But would you be willing to lobby your local mayor for support? Or take to the streets where you live with drums and banners or sandwich boards? Or travel to another continent to showcase sustainable-energy business models that you and your students have created together?

The challenge to get creative about sustainability was issued this year by the U4energy competition[w1], an initiative funded through the Intelligent Energy Europe programme of the European Union. A pan-European hunt was launched to recognise and reward exceptional efforts to promote energy efficiency in schools. The calibre of the entries certainly did not disappoint.

Among the exceptional projects identified by the campaign, there are several that deserve particular attention due to their originality and success.

As diverse and inventive as the children and teachers themselves, the winning projects share some key features and values. A common approach was to give the children a certain degree of freedom and responsibility, which encouraged fuller involvement and enthusiasm, as well as securing real learning outcomes. Also, in all the projects, engagement with local communities – from parents and families to friends, local businesses, and in some cases, the local authorities – has extended reach and impact.

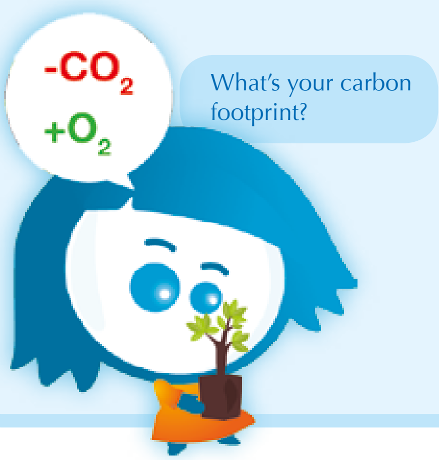


Image courtesy of the European Commission

Save energy – main concern

"If you want to pass on a message to the adults, first pass it on to the young ones," says Sister Claudia Zammit, headmistress of St Francis Primary School in Malta.

Winner of the category for 'best energy efficiency measures', the St Francis 'Save energy – main concern' project has engaged youngsters from ages 5 to 11 in conservation with a raft of activities. From rotating teams of 'auditors' and 'detectors' monitoring energy waste, to poetry, song and craft workshops, and even appearances on national radio and TV, pupils there have embraced the concept of saving energy with enormous enthusiasm.

"I was even told by a little girl aged 7 to switch off my unused computer," reports Sister Claudia.

A substantial drop of 20 % in energy consumption at the school was recorded last year, and effects logged by pupils at home attest to the reach of this project: "At home, we now use 2-3 units per day. My family is very happy because it used to be 5-10 units," reported Nigel, aged 10.

Image courtesy of the Grouping of Schools of the City of Castelo Branco, Portugal

Portugal's 'Environmentally friendly school' project spilled onto the streets with 'walking and biking to school' days

Image courtesy of St Francis Primary, Malta

Learning to save energy at St Francis Primary School in Malta

Images courtesy of the European Commission

Environmentally friendly school

Manuela Costa from Portugal also reports that pupils aged 3-15 at the Grouping of Schools of the City of Castelo Branco take the environment so seriously that she has noticed a role reversal, with pupils nagging the teachers about conservation.

Manuela is the driving force behind Portugal's 'Environmentally friendly school' project, an initiative that has so far touched the lives of 1000 students, staff, parents and members of the local community.

The project kicked off in 2010 when solar panels were installed right across the school. Today, water, electricity and waste 'brigades', made up of mixed groups of children from different years, patrol the school and report back to staff on their findings. All the pupils in the school have been involved in the project, and energy consumption across the school's buildings dropped by 15 % as a result.

Enthusiasm like this was hard to contain within the confines of the school itself, which is why activities spilled over into the community with 'walking and biking to school' days, and a range of inventive awareness-building campaigns. One of the most enjoyable elements, for staff and pupils, was the involvement of the school percussion band, who quite literally took to the streets of Castelo Branco with banners and flyers to beat the drum for renewable energy.

Parents have had a key role too, and many have come in to talk about energy consumption in their workplaces. And such is the zeal of these pupils that mums and dads have reported being lobbied at home by children as young as three.

For Manuela, dedication like this begins in the classroom: "The key is to teach children from a very young age about renewable energy and the need to use it rationally."

European Schoolnet

European Schoolnet[w2] is a network of 30 ministries of education in Europe and beyond. U4energy is the first pan-European competition on energy education organised by the European Commission and powered by European Schoolnet.

European Schoolnet

Energy work bike

Almerindo Capuani of the Alessandrini Marino Institute in Teramo, Italy, took a novel approach to mobilising students (aged 17-18) to think about sustainability, energy sources and development.

The 'Energy work bike' project is an undertaking so inventive, so dynamic and so multifaceted that it defies simple definition. Part electrical engineering, part technology, part design and part philanthropy, this extraordinary scheme has seen students produce four prototypes of energy-producing bikes that can charge a mobile phone, sharpen work tools, power a laptop, or harness the Sun's rays and convert them to electricity.

Two patents and a fully fledged business plan later, the whizz-kids from Teramo have travelled to the Butembo Mission in the Democratic Republic of Congo, where they met with monks and youngsters eager to find out how to replicate the bikes for energy and potentially for employment.

For Almerindo, the benefits and rewards of this project address a wide range of pedagogical, environmental and societal objectives: goals that for him and his colleagues were quite clear, if ambitious, from the start. "We wanted to address a range of diverse and complex elements when we began working on this. Inside the classroom we focused on integrating different subjects and disciplines from automatic electric systems to engineering," he says.

"At the same time, we wanted to encourage students to address real-life issues that affect us as citizens: urban pollution, sustainability and world poverty. The students were also keen to play their part in making a difference: the energy produced is limited, and does not solve any problems in Italy, but in Butembo and in developing countries it can become part of a solution to many needs."

Top ten ways to reduce energy consumption

1. Switch off electronic devices when you are not using them.
2. Turn down the thermostat by one degree and save 300 kg of CO_2 each year.
3. Switch off lights when not in use.
4. Insulate walls, roof and floors well.
5. Use reflective panels behind heaters to reflect the warmth into the living spaces.
6. When cooking, cover pots and pans with lids.
7. Turn the tap off while soaping hands or brushing teeth.
8. Invest in energy-efficient light bulbs.
9. Position your radiators with care.
10. Take short showers.

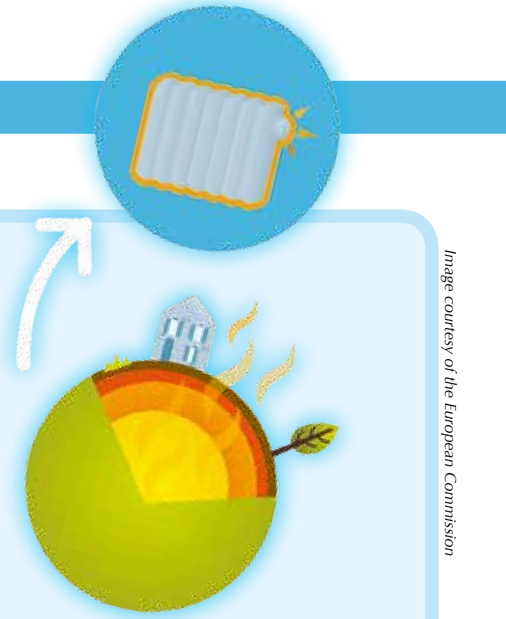


Image courtesy of the European Commission

Image courtesy of the Institute of Higher Education Alessandrini-Marino of Teramo, Italy

Monks from Butembo learning from the 'Energy work bike' team how the equipment works

Web references

w1 – More information on the projects as well as ideas and inspiration for teachers are available on the U4energy website: www.u4energy.eu

w2 – More information on educational projects for teachers across Europe is available on the European Schoolnet website. www.europeanschoolnet.org

Resources

In June 2012, Euronews reported on the successes of U4energy in Malta: www.euronews.com/2012/06/21/green-is-the-colour

U4energy is an initiative funded through the Intelligent Energy Europe Programme of the European Union

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

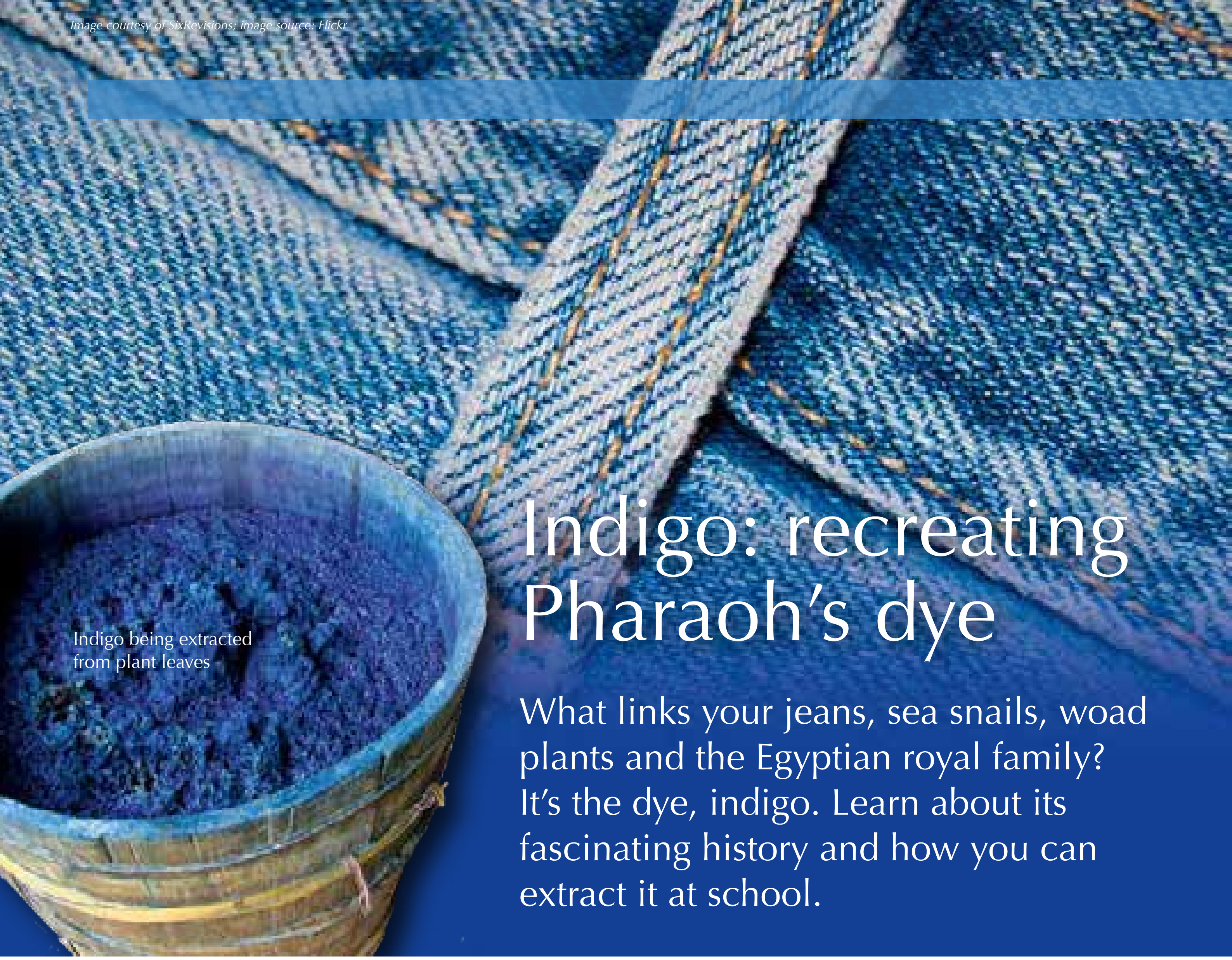


Image courtesy of SixRevisions; image source: Flickr

Indigo: recreating Pharaoh's dye

What links your jeans, sea snails, woad plants and the Egyptian royal family? It's the dye, indigo. Learn about its fascinating history and how you can extract it at school.

Indigo being extracted from plant leaves

Image courtesy of gitane; image source: Wikimedia Commons

By Gianluca Farusi

In ancient Egypt, only one boat had a purple-dyed sail. It belonged to the Pharaoh and was a vibrant and powerful sign to other Nile users that they should move aside to let the royal boat pass.

Even today, deep blue, purple and crimson are traditionally associated with royalty, luxury and wealth. This is because they are difficult and expensive colours to achieve using natural dyes. Until the advent of synthetic dyes 100 years ago, natural dyes (from plant, animal or mineral sources) were the only way to colour fabrics.

The vivid purple of the Pharaoh's sail was achieved using indigo – a natural dye that can be extracted from certain plants and animals. Thanks to Roman naturalist Pliny the Elder (see box on page 46), we even know the dyeing methods used by ancient civilisations. This activity allows your students to follow in the footsteps of these early chemists, extracting indigo from the leaves of the woad plant.

Using basic lab equipment, secondary students of all ages could carry out this extraction in one or two practical sessions. Younger students (ages 11-15) could simply do the extraction without going into much detail about the chemical reaction [although note that the reviewer suggested the activity was suitable for students aged 14+]. More advanced organic chemistry students (ages 16+) could investigate the compounds and reactions more thoroughly. The experiment is also relevant to the use of science in industry and could be used as part of a project on this topic.

All about indigo

Indigo is an organic compound that is found in three differently coloured forms – indigo itself, which is blue; purple mono-bromoindigo; and red-purple di-bromoindigo (figure 1). Naturally derived dyes can contain just one of these pigments or a mixture of two or three in variable proportions, leading to a range of colours from red to blue (Cooksey, 2001). The intensity of the colour is also influenced by the way it is processed, such as whether the dyed cloth is dried in the light or shade.

In ancient Egyptian times, the best quality indigo was extracted from *Murex* sea snails, which were once common in the coastal waters of the eastern Mediterranean. Archaeological evidence from Crete suggests that indigo extraction from *Murex* snails

Image courtesy of dudchik / iStockphoto

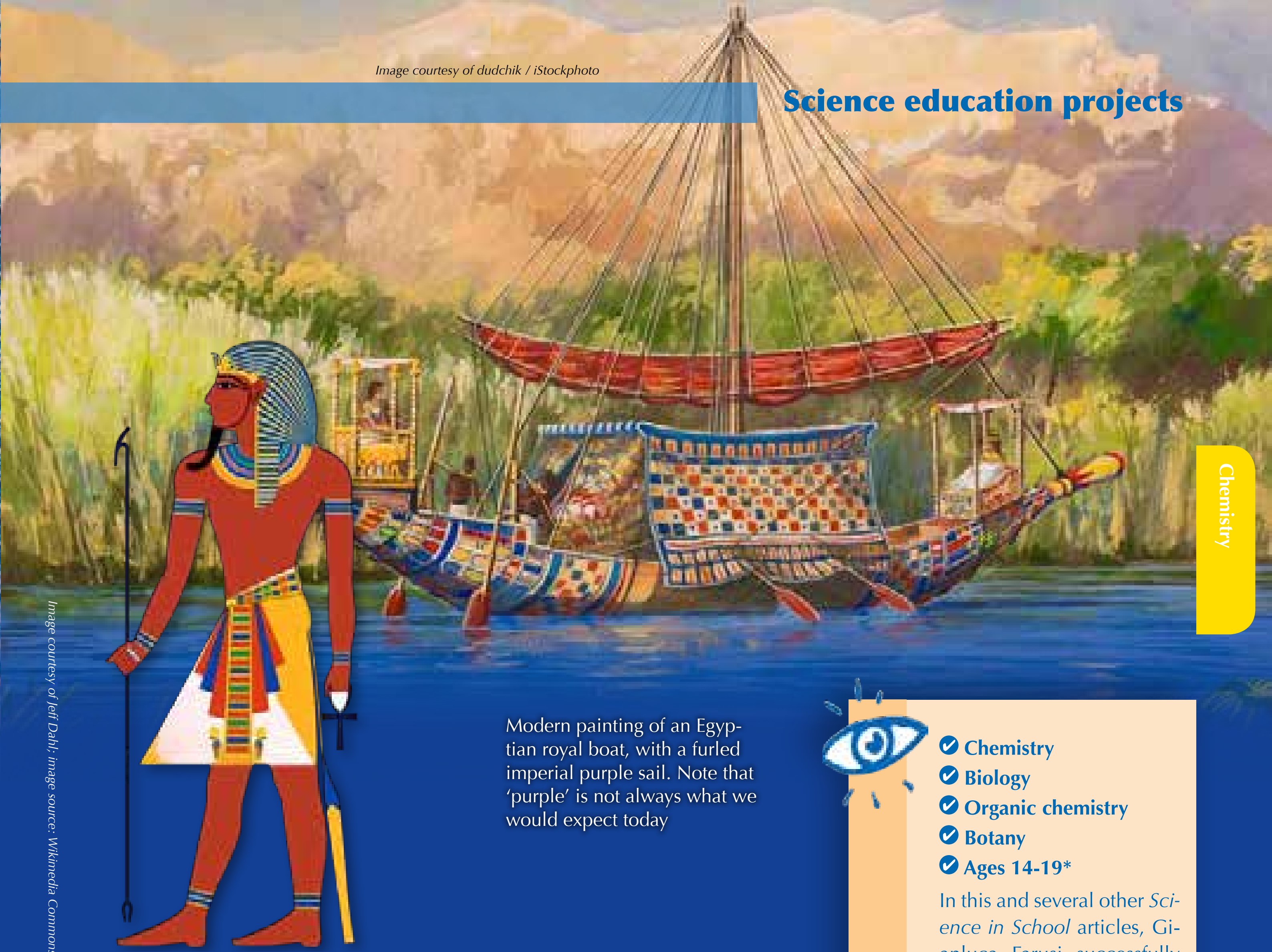


Image courtesy of Jeff Dahl; image source: Wikimedia Commons

Modern painting of an Egyptian royal boat, with a furled imperial purple sail. Note that 'purple' is not always what we would expect today

had begun by 2000 BC. By 1000 BC the Phoenicians, a civilisation centred in what is now Lebanon, were exploiting this valuable dye. Their entire economy was based on trading Tyrian purple, a violet-purple indigo dye derived from the snail *Murex brandaris* (now known as *Bolinus brandaris*). They were so famed for it that the name Phoenician is derived from the Greek word 'phoinísso', meaning 'to make red'.

Murex-derived indigo was so expensive because 12 000 snails yield just 1.4 g Tyrian purple – enough to dye a handkerchief! The compounds used to make the dyestuff are secreted by the snail's hypobranchial gland, found between the bowels and the branchial organ. The snails appear to produce these indigo precursors as a defence response and for their antimicrobial

Images courtesy of Gianluca Farusi

Figure 1: Structures of indigo (top), mono-bromoindigo (middle) and di-bromoindigo (bottom)

REVIEW

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

In this and several other *Science in School* articles, Gianluca Farusi successfully blends ancient history and chemistry in an unusual mixture – in this case, an innovative and simple practical activity to isolate the dye indigo from the leaves of the woad plant (*Isatis tinctoria*). In my experience, practical activities involving intense colours are an effective way to attract the students' attention.

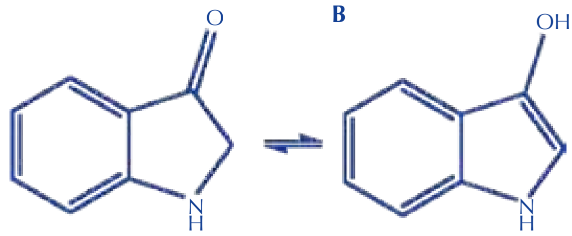
The additional activities and supplemental questions suggested in the article should help the students gain yet more practical skills and also stimulate intriguing questions, as well as offering sound answers.

Vladimir Petruševski, Republic of Macedonia

*Note that the author recommended the activity for 11- to 19-year-olds

Shell of the snail *Murex brandaris*, the secretions of which were first used to make indigo in 2000 BC

Image courtesy of H Zell; image source: Wikimedia Commons



Indoxyl (A) and indolin-3-one (B) are tautomers – isomers that exist together in equilibrium

properties. The fresh secretions are colourless, but darken when exposed to air. According to Pliny the Elder, the dye was extracted by crushing the snails, leaving them to putrefy for three days in alkaline salt water, and then boiling them for up to ten days – imagine the smell!

The Phoenicians perfected this process over hundreds of years and discovered that by varying the species of snail, extraction methods and processing, they could produce a range of colours from red to purple to blue (table 1).

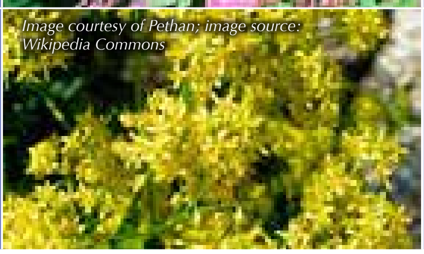
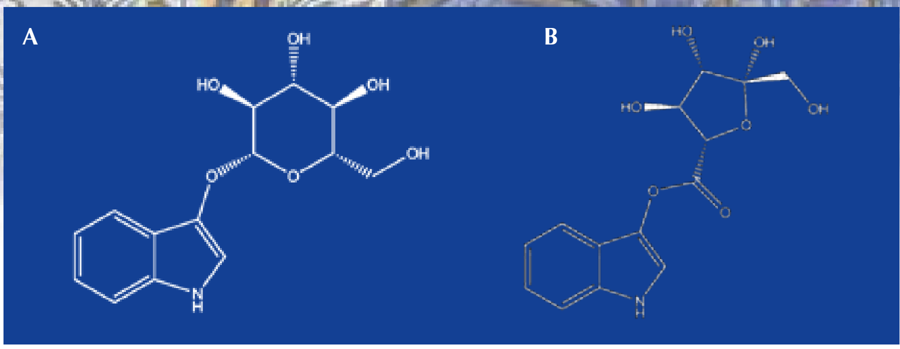
Species	Appearance	Dye precursors found in the organism	Dye name	Colour	Chemical composition of dye
Bolinus brandaris (formerly *Murex brandaris*)	 *Image courtesy of H Zell; image source: Wikimedia Commons*	6-bromoindoxyl	Tyrian purple / imperial purple / argaman	Red-purple	Mainly di-bromoindigo
Hexaplex trunculus (formerly *Murex trunculus*)	 *Image courtesy of Dezidor; image source: Wikimedia Commons*	Indoxyl and 6-bromoindoxyl	Royal blue / tekhelet	Blue-purple	Mixture of indigo, mono- and di-bromoindigo
Indigofera tinctoria (true indigo)	 *Image courtesy of Kurt Stüber; image source: Wikipedia Commons*	Indican	Indigo	Blue	Indigo
Isatis tinctoria (woad)	 *Image courtesy of Pethan; image source: Wikipedia Commons*	Isatan B	Indigo	Blue	Indigo

Table 1: Natural sources of indigo

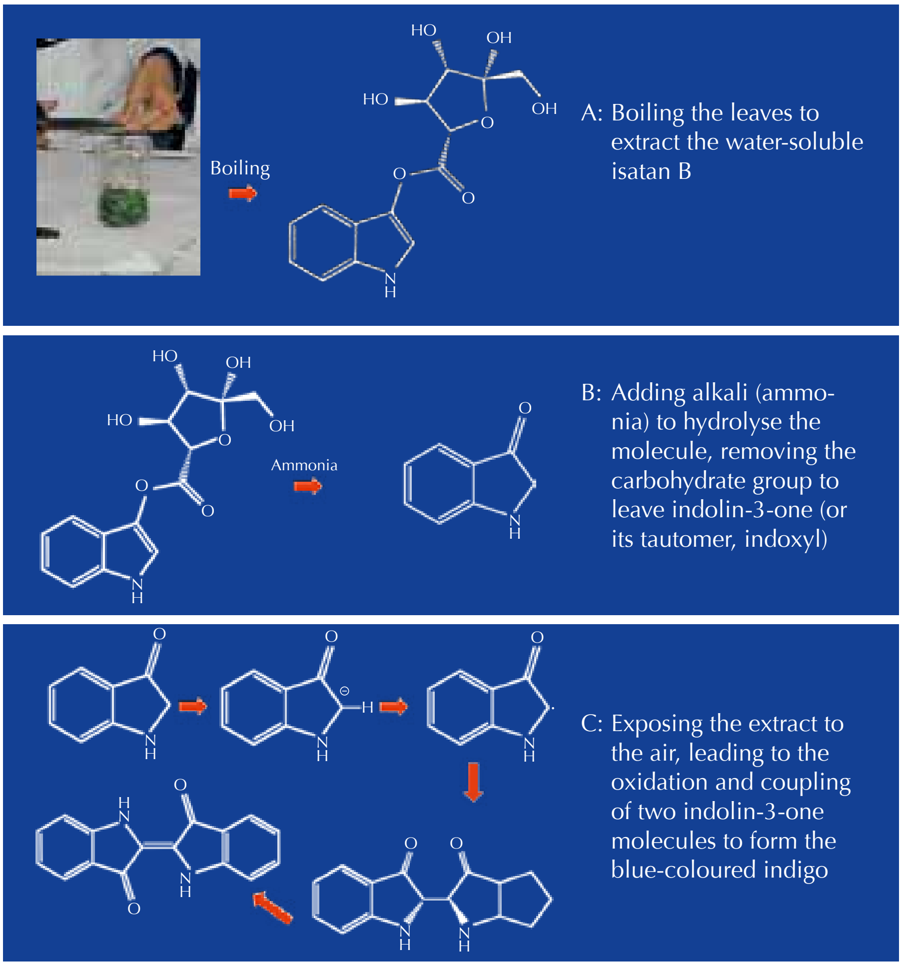
Image courtesy of PKM; image source: Wikimedia Commons

Indigo-dyed linen from 1873



Images courtesy of Gianluca Farusi

Figure 2: Indigo precursors found in plants: indican (indoxyl-β-D-glucoside, found in true indigo; A) and isatan B (indoxyl 3-ketogluconate, from woad; B)



Images courtesy of Gianluca Farusi

Figure 3: Chemical conversion of isatan B to indigo

Lower-quality indigo can also be extracted from certain plants, and this technique actually pre-dates the Phoenicians' snail-derived dye. In India, methods of extracting indigo from the 'true indigo' shrub *Indigofera tinctoria* were known before 2000 BC. In Europe, the dye was extracted from woad *(Isatis tinctoria)*. Although these two plants contain different precursors, indican in true indigo and isatan B in woad (table 1 and figure 2), they both ultimately yield the same dye – indigo.

The production of indigo from woad takes place in three main stages:

1. Boiling the leaves to extract the water-soluble isatan B (figure 3A; steps 1-6 in the activity below).
2. Adding alkali (ammonia) to hydrolyse the molecule, removing the carbohydrate group to leave indolin-3-one or its tautomer, indoxyl (figure 3B; step 7 in the activity below).
3. Exposing the extract to the air, leading to the oxidation and coupling of two indolin-3-one molecules to form the blue-coloured indigo (figure 3C; dyeing the wool and obtaining indigo powder in the activity below).

Student activity: extracting indigo from woad leaves

Materials

For each group of students:

- Fresh woad (*Isatis tinctoria*) leaves (enough to fill a 1 l beaker)
  Wood seeds are easily obtainable from garden centres, and in some countries woad is a very common plant.
- 20 wt% ammonia solution
- Three 1 l beakers
- Distilled water
- Octanoic acid (optional)
- Bunsen burner and tripod
- Stirring rod
- Sieve or strainer
- Measuring cylinders and / or 10 ml pipettes
- Heatproof gloves
- Funnel and filter paper
- Knife for cutting the leaves (optional)
- Wool for dying (optional)

I used a ball of white knitting wool, and some rough grey-white sheep's fleece.

Procedure

1. Fill a beaker with woad leaves. Remove the leaves from the beaker and cut or tear into small pieces.
2. Fill the beaker two-thirds full with distilled water and bring to the boil over a Bunsen burner.
3. Add a few torn leaves to the boiling water, stir and continue heating. When the water has returned to the boil, add a few more leaves. Continue adding leaves and heating until all the woad has been added.
4. When all the leaves have been added, continue boiling for 1 minute.
5. Strain all the liquid from the boiled leaves into a clean beaker.
6. Cool the extract to room temperature by floating the beaker in a shallow tray full of cold water, stirring both the extract in the beaker and the water in the tray. You now have a solution containing, among lots of other things, isatan B, which is an unstable glycoside of indoxyl.
7. When cool, measure the volume of your extract and add ammonia equivalent to 1 % of that volume, e.g. for 1 l extract, add 10 ml ammonia; for 100 ml extract, add 1 ml ammonia. The solution should immediately change from brown to brown-yellow then green. You now have a solution containing, among lots of other things, indoxyl.

Image courtesy of naturaldyer; image source: Flickr

Powdered indigo against a background of woad from which it was extracted

To dye wool

1. Wet the wool and place in the extract for 10 minutes. Remove and leave to air dry.

To obtain indigo powder

1. Aerate the extract by pouring the solution from one beaker to another for 10 minutes.
2. Optional: if too much foam develops during aeration, add some octanoic acid, drop by drop. This acts as a surfactant.
3. Filter the extract through ordinary filter paper to obtain the indigo powder.

To use the indigo powder as a dye, it needs to be dissolved in water and mixed with a reducing agent, such as sodium hydrosulphite ($Na_2S_2O_4$). When the dyed material (e.g. wool) is exposed to air, it will turn blue.

Safety notes:

Remember that indigo and many of its precursors are dyes, so take care not to spill them on clothes or skin. When handling concentrated ammonia solution, as well as indigo and its precursors, wear gloves and chemical splash glasses, and use a fume hood.

Questions for discussion

- Why do we boil the leaves? What is happening?
- What happens when the ammonia is added?
- When you dye the wool, why does the blue colour appear as the wool dries?
- When you produce the powder, what is happening when the solution is poured from beaker to beaker? Why does the indigo precipitate?
- Can you find out how indigo is produced industrially today? What are its major uses?

Image courtesy of Marcel Douwe Dekker; image source: Flickr

Chemistry

Made in the 11th century, the Bayeux Tapestry celebrates the Norman conquest of England; a turning point in English history. Shown here is the Battle of Hastings at which William, Duke of Normandy, defeated Harold, Earl of Wessex, on 14 October 1066. Three plant-based dyes were used alone or in combination to produce the ten colours found in the 70 m embroidery: woad (blues and greens), madder (*Rubia tinctorum*; reds) and weld (*Reseda luteola*; yellows and dark green). To achieve the desired colour intensity, the wool was successively soaked and air-dried.

BACKGROUND

Extension activities

You could also ask your students to further investigate the chemistry of indigo and other dyes with some of the following activities.

Calculating the yield of indigo

Weigh the leaves before the extraction and the dried indigo powder. Calculate the percentage yield of indigo as follows: (mass of indigo / mass of leaves) x 100. You could compare the yield from fresh and dried leaves, or compare it with that of other indigo sources such as *Indigofera tinctoria*.

Using indigo as a dye

Our experiment involves using indigo to dye wool. Can indigo be used to dye other materials? You could compare natural materials such as cotton, linen and silk with synthetics or synthetic mixes (e.g. polyester cotton, cotton lycra).

The effectiveness of indigo production

a) Which produces more indigo, larger, older leaves or younger, smaller leaves? Express the amount of indigo obtained by weight and per leaf (count leaves before extracting them). Which produces the most indigo?

b) Grow plants with and without added nitrogen fertiliser. Aim for 2-4 g nitrogen per m^2 of soil (you will need to calculate the amount of fertiliser that gives this amount of nitrogen). Does adding nitrogen fertiliser increase the amount of indigo produced?

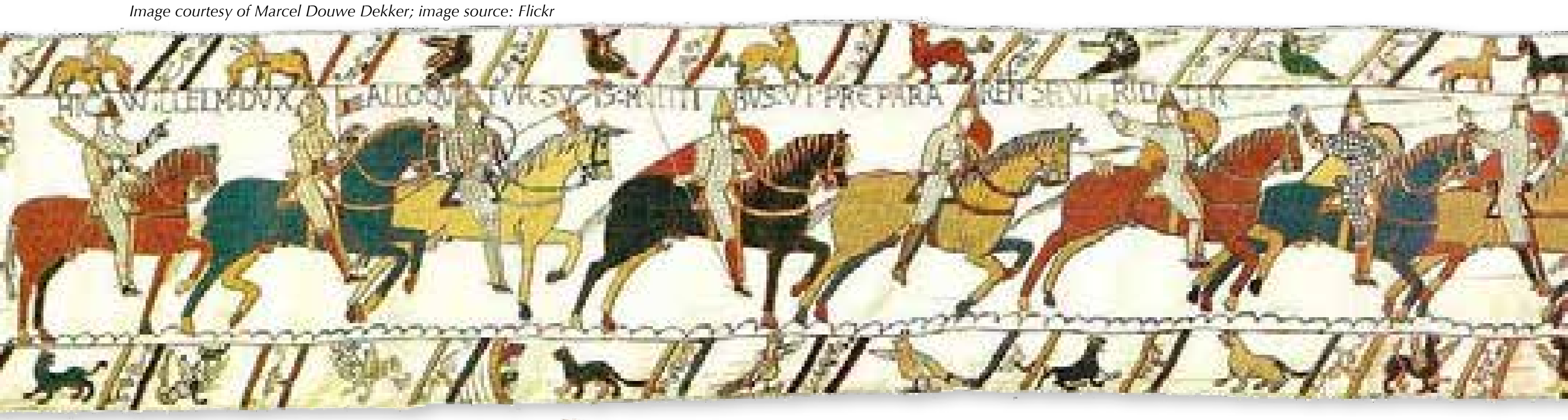
c) Try putting the plants in the dark for a few days (cover them with black plastic). Does this have an effect on the amount of indigo produced? What can you conclude about the metabolism of isatan B in the plant?

d) Investigate the effect of other treatments to the plants or the cut leaves.

e) Test the effect of varying the method of the extraction, for example using different kinds of alkali.

Investigating other dyes

My students produced dyes from onion skins, from madder (Farusi, 2006), and from myrtle berries. In addition, they tested how colour-fast their dyes were by washing the dyed materials using different methods.



The Battle of Hastings begins: under the leadership of William, Duke of Normandy, the Norman forces charge the English forces, led by Harold, Earl of Wessex.

BACKGROUND

Studying chemistry with Pliny the Elder

A 12th century manuscript of *Naturalis Historia*

This activity is part of a larger interdisciplinary project, developed together with 14- to 15-year-old students, to explore ancient scientific techniques. Pliny the Elder (23-79 AD) was a Roman author and naturalist. His encyclopaedia, *Naturalis Historia*, brings together much of the scientific knowledge of the time. We began each topic by discussing a passage from *Naturalis Historia* and then worked out how to recreate either the experiment described in the text or something similar. In this way, the students began in the same pre-scientific state as Pliny and, through laboratory work and discussion, gained modern scientific knowledge on each of the topics. The process motivated even the most unenthusiastic students.

Other activities in the project include recreating ancient perfumes (Farusi, 2011), preparing glass tesserae with boric acid, simulating the luminescence of the shellfish *Pholas dactylus*, and preparing iron-gall ink (Farusi, 2007).

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Farusi G (2011) Smell like Julius Caesar: recreating ancient perfumes in the laboratory. *Science in School* **21**: 40-46. www.scienceinschool.org/2011/issue21/caesar

Resources

Seefelder M (1994) *Indigo in culture, science and technology*. Landsberg, Germany: Ecomed Verlagsgesellschaft. ISBN 978-3609651606

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

Acknowledgement

The author would like to thank Dr David Hill from the University of Bristol, UK, for his tips on extraction of indigo from woad.

Gianluca Farusi teaches chemistry at the technical school (Istituto Tecnico Industriale) Galileo Galilei in Avenza-Carrara, Italy, and since 2004, he has lectured in stoichiometry at the University of Pisa, Italy, for the degree programme in medicinal chemistry and technology. He is also the regional tutor for the Italian ministerial project 'Insegnare Scienze Sperimentali' ('teaching experimental sciences'). For secondary schools, Gianluca is also the regional REACH (registration, evaluation, authorisation and restriction of chemicals) tutor. He has been teaching for 16 years and nothing gratifies him more than the delight on his students' faces when they grasp a difficult chemical concept.

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

Image courtesy of Digimist; image source: Flickr

Chemistry

Analysing wine at school

European countries produce more than half of the world's wine – and drink a lot of it too! These hands-on activities for schools reveal the science behind the perfect wine.

By Thomas Wendt

The age at which it is legal to drink alcohol varies from country to country, but most teachers would agree that drinking wine during chemistry lessons is inappropriate (and potentially dangerous!). However, producing and analysing wine at school can be fun and educational. These activities, developed at the science centre Experimenta[w1], invite students aged 15-18 to become vintners for a day, using analytical techniques to explore the changes that take place during the wine-making process.

Wine is produced by fermenting grape juice (which has particularly high levels of sugar) using specialised yeast cells. The sugar is converted into ethanol and carbon dioxide under anaerobic conditions:

$$C_6H_{12}O_6 + 2\,ADP + 2\,P_i = 2\,C_2H_5OH + 2\,CO_2 + 2\,ATP$$

The three main factors that determine the quality of the final product are sweetness, alcohol content and acid content. Using standard methods of a commercial wine laboratory, these three activities for the school laboratory explore how the quality of the starting grape juice and the must (fermenting grape juice) affect the final product. Each activity takes approximately 20-30 minutes.

1. In activity 1, students can determine the sugar content of grape juice using refractometry. Activity 1a (see below) offers an alternative, based on density measurement.
2. The exact determination of the alcohol content in commercial wines is performed by distilling the ethanol, then measuring the viscosity of the distillate using sophisticated apparatus. In activity 2, students can use the equipment used by hobby winemakers – a vinometer – to measure the alcohol content of the must and wine.
3. A well balanced wine needs a certain amount of fruit acid; the total acid content is a very important measure, because it directly affects the flavour. In activity 3, the acid content is determined by pH titration.

Four further activities[w2] can be downloaded from the *Science in School* website:

- Activity 1a: in an alternative to activity 1, students determine the sugar content of grape juice using density measurement instead of refractometry.
- Measuring levels of carbon dioxide, one of the products of the fermentation, is a useful way to monitor the progress of the reaction. In activity

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Image courtesy of RobW_; image source: Flickr

Grapes fermenting to make wine

Image courtesy of tomek.pl; image source: Flickr

Barrels of wine being stored in a cellar to mature

Image courtesy of JB London; image source: Flickr

4, students quantify CO_2 levels over the course of the reaction by literally shaking the gas out of solution.

- In activity 5, students use light transmittance to investigate the difference that fining (the addition of substances that clarify the wine by precipitation) makes to the cloudiness of the finished product.
- In activity 6, students examine fermenting yeast under the microscope.

To supply the must used in these experiments, you will need to set up a simple grape juice fermentation at least one day in advance, using red grape juice (e.g. from the supermarket). You will also need some basic chemistry laboratory equipment, plus a vinometer for measuring alcohol content, a pycnometer (also known as a specific gravity bottle) and a refractometer. A description of how to set up the fermentation can be found on the *Science in School* website[w2].

Image courtesy of Rennett Stowe; image source: Flickr

Determining sugar content

The sweetness of the wine is determined by the amount of sugar remaining after fermentation, together with the total acidity of the wine. A dry wine has up to 9 g/l sugar and an acidity level that is at least 2 g/l lower than the sugar content. A medium-dry wine has a sugar content of 9-18 g/l and an acidity level that should be no more than 10 g/l lower than the sugar content. A sweet wine has 18-45 g/l of sugar. To ensure the correct balance of sugar, acidity and alcohol in the final wine, it is important to determine the starting sugar concentration; if necessary, limited amounts of sugar can be added before fermentation.

The increased density of the must (compared to water) is mainly due to fermentable sugar. Density measurements or refractometry can be used to measure the sugar content, which in Germany is expressed as the must weight and measured in Oechsle (°Oe). In the English-speaking world, the sugar content is expressed in Brix (°Bx), which represents the concentration of dissolved sugar, in weight percent (wt%).

The must weight is calculated by:

must weight = (density – 1) X 1000

Where must weight is measured in °Oe and density in g/l.

As a rough estimate, 1°Oe corresponds to 2.37 g/l sugar (i.e. about 0.237 °Bx). Therefore, the sugar concentration can be estimated as:

sugar concentration = must weight X 2.37

Where sugar concentration is measured in g/l.

The fermentation of all fermentable sugar in a solution of 100 °Oe (sugar concentration 237 g/l or 23.7 °Bx) yields approximately 100 g/l ethanol (or 10 wt% alcohol). Because ethanol has a density of 0.79 g/ml, this converts to 12.67 vol% ethanol. Thus:

alcohol concentration (in % volume) = alcohol concentration (in g/l) X 0.1267

Image courtesy of Rennett Stowe; image source: Flickr

Student activity 1: determining sugar content using a refractometer

The amount of sugar in the grape juice will determine both the alcohol content and the sweetness of the finished wine. In this activity, you will use the refractive index to estimate sugar content.

Refraction is the change in direction of light when it passes from one medium to another (e.g. from air into water). The light-scattering behaviour of a solution changes as the concentration of solutes (dissolved substances) increases. A refractometer uses this principle to determine the concentration of dissolved particles in a solution. In wine, these are principally sucrose.

Most handheld refractometers give the concentration of the dissolved substance either in Brix (°Bx), a scale defined in terms of sucrose content, or in Oechsle (°Oe). A solution of 20 wt% sucrose in water is 20 °Bx. Oechsle can be converted approximately into Brix by multiplying by 0.237.

Image courtesy of Experimenta

Figure 1: Refractometer and scale

Materials

- Refractometer
- 20 wt% sucrose solution
- Grape juice
- Paper towels
- Pipette

Procedure

1. Pipette 2 drops of the sucrose solution onto the glass surface of the refractometer and close the lid.
2. Take a reading through the eyepiece and enter the data in table 1.
3. Using a paper towel soaked in distilled water, clean the glass surface, and then dry it.
4. Repeat the measurement with grape juice.
5. Calculate the missing numbers in table 1 using the equations above.

Questions

1. How accurate was your result for the sucrose solution compared to the expected value?
2. How reproducible were your measurements? Compare them to that of other groups.
3. If you carried out activity 1a as well, how comparable were your results for the two methods (density versus refractometry)?
4. A typical wine has about 12 vol% alcohol. Estimate how much sugar needs to be added to the grape juice to obtain 12 vol% alcohol.

	20 wt% sucrose	Grape juice
Must weight (°Oe)		
Sugar concentration (°Bx)		
Possible alcohol yield (vol%)		

Table 1: Calculation of sugar content of samples

Image courtesy of Maksud_kr / iStockphoto

Chemistry

Student activity 2: determining alcohol content

The amount of alcohol obtained by fermentation depends on the sugar content of the grape juice and the alcohol tolerance of the yeast strain: most yeast strains tolerate up to 16 % alcohol. The amount of alcohol can be measured quite accurately using a vinometer, a simple device developed for hobby winemakers. It is based on the principle that the surface tension falls as the alcohol content increases.

In this activity, you will measure the alcohol content of your must.

Materials

- Coffee filter
- Funnel
- Beakers
- Must
- Wine
- Vinometer
- Pipette
- Paper towels
- Distilled water

Procedure

1. Filter 20 ml must through a coffee filter to remove any remaining yeast cells.
2. Place a small amount of filtrate in the funnel of the vinometer (figure 2B) and wait until the capillary is full. Keep the remaining filtrate for activity 3.
3. Carefully invert the vinometer onto a layer of paper towels, then observe the level of liquid while it slowly drops (figure 2C). Once it stays constant, take a reading and enter it in table 2.
4. Rinse the vinometer with distilled water, then repeat the measurement using the wine.

Note: The alcohol content of the must is probably much lower than that of the wine. This may be because the fermentation process is not finished. It can also indicate that remaining sugar has increased the surface tension and is affecting the reading.

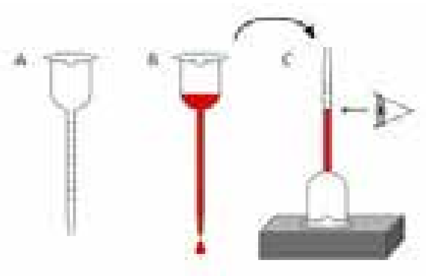


Image courtesy of Experimenta

Figure 2: Using the vinometer

Questions

1. You determined the sugar concentration of the grape juice in activity 1. Based on the available sugar in the grape juice, did you expect a higher alcohol content in the wine?
2. If the fermentation continued for longer, would you expect an increased alcohol content?

	Alcohol content (vol%)
Must (filtered)	
Wine	

Table 2: Alcohol content determined with a vinometer

Total acid content

Fruit juices can contain several different acids, including tartaric, malic, citric and oxalic acid, in differing ratios, depending on the type of fruit. The predominant acid in wine is tartaric acid, which has a pH between 3 and 4. However, due to the complex mixture of different acids and bases, proteins and salts, the total acid content of wine cannot be estimated from the pH value alone. Instead, it is determined by titration to neutrality and expressed as total equivalent amount of tartaric acid in g/l. The acid content of wine is typically 4-8.5 g/l but can be as high as 15 g/l. It must always be considered in conjunction with the amount of remaining sugar (see 'Determining sugar content').

Tartaric acid (molecular weight 150 g) is a diprotic acid (containing two hydrogen atoms per molecule that can dissociate in water as protons) that can be fully neutralised with sodium hydroxide. Because 1 mol NaOH neutralises 0.5 mol tartaric acid (75 g/l), 1 ml 0.1 M NaOH neutralises 7.5 mg tartaric acid.

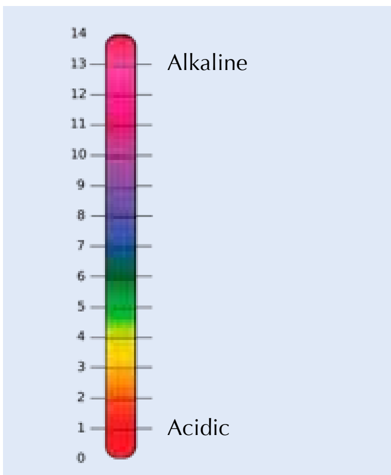


Image courtesy of Edward Stevens; image source: Wikimedia Commons

$$HOOC\text{-}CH(OH)\text{-}CH(OH)\text{-}COOH + 2NaOH \rightarrow Na^+\text{-}OOC\text{-}CH(OH)\text{-}CH(OH)\text{-}COO^- Na^+ + 2H_2O$$

Student activity 3: Determination of acidity by titration

All wines contain a certain amount of acid. The winemaker is interested in the total acidity, caused mainly by tartaric acid. The total acidity is determined by titration with diluted sodium hydroxide.

Materials

- pH meter
- Magnetic stirrer
- Beaker (250 ml)
- Two measuring cylinders (10 ml, 100 ml)
- Burette
- NaOH solution (0.1 M)
- Distilled water
- 10 ml must (filtered, from activity 2)
- 10 ml wine

Image courtesy of Experimenta

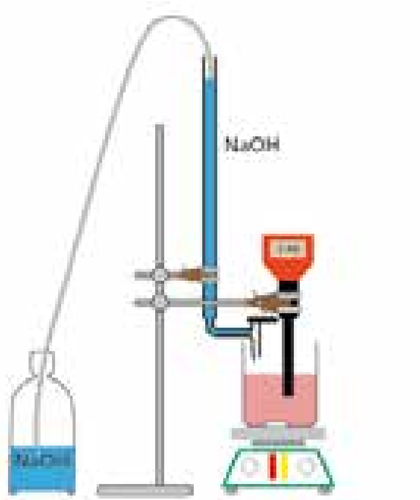


Figure 3: Set-up of the titration experiment

Procedure

For each sample (must or wine):

1. Fill the burette with NaOH solution. Enter the starting volume in table 3.
2. Measure 10 ml of your sample and place it in the 250 ml beaker. Add 100 ml distilled water.
3. Start the magnetic stirrer and insert the pH electrode so that the tip is in the sample, but not touching the sides of the beaker or the magnetic stirrer flea.
4. Add NaOH solution dropwise until neutral pH is reached. Take a reading on the burette and enter it in table 3.
   - Did you observe any colour changes?
   - If so, at what pH value?
   - What could be the reason for a colour change?
5. Calculate the amount of NaOH used and the acid concentration.
   Example: We used 14 ml 0.1 M NaOH to neutralise 10 ml solution. The concentration is therefore (14 x 7.5 mg / ml x 100) = 10.5 g / l acid.

	Must	Wine
pH at start		
Starting volume NaOH (ml)		
End volume NaOH (ml)		
Volume NaOH used (ml)		
Concentration of acid (g/l)		

Table 3: Determination of the total acidity

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

Questions

In activities 1-3, you analysed the three major factors that determine the quality of the final product: sweetness, alcohol and acid content. Now it is time to evaluate your product.

1. Is the total acidity within the limits for wine production?
2. Did the starting grape juice contain sufficient sugar to produce the expected alcohol content?
3. How long would you expect fermentation to take before the process is finished?

Image courtesy of L .. C .. U; image source: Flickr

Chemistry

Acknowledgements

The author would like to thank the wine laboratory of Pfäffle GmbH in Heilbronn, Germany, for support during the development of the activities. He would also like to thank in particular Christine Dietrich and Karsten Wiese from the teacher-training college in Heilbronn for their collaboration.

Web references

w1 – Visit the Experimenta website: www.experimenta-heilbronn.de

w2 – The following materials can be downloaded from the Science in School website (www.scienceinschool.org/2012/issue24/wine#resources):

- Instructions for preparing the materials – ideally at least a week in advance
- Activity 1a: to determine the sugar content of grape juice using density measurement
- Activity 4: to quantify CO_2 levels over the course of the reaction
- Activity 5: to use light transmittance to investigate the difference that fining makes to the cloudiness of the finished product
- Activity 6: to examine fermenting yeast under the microscope.

Resources

A basic guideline for common experiments in wine analysis:

Schmitt A (1975) *Aktuelle Weinanalytik, Ein Leitfaden für die Praxis.* Germany: Heller Chemie. ISBN: 978-3-9800498-3-2

For a comprehensive overview of topics that are relevant to the hobby winemaker, see the Fruchtweinkeller website (www.fruchtweinkeller.de; in German) and the Fruchtwein website (http://met-und-fruchtwein.de, also in German)

If you found this activity useful, why not browse the other teaching activities in *Science in School*? See: www.scienceinschool.org/teaching

Image courtesy of def110; image source: Flickr

BACKGROUND

Experimenta

Experimenta[w1] in Heilbronn is the largest informal learning and interactive science centre in southern Germany. In addition to the interactive exhibitions and science garden, Experimenta offers more than 30 laboratory-based programmes for school classes and individual pupils, from kindergarten level up to upper secondary school. These programmes address technology and all life sciences as well as providing teacher training.

Thomas Wendt received his PhD on structural biology from the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, in 1998. During his postdoctoral research in the USA and back in Germany, he then focused on protein biochemical and molecular biology methods. After supervising numerous students, Thomas decided to concentrate on encouraging young people to consider a scientific career. Since 2009, he has been the educational head of the teaching laboratories at Experimenta.

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

Image courtesy of ESA / AOES Medialab

Image courtesy of ESA / XMM-Newton (X-rays); ESA / Herschel / PACS / SPIRE / CD Wilson, McMaster University, Hamilton, Ontario, Canada (far-infrared and sub-millimetre)

Image courtesy of NASA / JPL-Caltech / D Gouliermis (Max-Planck Institute for Astronomy, Heidelberg, Germany) and ESA

More than meets the eye: the exotic, high-energy Universe

In the third article in this series on astronomy and the electromagnetic spectrum, learn about the exotic and powerful cosmic phenomena that astronomers investigate with X-ray and gamma-ray observatories, including the European Space Agency's XMM-Newton and INTEGRAL missions.

By Claudia Mignone and Rebecca Barnes

In the 1960s, the advent of the space age initiated the era of high-energy astronomy. For the first time, astronomers could see the Universe with X-ray and gamma-ray eyes. Electromagnetic (EM) radiation at these wavelengths is emitted by cosmic sources with extreme properties such as exceptionally high temperatures, extraordinarily high densities or remarkably strong magnetic fields. Ground-based observatories, however, had been unable to register these rays, which have wavelengths too short to penetrate Earth's atmosphere (figure 1). It took the first space observatories to unveil this turbulent and ever-changing Universe.

In just half a century, observations made at the highest energies have significantly changed our view of the cosmos. By studying the X-ray and gamma-ray sky, astronomers have discovered several new types of astronomical sources and have enhanced their knowledge of many other types of objects. To examine the Universe in this range of the EM spectrum[w1], the European Space Agency (ESA; see box) operates two missions: the XMM-Newton (X-rays) and INTEGRAL (X-rays and gamma rays) space observatories. The techniques used in X-ray and gamma-ray astronomy and by these two missions were introduced in the second article in this series (Mignone & Barnes, 2011b); this article provides an overview of what these missions have taught us, from the life of stars to the structure of the Universe. For an overview of the EM spectrum and its role in astronomy, see the first article in this series (Mignone & Barnes, 2011a).

Unveiling the birth and death of stars

Stars are born when gravity causes huge clouds of gas and dust to collapse, fragment and form protostars. These protostars later grow into fully fledged stars when nuclear fusion ignites in their cores. How a star then continues to evolve depends on its mass, with massive stars destined to a shorter life and a more spectacular demise than their lower-mass counterparts (figure 2).

It is the early and late stages of

REVIEW

- Physics
- Geography
- Astrophysics
- Optics
- Quantum physics
- Mass and gravity
- Ages 10-19

This article, the third in a series, describes European research activities within the field of high-energy astronomy. The second article in the series described the techniques used by two ESA missions, XMM-Newton (X-rays) and INTEGRAL (X-rays and gamma rays); this article describes some of their results, including insights into the birth and death of stars, as well as the more distant Universe.

For older students (16+), the article is ideal for physics lessons, where it could be used to address astrophysics (the life of stars, cosmic objects, the Big Bang theory), optics or even quantum physics (spectral ranges, relationship between wavelength and energy, EM waves), mass and gravity. It could also be used in geography lessons about the Universe, solar systems and cosmic objects.

To make it accessible to younger students (age of 10-15 years) as well, I would suggest the teacher selects just parts of the article to discuss.

The article could be very useful in English lessons too, or – once it has been translated – in German, French or other language lessons. Because the article is not too technical, even teachers who are not very familiar with physics could use it.

The article could also be used to stimulate discussion, with questions including:

1. Describe the European Space missions XMM-Newton and Integral.
2. Give an overview of the electromagnetic spectrum (including visible, infrared and UV).
3. What is the relationship between wavelength, energy and frequency?
4. Why do we use space observatories in addition to ground-based observatories?
5. Why are gamma rays emitted by hotter sources than X-rays?
6. What are X-ray binaries?
7. What can happen to massive stars at the ends of their lives?

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

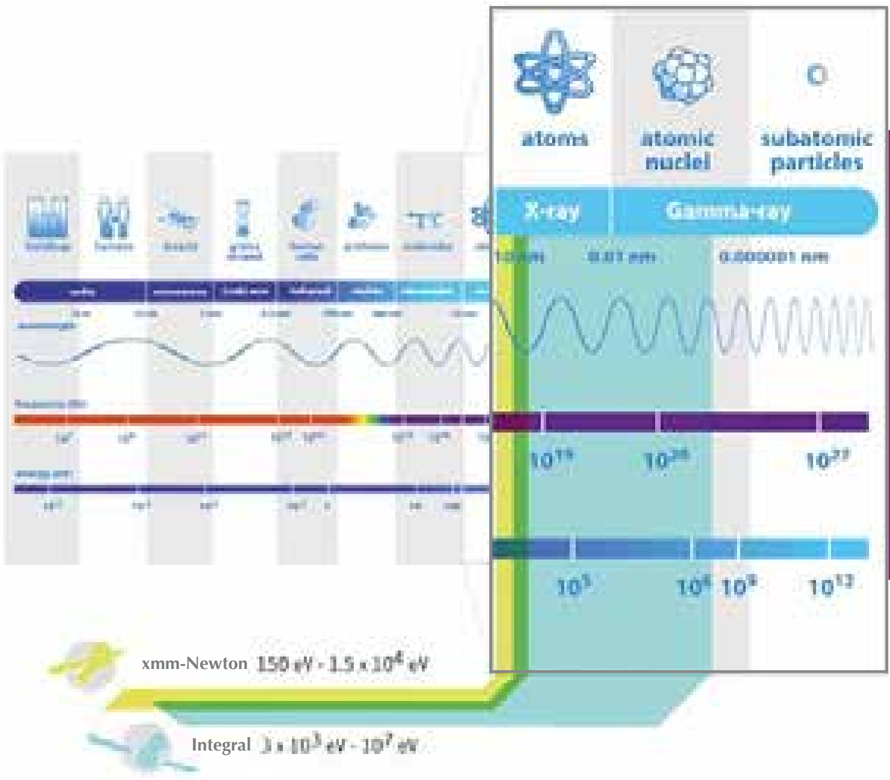
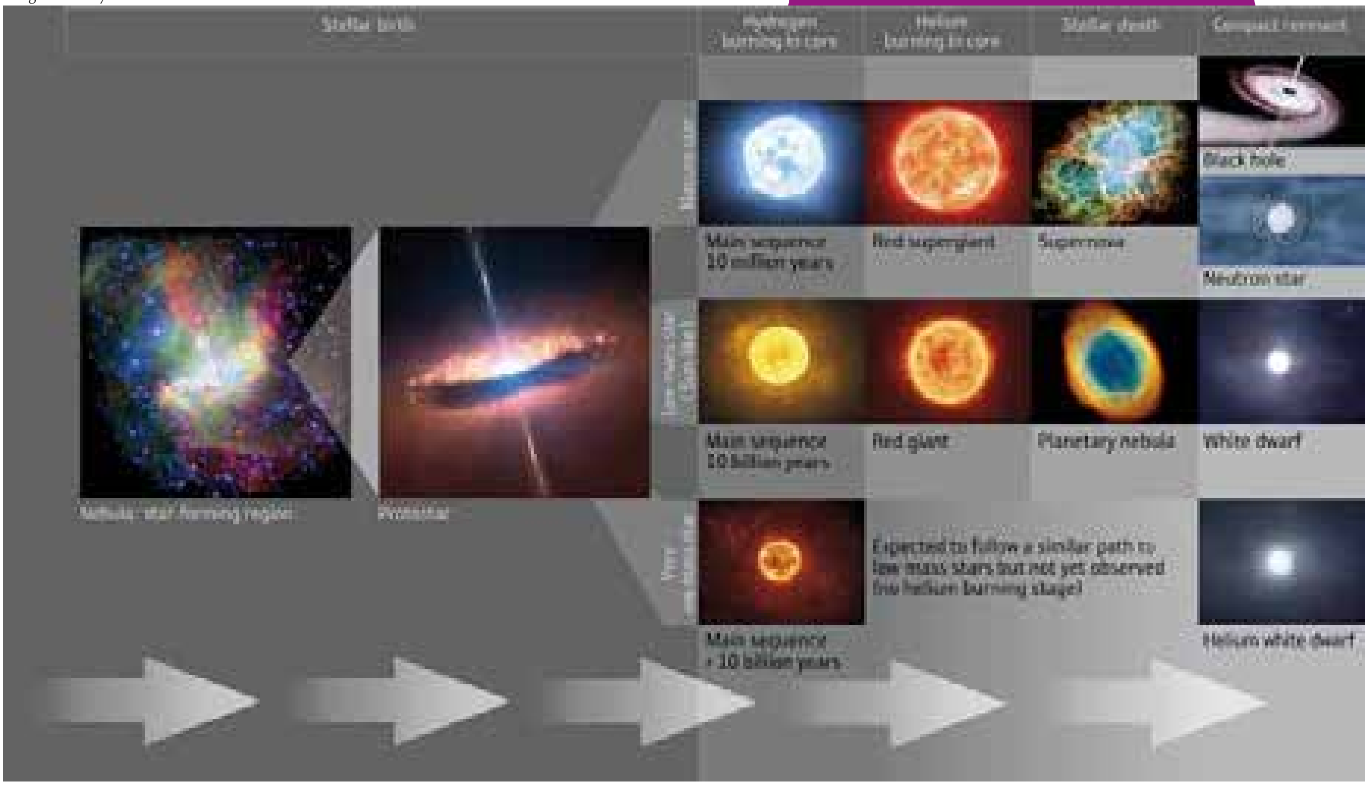


Image courtesy of ESA/ AOES Medialab

Figure 1: The EM spectrum, with the high-energy regions observed by ESA's XMM-Newton and INTEGRAL space observatories highlighted. X-rays are emitted by cosmic sources at millions of degrees Celsius; gamma rays by sources at hundreds of millions of degrees Celsius. XMM-Newton detects X-rays at energies of 150-1.5 x 10^4 eV, whereas INTEGRAL detects both X-rays at energies of 3 x 10^3-3.5 x 10^4 eV and gamma rays at 1.5 x 10^4 keV – 1.0 x 10^7 eV

Figure 2: The life cycle of stars

Image courtesy of ESA / AOES Medialab



a star's life cycle that are the most interesting for X-ray and gamma-ray astronomers. Because some very young stars shine brightly under X-rays, astronomers can detect many of them by looking at star-forming regions with X-ray telescopes such as XMM-Newton (figure 3). The most massive young stars release highly energetic radiation and extremely hot gas, which are observed at X-ray wavelengths and influence how other stars form in the surrounding area. Astronomers using XMM-Newton have detected bubbles of hot gas from young massive stars in many regions of the sky[w2], including the Orion Nebula and the star-forming region NGC 346. This research feeds into our understanding of how young massive stars affect star formation around them – a hot topic in modern astrophysics.

At the ends of their lives, massive stars explode as supernovae (as described in Székely & Benedekfi, 2007), heating the surrounding gas to extremely high temperatures and accelerating particles, such as electrons, to very high speeds. As a result, an abundance of X-rays and gamma rays are released (figure 4). Furthermore, many elements heavier than iron, such as lead, nickel and gold, are synthesised during supernova explosions (to learn more, see Rebusco et al., 2007). Some of these elements are radioactive and eventually decay into stable isotopes, producing gamma rays in the process. Astronomers using INTEGRAL have surveyed the Milky Way and found traces of the radioactive isotope aluminium-26. Just like archaeologists, they have delved into the history of our galaxy and performed a census of past supernovae. The results demonstrate that, in the Milky Way, supernovae occur on average once every 50 years[w3].

After a supernova explosion, all that remains of the massive star is an extremely compact and dense object – either a neutron star or a black hole. With such a huge mass squeezed into a restricted space, these remnants have exceptionally strong gravitational fields and exert an intense pull on nearby matter, but they are fairly difficult to detect. However, if the

Image courtesy of NASA / JPL-Caltech / D Gouliermis (Max-Planck Institute for Astronomy, Heidelberg, Germany) and ESA

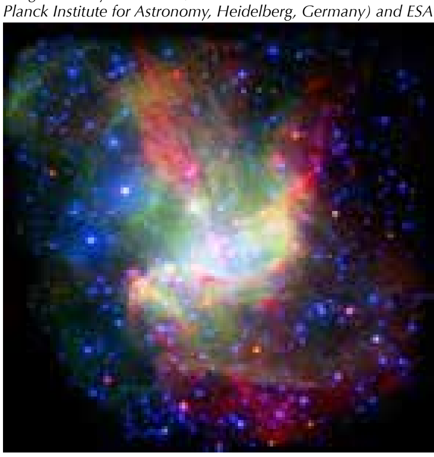


Figure 3: The star-forming region NGC 346 is located in the Small Magellanic Cloud, one of the Milky Way's neighbouring galaxies. This false-colour image combines observations performed with XMM-Newton in X-rays (blue) with data gathered in visible (green) and infrared (red) light with the Hubble and Spitzer space telescopes, respectively

Physics

Image courtesy of CEA / DSM / DAPNIA / SAp / J Ballet and ESA

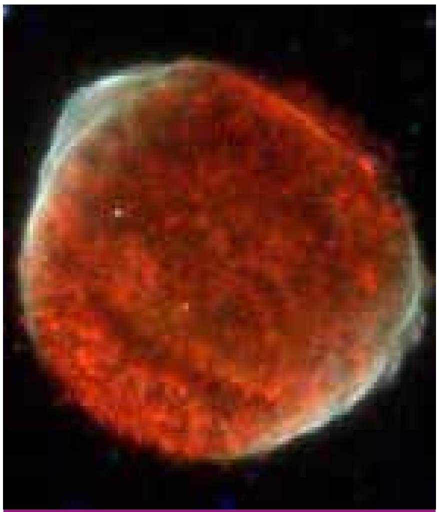


Figure 4: X-ray image of the supernova remnant SN 1006 as viewed with XMM-Newton. This object is the remains of a supernova that was seen by Chinese astronomers in 1006 AD. Visible in the upper-left and lower-right corners are shock waves where particles such as electrons are accelerated to very high speeds

Image courtesy of ESA / AOES Medialab

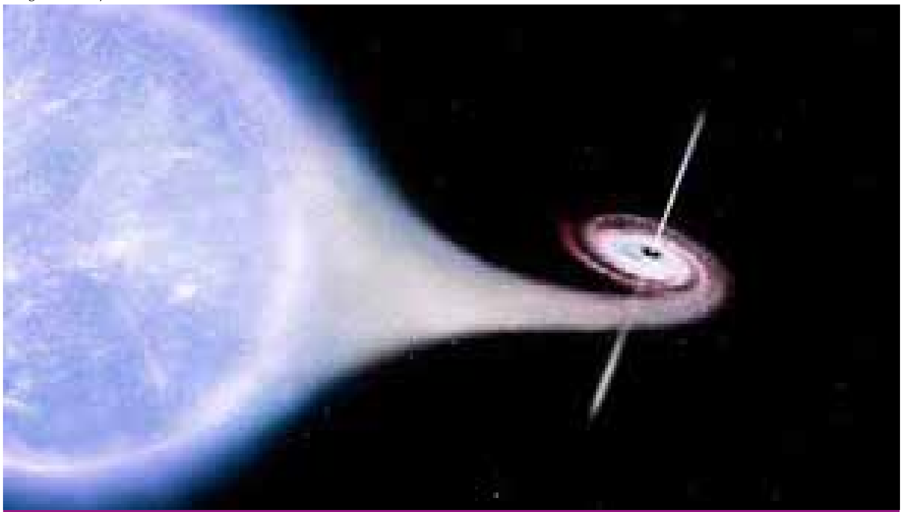


Figure 5: Artist's impression of an X-ray binary. With its intense gravitational field the black hole on the right draws matter from its companion, a blue super-giant star, on the left. The stripped material spirals around the black hole, forming an accretion disc, which shines brightly at the highest energies. Two powerful jets of highly energetic particles stem from the vicinity of the black hole

neutron star or black hole is part of a binary stellar system (two stars orbiting around a common centre of mass), it may start devouring matter from its companion star; the accreting matter then heats up to millions of degrees, emitting X-rays and gamma rays. This high-energy emission can be used to reveal the presence of a neutron star or black hole.

These systems are called X-ray binaries (figure 5) and were discovered in the late 1960s via X-ray observations. Back then, neutron stars and black holes had only been predicted by theory, so these observations provided the first proof of their existence. Since then, several generations of space-based observatories have helped astronomers to learn more. XMM-Newton and INTEGRAL have studied many X-ray binaries (which may also release gamma rays), revealing important details about the physics of black holes and neutron stars. For example, gamma rays from Cygnus X-1, observed using INTEGRAL[w4], helped astronomers to better understand how matter is accreted via a disc onto this black hole and partly expelled in two symmetric jets.

The distant Universe

High-energy astronomers not only observe the birth and death of stars within the Milky Way and nearby galaxies, but also use X-rays and gamma-rays to investigate the much more distant Universe – including super-massive black holes and clusters of galaxies.

All large galaxies harbour super-massive black holes at their cores, with masses a few million to a few billion times that of the Sun. Some galaxies, known as *active galaxies*, contain super-massive black holes that, unlike the one in the centre of the Milky Way, are active. Devouring matter from their surroundings, these black holes release high-energy radiation as well as powerful jets of highly energetic particles (figure 6). ESA's XMM-Newton and INTEGRAL are thus ideal tools to hunt for active galaxies and to investigate the mechanisms that power them. Astronomers cannot see all the necessary details in more distant high-energy sources, so they also collect data from as many nearby active galaxies as possible. By combining data from close and distant galaxies, astronomers have figured out how super-massive black holes accrete matter via a disc, and how these discs may be surrounded by absorbing clouds of gas[w5].

On a still larger scale, galaxies tend to assemble in clusters of up to several thousand galaxies. These clusters are the largest structures in the Universe to be held together by gravity, and release a diffuse X-ray glow. This glow, first observed in the 1970s, revealed that the intergalactic space in a cluster contains an enormous amount of hot gas. Together with other observatories that probe the sky across the EM spectrum, XMM-Newton has observed hundreds of galaxy clusters (figure 7).

Image courtesy of ESA / XMM-Newton (X-rays); ESA / Herschel / PACS / SPIRE / CD Wilson, McMaster University, Hamilton, Ontario, Canada (far-infrared and sub-millimetre)

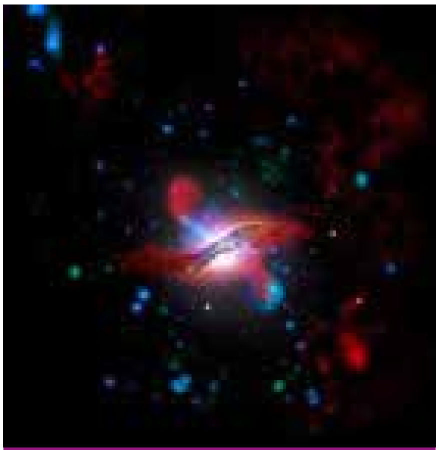


Figure 6: The nearby active galaxy Centaurus A (NGC 5128). This false-colour image combines observations performed with XMM-Newton in X-rays (cyan, blue and purple, in order of increasing energy) and data gathered at longer, far-infrared (yellow) and sub-millimetre (red) wavelengths using ESA's Herschel Space Observatory. At X-ray wavelengths, a number of foreground point-like sources are visible: these are X-ray binaries belonging to our galaxy, the Milky Way

Image courtesy of ESA / ESO / Subaru / R Gobat et al.

Figure 7: Observations of the very distant galaxy cluster CL J1449+0856 performed in X-rays (purple glow) with XMM-Newton are superimposed onto an image taken with ground-based telescopes at near-infrared wavelengths. Most objects visible in the image are very faint and distant galaxies. The galaxies belonging to the galaxy cluster are visible as a clump of faint, red objects. With a temperature above 20 million Kelvin, the hot gas pervading the intergalactic space shines brightly in X-rays

Image courtesy of NASA / ESA / R Massey (California Institute of Technology)

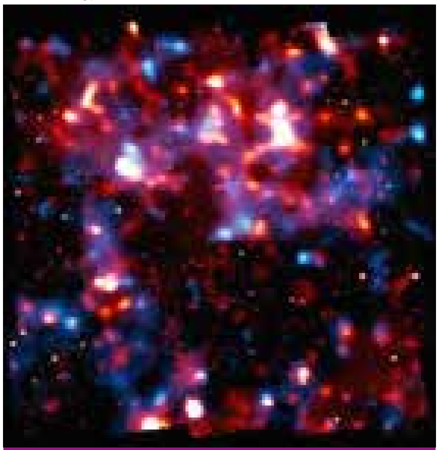


Figure 8: This map compares the distribution of 'normal' matter, traced via hot gas seen by XMM-Newton (in red) and stars and galaxies observed with the Hubble Space Telescope (in grey), to the distribution of the invisible dark matter (in blue), which has been inferred from the gravitational lensing effect. The map demonstrates how 'normal' matter across the Universe follows the structure of an underlying 'scaffolding' of dark matter

Physics

These include a very distant cluster that is one of the earliest structures to have formed in the Universe[w6], just 3 billion years after the Big Bang. This may sound like a very long time, but it is less than one quarter of the Universe's present age.

Galaxy clusters are located in the densest knots of the cosmic web, the gigantic network of structure that makes up the Universe and consists mostly of invisible dark matter[w7]. Using XMM-Newton, astronomers have spotted matter where it is most densely concentrated, thus tracing the distribution of cosmic structure across the Universe (figure 8).

From the birth of a star to the structure of the Universe – what next? X-ray and gamma-ray observatories, including ESA's XMM-Newton and INTEGRAL, continue to keep a close watch on the ever-changing, high-energy sky, recording sudden violent outbursts of X-rays and gamma-rays. By continuing to unveil celestial wonders to astronomers, these remarkable space observatories are helping to solve the mysteries of our Universe.

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Mignone C, Barnes R (2011b) More than meets the eye: unravelling the cosmos at the highest energies. *Science in School* **21**: 57-64. www.scienceinschool.org/2011/issue21/em

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Székely P, Benedekfi Ö (2007) Fusion in the Universe: when a giant star dies.... *Science in School* **6**: 64-68. www.scienceinschool.org/2007/issue6/fusion

Web references

w1 – To learn more about X-ray and gamma-ray astronomy at ESA, watch Rebecca Barnes in Episode 5 of the Science@ESA vodcast: *The untamed, violent Universe.* See the ESA Science and Technology website (http://sci.esa.int/vodcast) or use the direct link http://tinyurl.com/esaepisode5

w2 – Find out more about how XMM-Newton helped in studying the star-forming region NGC 346 and detected a hot-gas bubble in the Orion Nebula. See www.esa.int/science and http://sci.esa.int/xmm-newton

respectively, or use the direct links http://tinyurl.com/7xo9qez (NGC 346) and http://tinyurl.com/28d8ac (Orion)

w3 – Learn how INTEGRAL identified the supernova rate for the Milky Way and how XMM-Newton helped to analyse the remnants of the Tycho supernova. See www.esa.int/science or use the direct links http://tinyurl.com/72mhz4s (Milky Way) and http://tinyurl.com/752zbh6 (Tycho)

w4 – The ESA website has more information about X-ray binaries.

Find out how gamma rays from the Cygnus X-1 jets were observed with INTEGRAL ('Integral spots matter a millisecond from doom'). See www.esa.int/science or use the direct link http://tinyurl.com/6sxhlqx

Learn about how Supergiant Fast X-ray Transients were observed by XMM-Newton ('Neutron star caught feasting on clump of stellar matter'). See http://sci.esa.int/xmm-newton or use the direct link http://tinyurl.com/7caahph

w5 – Read more details of ESA's findings about active galaxies. See http://sci.esa.int/xmm-newton (XMM-Newton) and http://sci.esa.int/integral (INTEGRAL) or use the direct links http://tinyurl.com/om5sar and http://tinyurl.com/3rfws48

w6 – Read about how XMM-Newton helped discover an old galaxy cluster in the young Universe. See http://sci.esa.int/xmm-newton or use the direct link: http://tinyurl.com/5vcf3wz

w7 – Learn about the first 3D map of the Universe's dark matter scaffolding. See: www.esa.int or use the direct link: http://tinyurl.com/8r3gw7c

w8 – For more information on the European Space Agency, visit the ESA website (www.esa.int).

w9 – Find out more about EIROforum. See: www.eiroforum.org

Resources

ESA has produced many more education materials. See: www.esa.int/educationmaterials

All education materials produced by ESA are freely available to teachers in the 18 ESA member states. Many are translated into several European languages.

Learn more about the activities of the European Space Agency's Directorate for Science and Robotic Exploration. See: http://sci.esa.int

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More about ESA

The European Space Agency (ESA)[w8] 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, to 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[w9], the publisher of *Science in School*.

See all ESA-related articles in *Science in School*.
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To find out more about the education activities of the ESA Science and Robotic Exploration Directorate, contact Rebecca at SciEdu@esa.int

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

Image courtesy of lindenbaum; image source: Flickr

The new definition of crystals – or how to win a Nobel Prize

Why is symmetry so central to the understanding of crystals? And why did 'forbidden' symmetry change the definition of crystals themselves?

By Mairi Haddow

When asked to think of a crystal, you might think of those that are visible to the naked eye, such as:

Common salt (sodium chloride)

Image courtesy of Mark Schellhase; image source: Wikimedia Commons

Gypsum (calcium sulphate dehydrate)

Image courtesy of Tjflex2; image source: Flickr

Cinnamon stone ($Ca_3Al_2Si_3O_{12}$)

Image courtesy of Tjflex2; image source: Flickr

Image courtesy of tlindenbaum; image source: Flickr

Studying crystalline materials is one of the most powerful analytical techniques available to scientists. If it is possible to grow a single crystal of a salt, molecule, protein or even a whole virus, then it is usually possible to identify not only its connectivity (what atoms are bonded to what), but also its bond lengths, bond angles and molecular conformation (what shape a flexible molecule adopts). From the study of protein crystals, it is often possible to elucidate how that protein works in the body and where its active sites are.

Crystals are inherently beautiful, largely thanks to their symmetry. Conventionally, all crystals were thought to have one property in common: translational symmetry in three dimensions. Indeed, this is how crystals were originally defined – as materials in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating three-dimensional pattern. Translational symmetry is best illustrated in two dimensions by thinking about patterned wallpaper, which usually has this property – if hung properly. This means that we can draw a parallelogram (tile) containing a certain pattern, and by stacking the tile in two directions, derive the wallpaper pattern (figure 1).

In a similar way, we can derive a 3D crystal structure from a 'box' of atoms, by repeating the box along the

Figure 1: Wallpaper illustrating translational symmetry in two dimensions. The parallelograms indicate the repeating unit

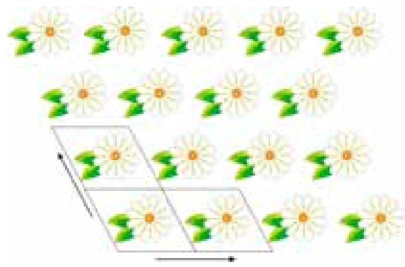


Image courtesy of Mairi Haddow

Figure 2: The unit cell (top) and crystal structure (bottom) of sodium chloride, derived by repeating the unit cell along three directions: x, y and z. Typically, the sizes of unit cells range from a few ångströms (10^{-10} m) for simple salts (the unit cell of sodium chloride is 5.64 Å), to a few tens of ångströms for small molecules, up to several hundred ångströms for protein crystals

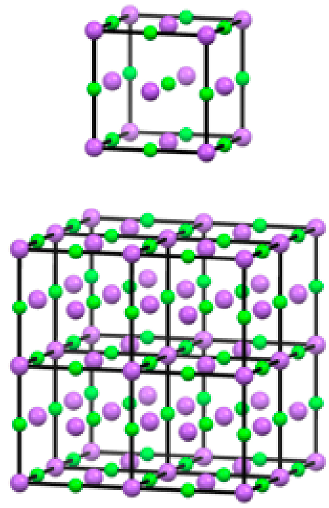


Image courtesy of Mairi Haddow

REVIEW

- **Chemistry**
- **Physics**
- **Earth science**
- **Maths**
- **Art**
- **Crystallography**
- **Atomic structure**
- **Diffraction**
- **Waves**
- **Symmetry**
- **Ages 11-19**

As the author writes, "crystals are inherently beautiful," but students often regard crystallography as a difficult and boring subject. For these students and for their teachers, Mairi Haddow's article is a valuable resource to look at crystals with a new and inspiring approach. In this enjoyable article, the topic is explained in clear and precise language, together with beautiful and impressive pictures (for example the one about wallpaper and translational symmetry).

The article could be used in school within chemistry (solid structures), physics (diffraction, waves, atomic structure), earth science (mineralogy, crystallography), and maths (symmetry) curricula. These subjects, with the addition of art history (tiling), offer different interdisciplinary opportunities.

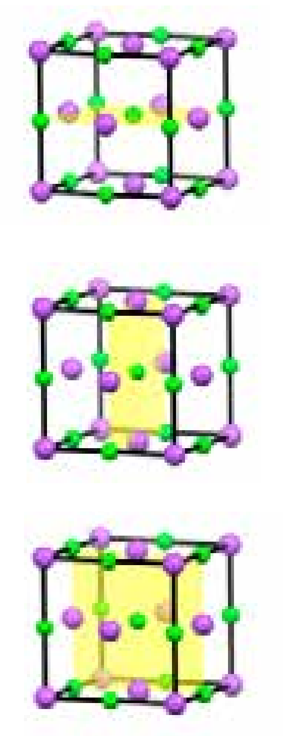
Suitable comprehension questions include:

1. From the article you can deduce that it is possible to grow a crystal of:
   a) A salt
   b) A molecule
   c) A virus
   d) A bacterium
2. With which of the following can diffraction analysis of crystals NOT be performed?
   a) X-rays
   b) Radio waves
   c) Neutrons
   d) Free electron laser
3. With which of the following types of tiles is it possible to completely cover a 2D surface?
   a) Triangles, squares, pentagons, and hexagons
   b) Triangles, rectangles and heptagons
   c) Triangles, squares, rectangles and hexagons
   d) Squares, rectangles and pentagons

Giulia Realdon, Italy

Image courtesy of Mairi Haddow

Figure 3: Unit cell of sodium chloride showing three mirror planes (coloured yellow)

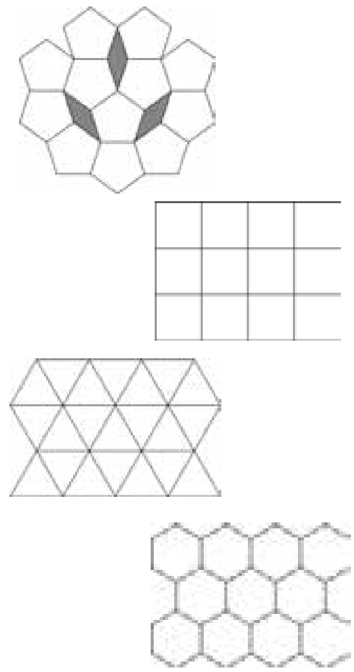


Public domain image (recycling symbol); other images courtesy of Mairi Haddow

Figure 4: Examples of shapes with two-fold or mirror symmetry (two of diamonds), three-fold (recycling symbol), four-fold (Celtic knot) and six-fold symmetry (star)

Image courtesy of Mairi Haddow

Figure 5: Packing of polygons: it is not possible for objects with five-fold rotational symmetry (pentagons) to be packed together without leaving gaps (grey shading) between them. In contrast, triangles, squares and hexagons can be packed without gaps



x, y, and z axes. The repeating box is known as the *unit cell* (figure 2).

Symmetry in crystals and quasi-periodicity

Crystals that have such translational symmetry in three dimensions are formally referred to as *periodic crystals* because the structures have a pattern that repeats at a certain distance or *period*. In 2011, however, the Nobel Prize in Chemistry was awarded to Dan Shechtman for his discovery of *quasi-periodic* crystals. These crystals are not periodic – they do not possess translational symmetry – but still have local order. They have the same repeating unit at different points in the crystal, but *not* at periodic intervals. The recent recognition of this work is a triumph of Shechtmann's perseverance over the ridicule that he received when he first published his work (Shechtman et al., 1984). So why was this idea so contentious? Because these crystals seemed to have symmetries that are forbidden in periodic systems.

In addition to translational symmetry, most periodic crystal structures have additional symmetry, such as mirror symmetry. For example, by looking at the unit cell of sodium chloride, we can see that each half is the mirror image of the other (figure 3; see also figure 4).

Rotational symmetry is also possible. This means that if we take an object and rotate it around a central point by a certain number of degrees, it will look the same (figure 4).

When a pattern or crystal has translational symmetry and is periodic, two-fold, three-fold, four-fold and six-fold rotational symmetries are all possible, but five-fold, or indeed seven-fold or higher symmetry, is not. This is because triangles, rectangles, squares and hexagons may all be packed in 2D space without leaving any space in between. In contrast, pentagons, heptagons and higher polygons may not (figure 5).

Image courtesy of Phillip Westcott, National Institute of Standards and Technology

Dan Shechtman explaining the atomic structure of quasi-periodic crystals at a meeting at the National Institute of Standards and Technology, USA, in 1985 – just months after he published his discovery

Image courtesy of Mairi Haddow

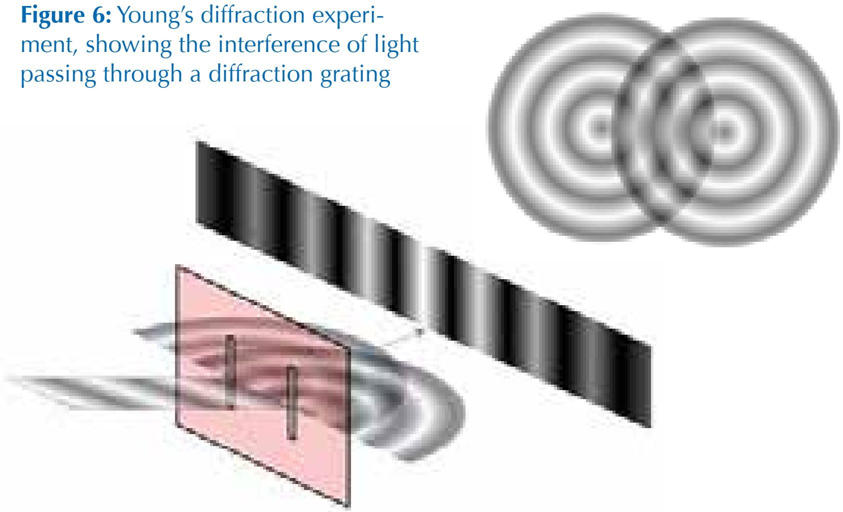


Figure 6: Young's diffraction experiment, showing the interference of light passing through a diffraction grating

Image courtesy of Mairi Haddow

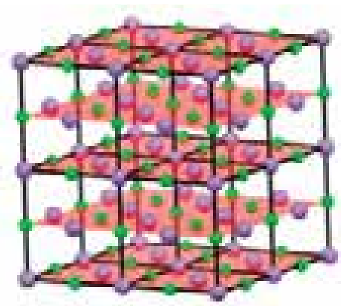


Figure 7: Layers of atoms in sodium chloride that act similarly to slits in a diffraction grating

Image courtesy of Mairi Haddow

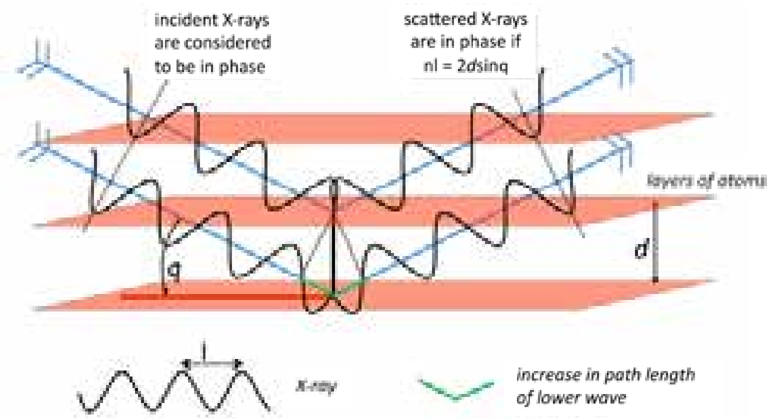


Figure 8: Derivation of Bragg's law. The extra distance (green path) travelled by the lower X-ray can be shown to be equal to 2d sinθ. The scattered beams will be in phase if and only if the extra distance travelled is equal to a whole number (n) of wavelengths (λ). Thus, a diffraction peak will be visible only if nλ = 2d sinq

How are crystals analysed?

Many students will have performed Young's famous double-slit experiment at school, in which a laser is shone through two slits in a diffraction grating, the spacing between which is comparable to the wavelength of the laser light. An interference pattern can be seen, caused by constructive and deconstructive interference of the waves diffracted by the slits (figure 6).

Crystals are studied using a technique known as X-ray diffraction, the theory of which was developed extensively in 1913 by William Henry Bragg and his son William Lawrence Bragg, who were jointly awarded the Nobel Prize in Physics in 1915 for their work. In a diffraction experiment, crystals act as a complex diffraction grating, where the 'slits' are layers of atoms in the crystal (figure 7).

For diffraction to occur, the wavelength of the radiation interacting with the crystal must be comparable to the distance between the atoms. Commonly in laboratories, the radiation will be X-rays (which are scattered by the electrons in atoms), but there are other possibilities, such as electrons or neutrons[w1].

The crystal is mounted in an X-ray beam of a selected wavelength, and the diffraction pattern is measured as the crystal is rotated. For layers of atoms positioned at an angle θ to the X-ray beam, scattered X-rays will be in phase (i.e. have constructive interference) if and only if the difference between the path lengths of two scattered X-rays is equal to a whole number of wavelengths, resulting in a measurable diffraction peak. This is known as Bragg's law, and the derivation is illustrated in figure 8.

As the crystal is rotated, different layers of atoms will satisfy Bragg's law and produce constructive interference. This results in a diffraction peak with an intensity related to the number and type of atoms in the layer, for example as shown in figure 9. A typical diffraction experiment will measure thousands to millions of *reflections*, and by careful analysis can be used to figure out the exact structure of the crystal.

The diffraction pattern produced by a crystal also has symmetry and this is

Image courtesy of Materialscientist; image source: Wikimedia Commons

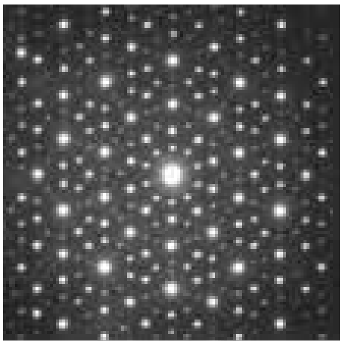
Figure 9: A typical diffraction pattern from a conventional crystal at one particular angle. Each bright spot (reflection) represents constructive interference from a different layer of atoms. (The shape on the right is the shadow of the beam stop, a metal shield which absorbs the unscattered X-ray beam)

Images courtesy of Mairi Haddow (right and left images); central image courtesy of Materialscientist; image source: Wikimedia Commons

Figure 10: X-ray diffraction pattern with two-fold rotational symmetry from a periodic crystal (A) and an electron diffraction pattern from a quasi-periodic crystal, showing 10-fold rotational symmetry (B). For comparison, the X-ray diffraction pattern from a glass fibre (broadly amorphous, i.e. non-crystalline) material (C)

A

B



C

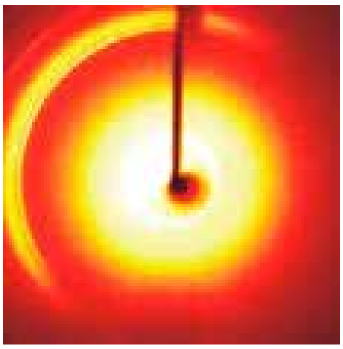
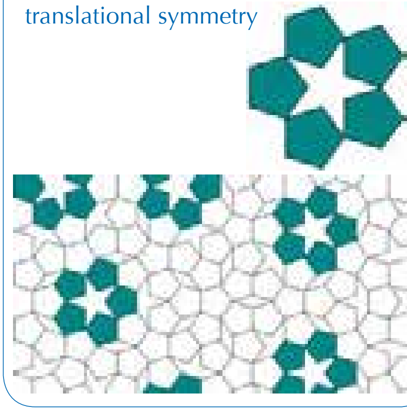


Image courtesy of Mairi Haddow

Figure 11: A single object may possess five-fold rotational symmetry (top) but these objects may not be combined into a periodic system. This occurs, for example, in Penrose tiling (bottom), in which instances of local five-fold symmetry may be found, but which does not have translational symmetry



related to the symmetry of the crystal. The diffraction patterns of quasi-periodic crystals have symmetry that is forbidden in periodic crystals, such as five- or 10-fold rotation (figure 10).

The structures of these unusual crystals are related to Penrose tilings (figure 11). These are structures that possess local symmetry, but not translational symmetry.

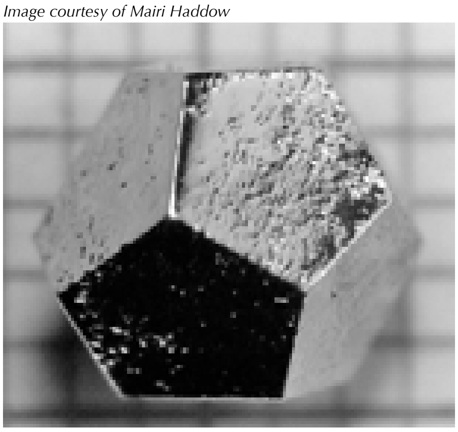
Research in this area led to a change in the definition of a crystal by the International Union of Crystallography in 1991. Crystals now no longer need to have translational symmetry: a material is a crystal if it has a sharp diffraction pattern, which quasi-periodic crystals certainly do.

However, it's unlikely that the school curriculum will be changed any time soon to reflect this new definition. Very few of these quasi-periodic materials have yet been discovered, and the first natural quasi-periodic crystal – icosahedrite ($Al_{63}Cu_{24}Fe_{13}$), a mineral that is probably of meteoritic origin and was found in the Khatyrka river in eastern Russia – was discovered only in 2009. Although more examples have been created since then, and quasi-crystals are now known to exist in many metallic alloys and some polymers, the crystals that school students grow in the lab are unlikely to be anything but periodic, and aside from their unusual and interesting properties, quasi-crystals have no real applications – yet.

Image courtesy of Roger McLassus; image source: Wikimedia Commons

Studying crystals relies on the analysis of the interaction of waves with layers of atoms

Image courtesy of Mairi Haddow



A holmium-magnesium-zinc quasi-periodic crystal

Chemistry

Physics

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Shechtman D et al. (1984) Metallic phase with long-range orientational order and no translational symmetry. *Physical Review Letters*, **53(20)**: 1951-1953. doi: 10.1103/PhysRevLett.53.1951

Web resources

w1 – Diffraction analysis is possible not only with X-rays, but also with neutrons and electrons. This is exemplified by three of the members of EIROforum (www.eiroforum.org), the publisher of *Science in School*.

The European Synchrotron Radiation Facility (ESRF; www.esrf.eu) uses the diffraction patterns of high-energy X-rays to analyse materials. The experiments carried out at ESRF have applications not only in materials science, but also in biology, medicine, physics, chemistry, environmental science and even palaeontology and cultural heritage. See the full collection of ESRF-related articles in *Science in School*: www.scienceinschool.org/esrf

The Institut Laue-Langevin (ILL; www.ill.eu) operates the most intense steady neutron source in the world. Diffraction studies of the neutron beams are used in research into condensed matter physics, chemistry, biology, nuclear physics and materials science.

The European X-ray Free Electron Laser (European XFEL; www.xfel.eu), due to start operation in 2015, will use X-ray flashes to examine samples. The basic idea behind a typical experiment is simple: illuminate a sample by intense X-ray flashes and count the photons that are scattered from the sample in different directions. The result is a diffraction pattern.

Resources

Cornuéjols D (2009) Biological crystals: at the interface between physics, chemistry and biology. *Science in School* **11**: 70-76. www.scienceinschool.org/2009/issue11/crystallography

To learn how to grow your own protein crystals at school, see:

Blattmann B, Sticher P (2009) Growing crystals from protein. *Science in School* **11**: 30-36. www.scienceinschool.org/2009/issue11/lysozyme

More information about Dan Shechtman and his discovery is available on the Nobel Prize website: www.nobelprize.org

Howes L (2011) Quasicrystals scoop prize. *Chemistry World* **8(11)**: 38-41. www.rsc.org/chemistryworld/Issues/2011/November/QuasicrystalsScoopPrize.asp or use the shorter link: http://tinyurl.com/7ek47aw

For an interview with mathematician and symmetry researcher Marcus de Sautoy, see:

Hayes E (2012) Finding maths where you least expect it: interview with Marcus du Sautoy. *Science in School* **23**: 6-11. www.scienceinschool.org/2012/issue23/dusautoy

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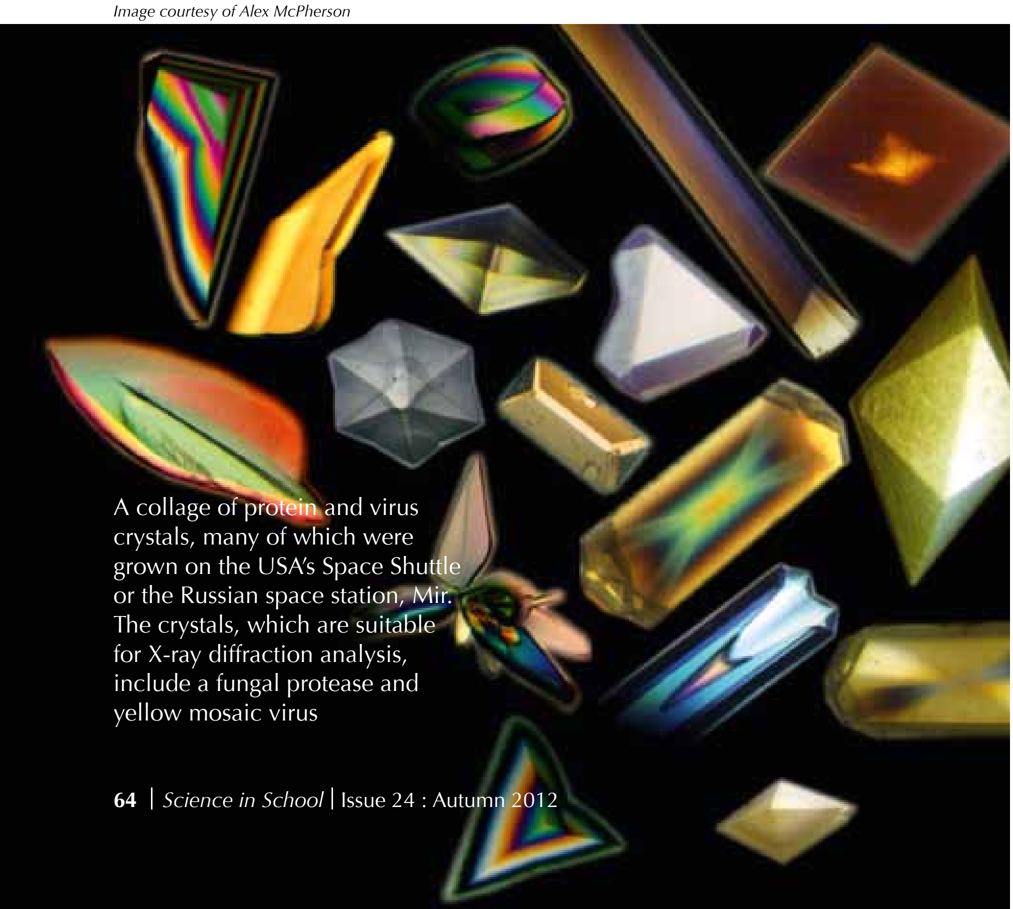
Image courtesy of Alex McPherson



A collage of protein and virus crystals, many of which were grown on the USA's Space Shuttle or the Russian space station, Mir. The crystals, which are suitable for X-ray diffraction analysis, include a fungal protease and yellow mosaic virus

Mairi Haddow studied chemistry at the University of Edinburgh, UK, has a PhD in chemistry from the University of Bristol, UK, and now works as a research fellow at the University of Bristol, in charge of the X-ray diffraction facilities in the School of Chemistry. She regularly gives demonstrations of the equipment to A-level students (aged 16-18) who take part in the School of Chemistry's (inappropriately named) 'spectroscopy tours'.

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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.efda.org/jet

EMBL

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

ESA

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

ESO

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

ESRF

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

European XFEL

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

ILL

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

Learning through investigation: Science on Stage visit to El Roure Gros primary school

The Catalan primary school El Roure Gros has a unique concept: all learning is done through experimentation and investigation. Science on Stage Germany invited eight teachers from Austria, Germany and Italy to visit the school.

Image courtesy of fatcat21 / iStockphoto

By Elena Lührs

At first glance, the building of El Roure Gros in Santa Eulàlia de Riuprimer does not resemble a school at all. It is small and very simple; only the yard gives the impression of a public institution. In April 2012, eight primary-school teachers travelled to Spain to look behind the façade of this very special school.

The idea of the excursion came about in 2011 at the Science on Stage international teaching festival in Copenhagen, where Carmen Alemany, head of El Roure Gros, and her colleague Eloi Arisa presented the concept behind their school. One of the board members of Science of Stage Germany, Ute Hänsler, realised how much other European teachers could benefit from a visit, and primary-school teachers who had attended the festival were invited to take part.

In the 1980s, Carmen Alemany decided that the school should break with administrational rules, and this break still determines the style of learning and teaching today: there is no separation of school subjects, no bell ringing at a certain time to mark the end of a lesson, and classroom doors are not closed. At El Roure Gros, all learning is integrative, interdisciplinary and project-based. The students themselves can propose topics and work on them independently or in small groups. The projects usually last one week and are documented on paper and with computers in a portfolio. The students only ap-

Image courtesy of Science on Stage Germany

Documentation at El Roure Gros. The pupils learn casually in everyday life how to read and write. Project documentation consists of summaries, reflections, photos and drawings – according to age level. Interdisciplinary portfolio folders and files on the school server gather together all of each student's project documentation. Handling media such as digital cameras or laptops and printers is a matter of course for the pupils from an early age. They learn the first letters of the alphabet in kindergarten

Image courtesy of Claudia Jacob

What is speed, and how do we measure it? A poster and a measuring tape are sufficient to fill an English lesson with this physics topic. A group of students and one teacher have a discussion; they work without school books. One student explains that information on distance and time is needed to measure speed. He stumbles upon the unit '100 feet'. The teacher explains that there are several measurement units, and encourages his students to convert different units. Eventually, the students compare the speed of different car types and even measure the velocity of light

Image courtesy of Monica Zanella

A recently purchased optics suitcase. The teacher takes out a power transformer and asks the older pupils what it might be used for: "To convert energy! To change luminosity! To vary voltage!" The children use technical terms as a matter of course. They take a lamp out of the suitcase and explore the change of light through a convex lens: they observe that rays can be refracted and focused on the same spot, but that the ray in the centre remains unchanged. They agree that the distance from the focal point to the lens always remains the same, and even guess that lenses with different focal points might exist

Image courtesy of Wilfried Meyer

The planetarium, a long-term project. Pupils of different ages cut out numerous hexagons, stuck them together and created a hemisphere with a diameter of 2.5 m. A wooden ring surrounds the hemisphere and is attached to it using angle irons. The whole construction hangs on steel ropes from the ceiling. A projector beams the starry sky onto the inner surface of the sphere. Ready, steady, go: the pupils become real astronomers

General science

Primary

Image courtesy of fatcat21 / iStockphoto

proach their teachers if they are stuck with their project.

Inquiry and communication are the main competences taught at El Roure Gros. The key for this concept of teaching and learning is the documentation of all learning processes. The pupils begin with drawings in kindergarten, and go on to learn how to write and read because of the need to apply these skills for their own documentation. They are not taught knowledge, but how to gain knowledge themselves. The aim of this concept is to raise independent young people who are capable of taking responsibility and initiative. During the two-day visit, the Science on Stage teachers had the opportunity to see this concept in action.

The two-storey building houses 142 pupils and 12 teachers. The pupils are allocated to the kindergarten (ages 3 to 5), the initial circle (6 to 7), the middle circle (8 to 9) and the upper circle (10 to 11), although doors are left open to encourage communication and collaboration between groups. Much of the work in the school is based on co-operation: between teachers, between pupils, and between teachers and pupils. The school is equipped with 60 laptops and desktop computers, a small sound studio and a planetarium built by the pupils. The everyday language is Catalan, although Spanish is taught from an early age, and older pupils learn English.

Excursions to science centres, museums, industry or natural surroundings take place every three months. The school aims to include the natural and social surroundings, such as the village, its inhabitants and its geography, in the teaching process. "A child is born with a lot of innate knowledge," explains Carmen, "but it needs to get to know its natural and social surroundings, and its customs. The teacher needs to accompany the child in its process of exploring its surroundings."

The school's aim is not to produce young scientists and engineers but to raise confident and independent humans. The pupils of El Roure Gros perform outstandingly well in public tests compared with other Catalan primary-school students. And the side effect of this concept: approximately 70% of El Roure Gros alumni have chosen careers in mathematics, science or engineering.

The visiting primary-school teachers were impressed with what they saw. "The atmosphere was one of respect and the children were taken seriously: the teachers responded to all the children's thoughts and questions," said Monica Zanella from Italy. Wilfried Meyer and Kirstin Yüzüncü from Germany commented, "We were amazed to see what a school can achieve with such limited resources when it doesn't have to constantly struggle with standards, competencies, exam-oriented content; at El Roure Gros, all the teachers' energy is poured into the children, their interaction with the world and their education."

Although it may not be possible for all teachers to recreate the El Roure Gros concept in their own schools – particularly in countries like Germany where school curricula are structured quite strictly – they can take away useful ideas. One important aspect that could be adopted at any school is more open documentation of the learning process. In the occasional lesson, teachers could also reduce their involvement, allowing children to take the lead in deciding what topics to explore, and how they want to document them. In this way, children gain the spirit of exploration while learning.

Thanks to its unusual concept, the Catalan primary school El Roure Gros is a prototype for schools throughout Europe: competence-based learning in inspiring learning environments – successful, sustainable and suitable for children.

Acknowledgement

Science on Stage Germany would like to thank Claudia Jacob, Wilfried Meyer, Carina Peschek and Monica Zanella for their contributions to this article, and THINK ING for supporting the teacher excursion to El Roure Gros.

Web references

w1 – Science on Stage is a network of local, national and international events for teachers, initially launched in 1999 by EIROforum, the publisher of *Science in School*. At each national Science on Stage event, a delegation of teachers is selected to represent their country at the Science on Stage international teaching festival.

The next international festival will be held on 25-28 April 2013, in Słubice-Frankfurt (Oder) on the Polish-German border. During the festival, 350 teachers from 27 countries will share their most innovative teaching ideas in workshops, on-stage performances and the teaching fair. Participation is free for delegates. For other science teachers, there will be a limited number of places for which a registration fee will be charged. See the Science on Stage Europe website for details. www.science-on-stage.eu

w2 – Learn more about Science on Stage Germany: www.scienceonstage.de

Resources

To learn more, browse the other Science on Stage articles in *Science in School*. www.scienceinschool.org/sons

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

Making physics flourish in Poland: Maria Dobkowska

Image courtesy of stock photos for free.co

Physics teacher Maria Dobkowska describes the challenges of remaining creative within a strictly defined national curriculum and of working with children with disabilities.

Physics

General science

By Katy Hewis

When the first two eminent speakers at a national conference for physics teachers in Poland pause in their opening comments to thank you for inspiring them to study physics, you must be doing something right.

There can be no doubt that the recipient of that recognition, Maria Dobkowska, followed the right career path: her happy 39 years of teaching experience in Poland prove it. "I've always been a social person. I liked working with people," she explains, "and I knew that working in a scientific laboratory wouldn't interest me. After my time as a trainee teacher, I knew for sure that it was the job for me."

Image courtesy of Bogusława Rotter

Maria's school 'science picnic'

Maria's enthusiasm has served her well, particularly when facing the considerable challenges posed by the Polish school system (see box). "In Poland we have strictly defined national curricula for each separate subject. You can only introduce your own topics in extra-curricular activities – outside of lessons," Maria explains.

Unfortunately, according to Maria, successive education reforms in Poland have reduced the number of lessons in physics, but not the extent of the material that needs to be covered before the national exams. "Even during extra-curricular activities, teachers are more focused on preparing students for the examinations than on expanding or introducing new content." Furthermore, the lack of funds for extra-curricular activities means that the needs of gifted and talented students are not always met.

Many teachers would struggle in such a constrained system but Maria has risen to the challenge. In doing so, she has created resources that have helped other teachers both nationally and internationally.

"I started a student competition, 'Taking photos of physical phenom-

Images courtesy of Julia Wojciechowska (aged 15)

In these photos entered in the student competition, 'Taking photos of physical phenomena', the student demonstrated how water expands as it freezes

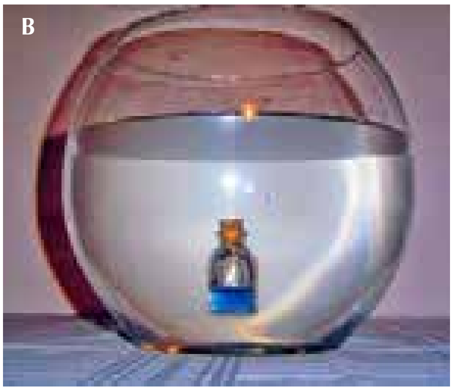
ena', initially in my school. It was a great success: some of the photos were so good that they were used as illustrations in the physics handbooks for lower secondary school. Many cities in Poland are now successfully conducting similar competitions – this makes me very proud."

About 10 years ago, together with Miroslaw Los, who teaches physics and information and communications technology (ICT), Maria began making videos of interesting physics experiments[w1]. This was in response to the needs of lower secondary-school physics teachers who wanted to make their lessons more engaging but lacked the time and / or equipment. Over time, Maria and Miroslaw extended this resource to include animations and interactive simulations. Today, all the materials are included

The Polish education system

Szkoła podstawowa (primary school)	**Stage 1**: age 7-10 All teaching is integrated, with no separate subjects. **Stage 2**: age 10-13 Separate subjects are introduced. The only scientific subject at this stage is nature, which consists mainly of biology and geography, with a small amount of physics and chemistry. The students receive three hours per week of nature lessons.
Gimnazjum (lower secondary school)	**Stage 3**: age 13-16 Teaching is based on separate subjects – biology, chemistry, geography and physics. For each of these subjects, the students receive 130 hours over the three-year period. For example, they may receive one hour per week in the first year, two in the second year and one in the third year.
Liceum ogólnokształcqce (upper secondary school)	**Stage 4**: age 16-19 As of 2012, science is taught as separate subjects only in the first year of Stage 4. Per subject, the students receive one hour of lessons per week. For the second and third years of Stage 4, students choose to focus on either science or humanities. Over those two years, students who focus on science receive four hours of lessons per week for each science subject (biology, chemistry, geography and physics). Students focusing on humanities receive one hour per week of integrated science (nature) lessons.

Images courtesy of Piotr Dobranowski (aged 15)



In these photos entered in the student competition, 'Taking photos of physical phenomena', the student demonstrated how to vary the buoyancy of a bottle by filling it with different amounts of coloured water, thus varying its weight.

A: When the weight of the bottle is less than the upward force of buoyancy, the bottle floats

B: When the weight of the bottle is equal to the upward force of buoyancy, the bottle is suspended in the water column

C: When the weight of the bottle is greater than the upward force of buoyancy, the bottle sinks

in Polish physics textbooks and are available on CD, as well as via the website of Wydawnictwa Szkolne i Pedagogiczne, one of the oldest and largest educational publishing houses in Poland. Maria has also co-authored many print publications to support the teaching and learning of physics.

Furthermore, through her involvement in Science on Stage[w2], a network of local, national and international events for teachers, Maria has shared her ideas with teachers from many other European countries. Not only has she presented projects at three Science on Stage international teaching festivals, but she has helped to organise Science on Stage Poland since 2006. Together with other teachers involved in Science on Stage, she has contributed to the international publications *Teaching Science in Europe: What European Teachers Can Learn From Each Other*[w3].

After many years of teaching, followed by a long career break to raise her family, Maria was ready for a new challenge. In 1994, she started teaching physics at a newly established integrated school, an open-plan school where able-bodied and physically disabled students (aged 6-19) learn together. In each class, there are about five students with disabilities and no more than 20 students in total. In addition to the subject teacher, there is a special educator in the classroom, and students with severe disabilities have a personal assistant, for example to help with writing. There are also specialists to help students overcome difficulties in speaking, reading and memorising, and to provide medical assistance. Such schools are rare in Poland.

"The way of working with these students was something entirely new for me and it was a real challenge. I had to change my working methods. Thanks to this school, I became more creative, innovative and courageous in my selection of experiments and demonstrations. I started to give my students more freedom to find their own solutions and I also started to work with projects – an almost unknown method in Poland." This creativity led to Maria's involvement in three international, EU-funded school projects, such as 'Handicapped children in Europe get to know each other', which integrated science with art, food and cultural heritage.

Of course, even the best teacher's lessons don't always go to plan. "Last year, I had been preparing a scien-

Image courtesy of Boguslawa Rotter

Maria explains the transit of Venus

tific experiment to show that fresh eggs sink in water, but that as they get older, their density changes until they float. I don't remember how long I kept these eggs in my lab before I decided to use one of them in another lesson to show that eggs are fragile. I wanted to show it spectacularly and I dropped an egg onto a tray on the floor. The stinking gas from the egg quickly spread throughout the whole school! The students were very amused by what had happened during their lesson. Other students still ask when I am going to make such an egg again!"

It could be argued that the success of a teacher can be proven by the success of their students. Maria recounts, "Michal is severely disabled with cerebral palsy: he is confined to a wheelchair and has difficulty with speech and co-ordination. I taught him physics at our gimnazjum and liceum and now he is finishing his third year of physics at Warsaw University!"

In an ideal world, Maria would like more science lessons per week and more freedom within the curriculum. More funds for equipment would mean more hands-on experiments. Open science labs, maybe at universities, would encourage students interested in pursuing physics at a higher level. Above all, however, Maria is keen to continue her professional development: "Conferences and workshops are very helpful, and despite my many years of work as a teacher, I can still learn something new." That's an attitude worth passing on to any student.

Web references

w1 – One of the activities that Maria and Miroslaw devised together involves using infrared cameras, for example to visualise the transfer of energy from a bouncing ball to the surface it bounces on.

For an English description of the project, see pages 66-67 of the Science on Stage publication *Science Teaching: Winning Hearts and Minds*. See: www.science-on-stage.de/?p=255 or download the PDF directly from: http://tinyurl.com/bnjysh6

A Polish explanation of the project (*'Kamera na podczerwień w nauczaniu przedmiotów przyrodniczych'*) is available on the website of Wydawnictwa Szkolne i Pedagogiczne. See: www.wsipnet.pl/edukacja/index.html?id=65 or use the shorter link: http://tinyurl.com/candk8j

The Naked Scientists website offers instructions for making your own infrared camera. See: www.thenakedscientists.com or use the direct link: http://tinyurl.com/crxehzh

w2 – Science on Stage is a network of local, national and international events for teachers, initially launched in 1999 by EIROforum, the publisher of *Science in School*. At each national Science on Stage event, a delegation of teachers is selected to represent their country at the Science on Stage international teaching festival.

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w3 – As part of her involvement in Science on Stage, Maria contributed to the publications *Teaching Science in Europe: What European Teachers Can Learn From Each Other*. The PDFs of all three publications (2006, 2008 and 2010) can be downloaded from the Science on Stage website. Visit: http://science-on-stage.de/?p=255

Resources

If you enjoyed this article, why not browse all the teacher profiles in *Science in School*? www.scienceinschool.org/teachers

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Maria representing her school at the national 'science picnic'

Image courtesy of Natalia Witt

The Eduspace website

By the European Space Agency

Reviewed by Marco Nicolini, Italy

If you teach geography, earth science, physics, or even information and communications technology (ICT) or biology, you should definitely visit the Eduspace website from the European Space Agency (ESA). Completely revised in 2010, the latest version offers a wide range of tools and exercises to help users learn about and apply Earth observation concepts and techniques. The site's entire contents are available in English, Danish, Dutch, French, German, Greek, Italian, Portuguese and Spanish.

Earth observation (EO) is the name given to a set of activities for gathering data about Earth's physical, chemical and biological systems. The majority of EO activities are now performed almost entirely by satellites, which is why space agencies such as ESA play a central role in providing EO data. Amongst other applications, EO is used to monitor elevation, changes in vegetation (in cultivations or during deforestation), weather and climate, disasters and the behaviour of the oceans and atmosphere. These are all topics that science teachers can use to develop multidisciplinary activities.

The Eduspace website offers activities and projects involving EO techniques and applications that are suitable for secondary-school science teachers to include in their lessons, as well as for interested secondary-school students.

A section on remote sensing helps to familiarise beginners with remote-sensing concepts, satellite-based EO and data acquisition, and shows them how the information can be used and organised in geographical information systems (GIS). Sub-sections include remote sensing in-depth; the history of EO; satellite orbits; and EO satellites.

The most valuable aspect of Eduspace for teachers is the wealth of software-based activities that can be downloaded from the resources section. Using these, teachers can develop multidisciplinary activities for their students. For example, the image catalogue viewer allows you to search and download satellite images from the huge image database of the main ESA-supported missions. The viewer's companion, LEOworks, is a simple but powerful programme for processing the images. For example, it allows you to crop, zoom and resize images; measure distances; check geographical coordinates; produce statistical histograms; combine and animate a series of images; and use GIS tools. ICT teachers can show students how numbers represent coloured pixels, whereas geography, earth science and physics teachers can focus on the interpretation of those pixels and other data.

Another useful programme to download from the Eduspace website is Arcexplorer, with which you can view and query geographic data stored on your computer or the web, display a wide variety of image formats, and create maps. Note that this programme has now been superseded by Arcgisexplorer, which includes GPS integration, geo-referencing and geo-tagging tools and can be downloaded from the website of software company Esri (www.esri.com). All of the programmes available on Eduspace are accompanied by succinct but complete tutorials, plus online help.

Also helpful are the case studies of EO applications in the 'Earth from space', 'environmental issues' and 'Envisat for schools' sections. These case studies focus on regions across the world, and are good examples of how you can use Eduspace to download and process ESA satellite images of your region, your town, or even your backyard.

In short, the Eduspace website provides teachers with a vast supply of material that can be integrated into their lessons.

Physics

General science

Details

URL: www.esa.int/eduspace

Resources

To learn more about GIS and Arcgisexplorer, see:

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

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

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The Periodic Table of Videos website

By the University of Nottingham, UK

Reviewed by Marie Walsh, Ireland

There are a number of reasons why you might *not* want to read this review: perhaps you do not teach chemistry, you are resisting the use of video clips in your teaching, or you are looking for non-English teaching materials. These are not good reasons though, as you will see. I challenge you to visit The Periodic Table of Videos website, as it might just convert you.

You may feel that the website is primarily a resource for chemistry teachers. However, chemistry sits directly between physics on the one hand and biology on the other, so you can be reassured that there's something here for teachers and students of all the sciences. For example, the site has a link entitled 'sixty symbols' that leads to short video clips about the symbols used in physics and astronomy. There is also a link to the Foodskey website, about the science behind what we eat and drink. And the molecular videos feature a range of well-known drugs such as aspirin, morphine and salbutamol.

Importantly, all of the videos are short, engaging and interactive. My colleagues and I use them to trigger discussions on specific topics, but also just for general interest. The Periodic Table of Videos was a difficult website to review because I just kept going back to watch one more video. I defy you not to become entranced by these clips!

The home page features an interactive periodic table linked to short videos on each element. Caesium, for example, is presented in the context of its use in exact time measurement, and by showing its explosive reaction with water. Most videos are about 10 minutes long, and in the classroom you may decide to use all or just part of a clip. Some videos are available on Youtube in other languages, such as Spanish, Portuguese, Indonesian or Italian.

The Periodic Table of Videos is produced by a multidisciplinary team of scientists at the University of Nottingham, UK, all of whom feature in the videos. The team is led by Martin Poliakoff, who has a very distinctive, relaxed and engaging camera presence. Other members of the team include lecturers who present their own specialities, such as Pete Licence with his explosive practical demonstrations; technicians; a public awareness scientist; and Brady Haran, a video journalist with a passion for science communication, who is also the creator of the website. With this wealth of expertise, it is no surprise that the team has created such a marvellous resource for teachers and students. As well as via their website and on Youtube, you can follow the team on Facebook and Twitter and by RSS feed. Brady Haran also has a blog with links to his photos on the online photo repository, Flickr.

The Periodic Table of Videos links to a sister site, Test Tube[w1], which is another brainchild of Brady Haran, featuring a collection of videos. Test Tube started in 2007, when Brady was appointed filmmaker-in-residence for the Nottingham Science City website[w2]. Test Tube's purpose is to show what science is really like, from the highs of exciting breakthroughs to the lows of tedious experiments. The Periodic Table of Videos grew from this idea.

Although the elements of the periodic table are the main focus of The Periodic Table of Videos website, it offers so much more: there is a large assortment of miscellaneous chemistry-related videos. One of my favourites is 'Perfect perfume', in which the team try to create the ultimate Valentine's Day scent. Others cover topics ranging from the pesticide DDT to dynamite and Viagra® – and the 'elements song' is an excellent piece of comedy! There is even a set of videos on road trips that the team have taken to parts of the UK, Europe and beyond. For example, during a trip to Turin in Italy, they produced a video on the chemistry of the Turin shroud and radioactive carbon dating.

The Periodic Table of Videos is a work in progress; new videos are constantly being added, and the elements videos are updated as the team sees fit. One recent update was to the carbon video: to include more information on allotropes and the wonderful Nobel prize-winning material, graphene. The website is an example of the way students should be engaging with science. No textbook could ever capture the imagination in the way these presenters do. They also have the facilities and experience to demonstrate experiments that would not be possible in a school laboratory.

The latest video I watched was filmed on Martin Poliakoff's birthday. He visited the Nottingham Nanotechnology and Nanoscience Centre, where one of the researchers there took a hair from Martin's head and beamed a stream of electrons onto it, creating a microscopic lithograph of the periodic table on the hair. Just one more wonder of modern science and technology, and just one more imaginative video on this marvellous, highly recommended website. Do visit it and experience it for yourself.

Details

URL: www.periodicvideos.com

Web references

w1 – The forerunner of the Periodic Table of Videos website, the Test Tube website, hosts a wide range of videos about the world of science. See: www.test-tube.org.uk

w2 – Nottingham was designated a 'science city' by the UK government in 2005. See: www.science-city.co.uk

Resources

The Elements of the Periodic Table website, developed by the UK's Open University, enables visitors to explore the impact of chemical elements on our bodies and the world around us, and see how their discovery changed the course of history. See: www.open.edu or use the direct link: http://tinyurl.com/d4levwb

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

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