Spring 2011 Issue 18

SCIENCE in SCHOOL

In this issue:

Biomimetics:
clingy as an octopus or slick as a lotus leaf?

Also:

News from the EIROs:
Mars, snakes, robots and DNA

EIROforum

Highlighting the best in science teaching and research

Editorial

Happy birthday, *Science in School*!

This issue of *Science in School* is rather special: it's now five years since *Science in School* was launched, in March 2006.

During the past five years we have published 350 articles, on topics ranging from particle physics and astronomy, via climate change, earthquakes and spectrometry, to evolution, biodiversity and diabetes. Many of those articles have been translated for publication on our website – producing a further 788 articles in 28 European languages.

Likewise, our readership continues to grow and grow: about 15 000 copies of the English-language print journal are distributed across 41 European countries, and our website receives well over 30 000 visitors from across the world every month – a figure that continues to rise. *Science in School* is read not only by teachers, but also by teacher trainers, scientists and many others who are interested in science education.

Perhaps you, as one of our readers, have wondered who is behind *Science in School*? Who makes it possible for science educators across the world to share inspiring teaching ideas or keep up-to-date with cutting-edge science – for free?

First, there are the publishers of *Science in School*: the eight European inter-governmental research organisations that make up EIROforum (see page 2). The idea for the journal was born of EIROforum's commitment to supporting and improving science education in Europe, and EIROforum has funded the journal right from the beginning. From 2005 to 2008, there was also generous support from the European Commission.

Francesco Romanelli, current chairman of EIROforum, explains: "EIROforum recognises the importance of science education, both to train the next generation of scientists and to ensure a scientifically literate public. Teachers are a vital element in this process, and we are proud and happy to support them with *Science in School*."

On a day-to-day level, the journal is run by a two-person editorial team. Before moving into publishing, both my colleague Dr Marlene Rau and I spent several years in research: Marlene in developmental biology, and I in insect ecology. We source, edit and sometimes write the articles; organise the copy-editing, layout, printing, distribution and translation; maintain the website; publicise the journal; sell advertisements and generally keep everything running. It's a lot of work but enormous fun.

Of course, none of this would be possible without a great deal of voluntary help. We currently have 76 referees – European science teachers who help us decide which articles to publish and how they could be improved. More than 250 scientists and teachers have volunteered to translate articles into languages from Albanian and German to Portuguese and Ukrainian. And of course there are the authors, who share their teaching ideas and scientific knowledge with our readers.

We would like to extend our grateful thanks to these people and to everyone else involved. We look forward to the next five years of *Science in School*!

Eleanor Hayes
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www.scienceinschool.org

About *Science in School*

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

The journal addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge research.

It covers not only biology, physics and chemistry, but also earth sciences, engineering and medicine, focusing on interdisciplinary work.

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

Science in School is published quarterly, both online and in print. The website is freely available, with articles in many European languages. The English-language print version is distributed free of charge within Europe.

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Subscriptions

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- Swap ideas with teachers and scientists in the *Science in School* online forum
- Post comments on articles in *Science in School*.

Submissions

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

Referee panel

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

Book reviewers

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

Translators

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

Contents

Additional online material

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

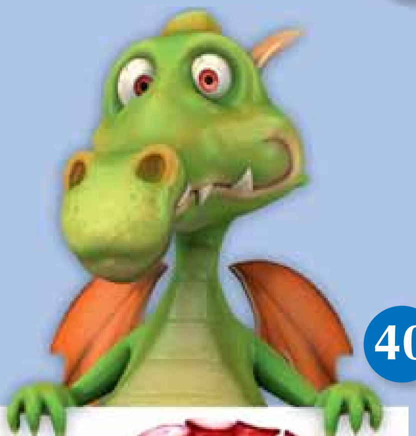
See: **www.scienceinschool.org/2010/issue18**

At the end of each article in this issue, you may notice a square black and white pattern. With the aid of a smart phone, this QR code will lead you straight to the online version of the article. All you need to do is download a free QR code reader app (such as BeeTagg or i-Nigma) for your smart phone and scan the code with your phone's camera. To find a suitable one for your phone, see: http://tinyurl.com/byk4wg
Hint: the apps works better in good light conditions, and with a steady hand. You may also want to try holding your camera at different distances from the code.

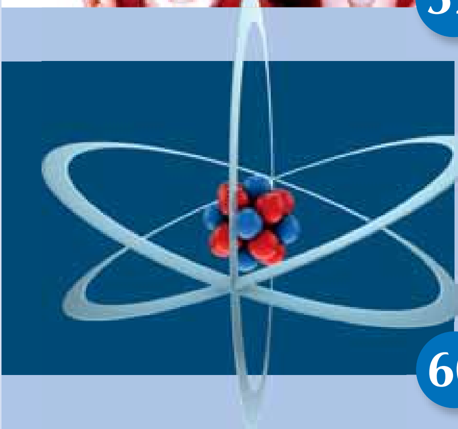
You can then use all the live links to the references and resources, download the PDF, send the article to your friends, leave comments, and much more. What do you think about this new feature? Does it work for you? Leave your feedback here: www.scienceinschool.org/QRfeedback


17


32


40


52


60

Mars, snakes robots and DNA

EIROforum, the publisher of *Science in School*, is a partnership of eight European inter-governmental scientific research organisations (EIROs). As regular readers of *Science in School* will know, the range of research done at these organisations varies widely – from molecular biology to astronomy, from fusion energy to space science. The equipment is also very disparate – including enormous particle accelerators; beams of neutrons or high-energy X-rays; large telescopes or the International Space Station.

Whether individually or as part of EIROforum, the EIROs are also involved in many outreach and education activities – for school students, teachers or the general public. *Science in School* is one example of a joint EIROforum activity; this article details some of the other research and outreach activities of the EIROs.

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

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

Image courtesy of CERN

Juliette Davenne (left) and Marie Bugnon (centre) from CERN's communication group prepare the mystery boxes for primary schools with Olivier Gaumer (right) of PhysiScope

CERN: young scientists in the making

With help from CERN, some 700 Swiss primary-school children from the Geneva area will try out the scientific method for themselves this year. On 26 January 2011, 30 local primary-school teachers met at the site of the LHCb experiment for the launch of the '*Dans la peau d'un chercheur*' ('Be a scientist for a day') project, a joint activity by CERN, PhysiScope (University of Geneva) and the local education authorities in the Pays de Gex and the Canton of Geneva.

From February to June 2011, children aged 9-12 will carry out their own investigations to try to discover what is inside a mystery box, just like CERN scientists attempting to detect particles which cannot be seen with the naked eye.

The pupils will begin by designing and carrying out experiments, after which they can compare their ideas and send questions to CERN scientists via the project website. In April and May, they even get to visit a CERN experiment or take part in a PhysiScope event – a chance to grill the physicists about their own experimental methods. Finally, the children will give a lecture of their own, just like real scientists do.

For more information, visit the website (in French): www.cern.ch/danslapeaudunchercheur

For more ideas for teaching about black boxes, see: www.scienceinschool.org/advent2010/day1

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

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

Image courtesy of CERN

Science in School is published by EIROforum, a collaboration of research organisations. **Eleanor Hayes**, Editor-in-Chief of *Science in School*, reviews some of the latest news from the EIROforum members.

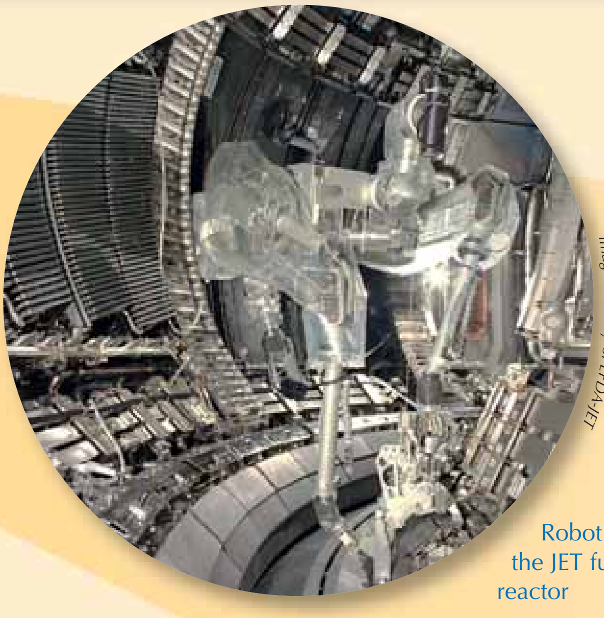


Image courtesy of EFDA-JET

Robotic arm inside the JET fusion reactor

EFDA-JET: fusion energy for schools

Fusion holds many attractions for school students of all ages – the concepts of atoms, the Sun and clean energy resonate just as much with 5-year-olds as with pre-university students. Catering for this range has led the communications group at Culham, UK, to develop different tools: on-site visits and off-site talks for the older children and school visits with the 'Sun Dome' – a sort of mobile planetarium – to engage the younger children.

Visits to EFDA-JET are very popular. Some 1500 school students visited in 2010 and so many schools want to visit (and revisit) that bookings are now being made for 2012. Over the past 18 months, visiting school classes have had the additional excitement of getting a glimpse of the actual fusion reactor (JET), which is being refurbished. When it is operating, the reactor is of course sealed off for safety reasons. Even then, however, visitors can see a full-scale model; this shows the interior of the reactor and the robotic arms that carry out most of the work inside (see image).

Education manager Jo Silva is delighted that so many students are learning about fusion: "It's fantastic to see this enthusiasm that hopefully will translate into a new generation of scientists and informed public."

To learn more about EFDA-JET, see: www.jet.efda.org

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

EMBL: the first annual schools lecture

On 10 December 2010, Dr Jan Korbel addressed 150 school students and their teachers at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany. Several hundred more watched live over the Internet from classrooms across Europe. In the first in a series of annual EMBL Insight Lectures, Jan described the advances that have recently been made in DNA sequencing technology and human genome analysis, and the possible implications that these advances could have for disease research – particularly cancer research. Questions came from both the lecture hall and classrooms via Skype.

"As scientists we have an obligation to explain our research to the public, which obviously includes the young public who are still undecided about their career path," says Jan. Philipp Gebhardt, education officer at the European Learning Laboratory for the Life Sciences, EMBL's education facility, which organised the lecture, points to the value of communicating science in such a way: "There is a great social aspect to this. Many people in different countries can watch the same lecture at the same time and ask questions directly to the speaker. It makes it accessible to everyone."

The lecture remains accessible, as it can be watched here: www.embl.org/ells/insightlectures

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

To learn more about EMBL, see: www.embl.org

Image courtesy of André-Pierre Olivier and Jan Korbel

Image courtesy of EMBL Photolab

ESA: walking on 'Mars'

The first humans have landed on 'Mars'! On 14 February 2011, Italian Diego Urbina, Russian Alexandr Smoleevskiy and Chinese Wang Yue took their first steps on the simulated Martian surface. The sandy 60 m^2 terrain, designed to resemble the Gusev crater on the Red Planet, is housed in the Institute of Biomedical Problems in Moscow, Russia, one storey above the cylindrical modules housing the crew.

"Today, looking at this red landscape, I can feel how inspiring it will be to [be] the first human to step foot on Mars," said Diego at the beginning of his three-hour 'Mars-walk' with Alexandr.

This was the highlight of the first full-duration simulated flight to Mars, the international Mars500 project with extensive participation by the European Space Agency (ESA). For more than eight months, Diego, Alexandr and Yue and three colleagues had been isolated on a virtual 'flight to Mars'.

Once the mothership arrived in 'orbit' around Mars, Diego, Alexandr and Yue entered the lander on 8 February 2011 and 'landed' on Mars four days later. After three Mars-walks, they returned to the mothership on 24 February, rejoining their colleagues who had continued to orbit Mars.

Finally, on 1 March 2011, the most difficult part of this psychological study of long flights began: another eight months of monotonous 'interplanetary cruise' to get back home. Except this time, the astronauts won't be able to look forward to a trip to Mars.

To watch a video of the crew's first Mars-walk, see: www.esa.int/SPECIALS/Mars500/SEMRCFOT1KG_0.html

For more information on the Mars500 project, including a downloadable information kit, text and video diaries by the crew, and much more, see: www.esa.int/SPECIALS/Mars500

The crew will even answer your personal questions by email (to mars500crew@esa.int). Keep them short and think carefully – only the best questions will be relayed to them through 'mission control'.

To find out how scientists envisage that Mars could be made habitable for humans, see:

Marinova M (2008) Life on Mars: terraforming the Red Planet. *Science in School* **8**: 21-24. www.scienceinschool.org/2008/issue8/terraforming

To learn more about the European Space Agency, see: www.esa.int

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

Diego Urbina and Alexandr Smoleevskiy on their simulated Marswalk

An artist's impression of the super-Earth exoplanet orbiting the star GJ 1214. The planet appears as a large crescent in the foreground with its red host star behind

ESO: first super-Earth atmosphere analysed

Using the Very Large Telescope of the European Southern Observatory (ESO), the atmosphere around a super-Earth exoplanet has been analysed for the first time. The planet, which is known as GJ 1214b and has 6.5 times the mass of Earth, was studied as it passed in front of its parent star and some of the starlight passed through the planet's atmosphere. We now know that the atmosphere is either mostly water in the form of steam or dominated by thick clouds or hazes.

GJ 1214b lies about 40 light-years from Earth in the constellation of Ophiuchus (the Serpent Bearer), and its planetary nature was confirmed in 2009, also using ESO telescopes. Initial findings suggested that it had an atmosphere, which has now been confirmed and studied in detail by an international team of astronomers, led by Jacob Bean (Harvard–Smithsonian Center for Astrophysics). "This is the first super-Earth to have its atmosphere analysed. We've reached a real milestone on the road toward characterising these worlds," says Bean.

To learn more, see the press release (www.eso.org/public/news/eso1047/) and the research paper:

Bean JL (2010) A ground-based transmission spectrum of the super-Earth exoplanet GJ 1214b. *Nature* **468**: 669–672. doi: 10.1038/nature09596

Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2011/issue18/eiroforum#resources), or subscribe to *Nature* today: www.nature.com/subscribe.

To find out more about the search for Earth-like exoplanets, see:

Jørgensen UG (2006) Are there Earth-like planets around other stars? *Science in School* **2**: 11-16. www.scienceinschool.org/2006/issue2/exoplanet

Fridlund M (2009) The CoRoT satellite: the search for Earth-like planets. *Science in School* **13**: 15-18. www.scienceinschool.org/2009/issue13/corot

and ESO exoplanet press kit: www.eso.org/public/products/presskits/exoplanets

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

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

Image courtesy of European XFEL

A montage of the main European XFEL building with the underground experiment hall

European XFEL: EIROforum's new member

In November 2010, the seven original members of EIROforum were joined by a new, eighth member: the European X-ray Free-Electron Laser Facility (European XFEL), based in Hamburg, Germany. Like the other members of EIROforum, European XFEL is a European inter-governmental research organisation (EIRO), funded by member states.

The facility will produce ultra-short X-ray flashes which will enable scientists to map the atomic details of viruses, decipher the molecular composition of cells, take three-dimensional images of the nano-world, film chemical reactions and study processes such as those occurring deep inside planets. The European XFEL is currently under construction, and the first X-ray beams will be produced in 2014.

As a member of EIROforum, European XFEL will contribute not only to the funding, but also to the organisation and contents of *Science in School*. The editorial team are looking forward to welcoming a new member to the editorial board and to articles about the work of European XFEL.

To learn more about European XFEL, see: www.xfel.eu

ESRF: shining light onto snake evolution

If you ask someone to describe what characterises a snake, one of the answers is likely to be 'no legs'. We know that this wasn't always the case – the ancestors of snakes probably looked similar to modern lizards, but over time, they lost their legs. How did that happen?

Scientists at the European Synchrotron Radiation Facility (ESRF) are helping to solve this puzzle using novel X-ray imaging technology to investigate a fossilised snake, *Eupodophis descouensi*, which lived 95 million years ago in Lebanon, and has two small limbs at its pelvis. The detailed 3D images revealed that the internal architecture of these fossilised bones strongly resembles that of modern terrestrial lizard legs. Moreover, the results suggest that *E. descouensi* lost its legs not because they grew in a different pattern, but because they grew more slowly, or for a shorter period of time, than those of their lizard relatives.

To learn more, see the press release (www.esrf.eu/news/general/Snake-with-leg) and the (freely available) research paper:

Houssaye A et al. (2011) Three-dimensional pelvis and limb anatomy of the Cenomanian hind-limbed snake *Eupodophis descouensi* (Squamata, Ophidia) revealed by synchrotron-radiation computed laminography. *Journal of Vertebrate Paleontology* **31(1)**: 2-7. doi: 10.1080/02724634.2011.539650

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

To learn more about ESRF, see: www.esrf.eu

Image courtesy of Chantal Argoud / ESRF

A detail of the *Eupodophis descouensi* fossil, with a finger pointing to the leg

ILL: a silken surprise

For about five thousand years, silk has been a precious commodity, prized for its beauty, lightness and strength. For three thousand years, the Chinese managed to keep a monopoly on the lucrative silk trade by guarding the secret of how to produce it. Finally, however, the secret got out: silk is produced by moth larvae, also known as silkworms.

Even today, silk continues to fascinate us. For example, how is the silk fibre assembled from the protein precursors inside the silkworm? A recent study at the Institut Laue-Langevin used neutron beams to reveal some unexpected properties of silk proteins. Usually, proteins are stable at a concentration of approximately 1 mg / ml, and only start to aggregate at a concentration of about 5-10 mg / ml. The silk precursor proteins, however, behave very differently. The concentration inside the silkworm can be up to 400 mg / ml and yet the proteins remain in solution. When the concentration drops, however, the proteins begin to unfold and expand, eventually clumping together. Under lab conditions, the effect is rather like a neat ball of string unravelling into a tangled mess, but inside the silkworm, order reigns: the insect controls the process, spinning the proteins into highly ordered silk filaments. These results are a big step towards understanding the amazing properties of silks and how to synthesise them and develop materials.

To learn more, see the press release on the ILL news website (www.ill.eu/nc/quick-links/news) or use the direct link: http://tinyurl.com/658slrp

See also the research paper:

Greving I et al. (2010) Small angle neutron scattering of native and reconstituted silk fibroin. *Soft Matter* **6**: 4389-4395. doi: 10.1039/C0SM00108B

To find out about previous ILL research into spider silk, see:

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

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

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

To learn how to use this code, see page 1.

A silkworm: larva of the domesticated silkmoth

Image courtesy of arlindo71 / iStockphoto

Science on Stage: countdown to the international festival

Science on Stage brings together many of Europe's most innovative and inspiring science teachers. **Andrew Brown** reviews some of the recent national activities.

Science on Stage offers a platform for European science teachers to share their teaching ideas, workshops and performances. Via national events, teachers compete for places at the Science on Stage international teaching festival, which this year will be held in Copenhagen, Denmark, on 16-19 April[w1]. The 2011 festival, with the motto of 'Science teaching: winning hearts and minds', will bring together 350 European science teachers.

France: Solar-powered curry and musical sunshine

The French organisers of Science on Stage, *Science à l'Ecole*[w2], collaborated with a national science contest for middle- and high-school students called *CGenial*. On 15 May 2010, 81 projects were presented in Nantes and 12 teachers were selected to attend the international Science on Stage festival this year.

Guillaume Lebatard and Amandine Sultana described how their students, aged 11-12, used little more than an old satellite dish and some aluminium foil to make a steaming hot gourmet meal. The foil was used to line the surface of the dish, creating a parabolic reflector capable of concentrating the Sun's energy. This solar cooker proved sufficiently powerful to boil water and even to make a delicious chicken curry!

Mathematics teacher Francis Loret challenged his 14-year-old students to battle against him in the Internet's biggest virtual sailing race, the Vendée Globe[w3]. Students were given expert training in the basic principles of sailing and in meteorology and the interpretation of weather maps. They had to grapple with the unfamiliar concepts of spherical geometry, which underpin the calculations necessary to sail in the race. Of the 340 000 race participants, Francis's most accomplished student sailor finished in an impressive 216th place.

Mozart, Bach, Beethoven, Rachmaninoff… and the Sun? Who would have thought that in addition to sustaining all life on Earth, the Sun also produces music? Jean-Michel Laclaverie and Elisabeth Martre's students studied the frequency of vibrations emitted by the Sun and used them to show how this 'music' compares to that produced by more traditional musical instruments.

Greece: Rainbows and Mars

On 15-16 October 2010, 3000 visitors – including 2000 students – flocked to the Hellenic Science on Stage event[w4] at the Laboratory Centre for Physical Sciences of Aigaleo. There, teachers and students from across Greece presented 110 high-school projects, including laboratory exhibits and two student performances.

Physics teacher Elias Kalogirou described how his students designed experiments to explain the wonders of the rainbow using their understanding of optics; why is a rainbow coloured, why is it bow-shaped and how can we create one in the classroom? (Elias has also written an article on microscale chemistry for *Science in School*: see Kalogirou, 2010.)

Image courtesy of Guillaume Lebatard

Creating the parabolic reflector

Image courtesy of Guillaume Lebatard

Solar-powered cooking

Using everyday materials, Ioannis Gatsios built 10 devices designed to teach his students about the behaviour of gases. One consisted of an inflated balloon attached to a metal bottle. When the bottle was plunged into liquid nitrogen at -190°C, the balloon deflated, illustrating that the volume of a gas is reduced by a decrease in temperature.

Theodoros Pierratos encouraged his students to think like astronauts. He asked them to consider everything that is required to plan a trip to Mars and live on its surface. Classroom experiments helped answer questions such as: how does the solar wind affect electronic equipment, and how can we produce the energy required to maintain a manned base on Mars? (Theodoros's work has also been featured in *Science in School*. See Patterson, 2009.)

Image courtesy of Elias Kalogirou

Image courtesy of Elias Kalogirou

Elias Kalogirou demonstrates why a rainbow is bow-shaped

Image courtesy of Ioannis Catsios

The balloon deflates when the metal bottle to which it is attached is immersed in liquid nitrogen

Image courtesy of Theodoros Pierratos

Dimistra Milioni, president of the education council of the municipality of Aigaleo, learns about the 'capacitor in action' project at the Science on Stage Greece event. The municipaty of Aigaleo is the main sponsor of Science on Stage Greece

Attending the international festival

At each national Science on Stage event, a fixed number of teachers were selected to represent their country at the international Science on Stage festival in Copenhagen. For these teachers, participation will be free.

For other science teachers who wish to attend the international festival, there are a limited number of places for which a registration fee will be charged. See the Science on Stage website[w5] for details.

References

Kalogirou E (2010) Microscale chemistry: experiments for schools. *Science in School* **16**: 27-32. www.scienceinschool.org/2010/issue16/microscale

Patterson L (2009) A classroom in space. *Science in School* **12**: 50-54. www.scienceinschool.org/2009/issue12/spaceclassroom

Web references

w1 – To find out more about Science on Stage Europe and to contact your national organisers, see: www.science-on-stage.eu

w2 – To learn more about Science on Stage France, see: www.sciencesalecole.org

w3 – Details of the Vendée Globe can be found here: www.vendeeglobe.org/en

w4 – For more information about Science on Stage Greece, see: www.physics.ntua.gr/SOS-GREECE/contest.html

w5 – To learn more about the international festival and how to apply to take part, see: http://science-on-stage.eu/?p=3

Resources

After each of the previous international Science on Stage festivals (and the Physics on Stage festivals that preceded them), the Irish delegates produced a book describing how to carry out their favourite experiments in the festival. These books can be downloaded free of charge from the Science on Stage Ireland website: www.scienceonstage.ie/resources.html

To view all other *Science in School* articles about Science on Stage, see: www.scienceinschool.org/sons

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Andrew Brown recently graduated from the University of Bath, UK, with a degree in molecular and cellular biology. During his course, he took a year out to work for the agrochemical company Syngenta where he specialised in light and electron microscopy. He now works as an intern for *Science in School*, based at the European Molecular Biology Laboratory in Heidelberg, Germany.

To learn how to use this code, see page 1.

Image courtesy of Theodoros Pierratos

Investigating how solar wind affects electronic equipment

Young scientists at the cutting edge: EIROforum prize winners

Courtney Williams, winner of the CERN prize at the European Union Contest for Young Scientists 2009, reports on her experiences and those of the other EIROforum prize winners.

In September 2009, in the Palais de la découverte in Paris, France, 132 young scientists aged 14 to 21 from Europe and beyond came together for the 21st European Union Contest for Young Scientists (EUCYS)[w1] (see Rau, 2009). As part of the contest, participants presented original projects from all corners of science and competed for prizes while sampling some of Paris's world-famous culture and getting to know each other. In addition to the main prizes from the European Union, a number of special prizes are awarded each year, including one-week visits to the EIROforum[w2] institutes – a group of seven (now eight) research organisations around Europe, incorporating some of the world's most exciting science. One of the lucky winners in 2009, I will share with you my experiences and those of four other winners of the EIROforum prizes that year.

Kristina Aare – studying bacteria in polluted water

"My interest in science started in secondary school, with a focus on biology and chemistry, which led to my successful participation in a number of national competitions in my home country of Estonia. My main passion is biochemistry, so I decided to work on the project which was to win the European Molecular Biology Laboratory [EMBL][w3] prize at EUCYS."

Kristina Aare, winner of the 2009 EMBL prize at EUCYS

© European Communities, 1995-2009

Jake Martin with his winner's certificate

© European Communities, 1995-2009

Image courtesy of Chantal Argoud / ESRF

Image courtesy of techengine / iStockphoto

Kristina's research was dedicated to the problem of environmental pollution with oil. She studied the soil bacterium *Pseudomonas putida*, which has an extremely high tolerance of phenol, toluene and other toxic organic solvents found in oil. She is really looking forward to her visit to EMBL in Heidelberg, Germany, and the insights this will provide her with.

Jake Martin – developing a new way of creating fuel

Jake travelled halfway around the world to compete in EUCYS – from Auckland, New Zealand – and then again when he visited Culham, UK, for his visit to the European Fusion Development Agreement - Joint European Torus (EFDA-JET)[w4].

Jake, now 19, has been competing in science fairs since he was 14. His EUCYS project consisted of a gasifier he built, which turns wood into a fuel gas that can run a normal petrol engine. Another output of his gasifier is biochar, a type of charcoal you get from pyrolising biomass. The primary use of biochar is not as a fuel, however, but to take carbon dioxide out of the atmosphere. For his prize Jake visited the EFDA-JET facility, which itself is looking at alternative methods of generating energy: it is the only operational fusion experiment capable of actually producing fusion energy. He received advice and information from scientists working there, and learned more about how international co-operation plays a part in European science – a lot more so than in New Zealand.

Damian Steiger – building a miniature particle accelerator

"My project was to design and build a small cyclotron, small enough to fit on a desk. Therefore, I tried to apply as many new technologies as possible to the design of the first cyclotron, built in the 1930s. With my project I showed a way of building small cyclotrons with state-of-the-art technology and at low cost. In future some of the knowledge might be used to build small and compact cyclotrons for medical applications or materials research."

For his prize, Damian went to the European Synchrotron Radiation Facility (ESRF)[w5] and the Institut Laue Langevin (ILL)[w6] at their joint campus in Grenoble, France, where he visited all the different laboratories and control rooms. "I enjoyed the visit to the reactor at ILL most," he says. "The blue glow of the reactor due to the characteristic Cherenkov radiation was especially impressive. At the moment I am studying physics at ETH Zürich, Switzerland, and thanks to my visit to ESRF and ILL, I have a better idea of which field I want to work in afterwards."

Julian Petrasch – tracking asteroids from the computer

In his winning project, 'Sky Alignment Simulator (SAMS) – improved determination of minor planet positions', Julian Petrasch from Germany developed software to measure the positions of asteroids more precisely. The 17-year-old used the new software to pinpoint the positions of about 20 asteroids and two space probes. He reports that some publications on this topic from the Berlin Observatory have already used data processed with this new method.

As the winner of the ESO prize, Julian enjoyed the trip of a lifetime to two of ESO's[w8] observatories in Chile from 7 to 13 February 2010. "It was amazing to walk between these giant telescopes and see how such large machines can be controlled and moved so precisely just by one person," he said after his visit to Paranal

Damian Steiger in front of ESRF

Julian Petrasch visiting the Paranal Observatory in Chile

Image courtesy of ESO

Courtney Williams pays a visit to the CERN library

Image courtesy of CERN

Image courtesy of techengine / iStockphoto

Observatory. Julian, who became an amateur astronomer when he was only six years old, also feels deeply impressed by Chile, its nature, its enormous distances and the astonishing silence of the desert.

Courtney Williams – investigating underwater neutrino detection

Unlike for many other contestants, EUCYS was my first international science fair. My project, 'Listening for ghost particles: the acoustic cosmic ray neutrino experiment', had two aspects: analysing background noise from an underwater neutrino detector, and simulating the acoustic pulses that high-energy neutrinos should make when they enter water.

EUCYS was a great experience and one of the best weeks I've ever had – quite apart from winning a prize. As it happens, I was lucky enough to be awarded the CERN[w7] prize: when I visited the institute this summer, I enjoyed learning about how all the different detectors work, as well as talking to people from different departments, including the press office, the director general and the engineers. My trip has intensified my desire to work in neutrino astrophysics and I'm really eager to go back to CERN!

Further EIROforum winners

The other EIROforum winner at EUCYS 2009 was Ana Shvetsova from Russia. Ana, who designed a vehicle to move on Venus, was awarded the European Space Agency[w9] prize. She explained her project in an online video[w10].

With the 22nd EUCYS event, which took place in 2010 Lisbon, Portugal (see Rau, 2011), the number of young scientists visiting the EIROforum organisations continues to grow.

References

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

Rau M (2011) Young minds in science: the European Union Contest for Young Scientists 2010. *Science in School* **18**: 13-16. www.scienceinschool.org/2011/issue18/eucys2010

Web references

w1 – Find out more about the European Union Contest for Young Scientists on their website: http://ec.europa.eu/research/youngscientists

For a preview of the 2011 contest to be held in Helsinki, Finland, see: http://eucys2011.tek.fi

w2 – To learn more about EIROforum and its research organisations, see: www.eiroforum.org

w3 – The EMBL website can be found here: www.embl.org

w4 – To find out more about EFDA-JET, see: www.jet.efda.org

w5 – Visit the website of ESRF for more information: www.esrf.eu

w6 – To learn more about ILL, see: www.ill.eu

w7 – For more information about CERN, see: www.cern.ch

w8 – Learn more about ESO online: www.eso.org

w9 – Find more information on ESA on their website: www.esa.int

w10 – To watch Ana Shvetsova explain her project (in English with French subtitles) see the www.universcience.tv website or use the direct link: http://tinyurl.com/5vy9yub

Resources

To read Courtney's full report on her stay at CERN and her experience as a EUCYS participant, see her blog: www.butrousfoundation.com/ysjournal/?q=blog/70

To learn more about the individual EIROforum institutes, see:

EIROforum (2010) EIROforum: introducing the publisher of *Science in School*. *Science in School* **15**: 8-17. www.scienceinschool.org/2010/issue15/eiroforum

Courtney describes how she came to be interested in physics in an article in *Symmetry*: www.symmetrymagazine.org/cms/?pid=1000859

If you enjoyed reading this article, browse our collection of event reports online: www.scienceinschool.org/events

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Courtney Williams is studying theoretical physics at Imperial College London, UK. Her main interests lie in neutrino physics and science communication. She has worked at the University of Sheffield and Rutherford Appleton Laboratory, and written articles for publications including *IoP Interactions*, *E&T Education* and *Symmetry*. She is involved in promoting physics to young people as a British Science Association CREST Alumnus, Ignition Creative Spark and STEM ambassador. Her personal website can be found at courtneywilliams.co.uk.

To learn how to use this code, see page 1.

Young minds in science: the European Union Contest for Young Scientists 2010

Marlene Rau reports on the 22nd European Union Contest for Young Scientists (EUCYS).

A sunny afternoon in Lisbon – boatmen set sail from the shores of the River Tejo, evoking thoughts of the many great explorers that have ventured forth from here to discover uncharted territories. It is a late September day in 2010, and in the nearby Electricity Museum, 124 vibrant minds from 37 countries are presenting their own ventures into science.

The hall is abuzz with young contestants (aged 14-21) who have travelled from across Europe and beyond. We, the 18 members of the international jury, have a tough time choosing among these excellent projects: how can you compare the design of a flat-packed Christmas tree with behavioural studies of birds; a collection of Moroccan folk tales with a dig for dinosaur bones; face-recognition

The Portuguese Monument to the Discoveries in Lisbon

Image courtesy of Carlos Paes; image source: Wikimedia Commons

Lisbon's Electricity Museum, host to the 2010 contest

Francesco Romanelli, director general of EFDA-JET and chairman of EIROforum, presents the ILL prize to Radko Kotev. In the background, CERN prize winner Volha Shumskaya (left) and ESA prize winner Vladimíra Bejdová (right)

algorithms with improved methods for wastewater treatment; a gadget for identifying fraudulent drycleaners with a study on whether Internet addiction causes brain lesions?

The European Union suggests a good recipe for creating a winning project: "Choose a subject that interests and inspires you (the idea must of course be an original one). Add a little curiosity and know-how, a touch of perseverance and obstinacy, some advice from specialists, a good pinch of ingenuity, a large measure of a critical mind, enthusiasm and an enterprising spirit and, above all, the best part of your imagination."

While the jury is locked in fierce discussions behind closed doors, the contestants explore Lisbon and its surroundings: they dance the quadrille with costumed guides in the baroque palace in Mafra; dine in the adjoining monastery, served by soldiers training for conflict zones; listen to talks on biodiversity and patenting; and satisfy their curiosity in the 'Explore' room at the Park of Nations Knowledge Pavilion: can you touch a tornado? Are all shadows just black and white?

And of course, there is much to explore inside the Electricity Museum, too: during the breaks, students peruse the museum's marvellous interactive exhibition.

Finally, the 26 prizes are allocated. First-prize winners are Miroslav Rapcak and David Pegrimek from the Czech Republic, who computer-predicted a complete phase diagram of CO_2 nanoclusters; Márton Balassi and Dávid Horváth from Hungary, who developed a computer simulation of ecosystems for the classroom, which can also be used for risk assessment; and Lukasz Sokolowski from Poland, who studied the foraging strategy of the ant *Formica cinerea*.

The ten main prizes sponsored by the European Union are complemented by a range of prestigious special prizes, including those offered by EIROforum[w1]: seven one-week stays at one of its member organisations, each of which is awarded to a worthy participant who would profit from a visit to that institute.

Volha Shumskaya (aged 17) from Belarus will travel to CERN[w2], the European Organization for Nuclear Research in Geneva, Switzerland, where enormous amounts of data are generated and processed every day. This enthusiastic mathematician has studied the extrema of least common multiples and greatest common divisors for sequences of numbers. Janis Smits (aged 18) from Latvia is the proud winner of a visit to the fusion reactor at EFDA-JET[w3] in Culham, UK. Like his host organisation, Janis is concerned with improving energy generation, and has developed a light thin-layer lithium iron phosphate battery to propel his bicycle.

Vladimíra Bejdová (aged 19) from the Slovak Republic will visit the European Space Agency[w4]. The space enthusiast has discovered and analysed a new binary star in the Andromeda constellation using a small telescope.

The biologist among the EIROforum prize winners is Raghd Rostom (aged 19) from the UK. Her use of cells from embryonic chick bones as a model for osteogenic versus chondrogenic differentiation in stem cells won her a visit to the European Molecular Biology Laboratory[w5] in Heidelberg, Germany. Young astronomer Pavel Fadeev (aged 19) from Israel will travel to the European Southern Observatory's[w6] telescopes in Chile, where he can discuss his unique catalogue of 270 extragalactic star-forming regions with professional colleagues.

Maths enthusiast Radko Kotev (aged 18) from Bulgaria was awarded a trip to the Institut Laue-Langevin (ILL)[w7] for finding a new solution to the geometrical Apollonius problem –

The winners of the European Union prizes at EUCYS 2010

Sandro Young from Canada demonstrates his 3D user interface

Image courtesy of the Portuguese Youth Foundation, Host Organiser of EUCYS 2010

constructing a circle that is tangential to three given circles. He will be joined at the campus of ILL and the European Synchroton Radiation Facility (ESRF)[w8] in Grenoble, France, by ESRF prize winner Sebastian Cincelli (aged 19) from Italy, a young engineer who designed 'social' robots on wheels for exploring uncharted areas.

Read about these and all other award winners and their projects on the EUCYS 2010 website[w9].

Apart from explaining their projects to the jury, the contestants also have the chance to present their work to the general public. Over 3000 students from schools across Portugal visit the EUCYS stands and marvel at their peers' ingenuous ideas. This may lay the foundation for the next generation of EUCYS contestants. The event does have an impact, as João Amaral (aged 21) is well aware – one of the many Portuguese student helpers, he was himself a contestant in EUCYS 2007. These helpers not only solve any minor or major problems the contestants have, and guide them through their social programme, but this year also give their own set of awards at the final ceremony, in 14 categories such as 'the funniest', 'the most enthusiastic' or 'the most Portuguese' project (which goes to the Brazilian contestant).

The impact of EUCYS is something Maximos Tsalas from EFDA-JET can vouch for, too – together with Claus Habfast from ESRF, he offered an enjoyable evening of lectures on energy to the students, demystifying the concept of fusion energy, to coincide with the theme of the Electricity Museum[w10]. "EIROforum has been a part of this contest for many years, and last year's winner is currently visiting EFDA-JET, working with us," says Maximos. "We are always looking for bright minds, so we offer selected participants the opportunity to visit EIROforum organisations."

And what is the contestants' verdict? "I'm certain we will carry these memories with us for the rest of our lives: to meet other young scientists, to understand their projects and to share some ideas are our main goals during these days," explains Guoda Radaviciute from Lithuania.

EUCYS is a great experience for everyone involved – and we are already looking forward to EUCYS 2011 in Helsinki, Finland[w11].

Web references

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

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

w3 – More information about EFDA-JET is available here: www.jet.efda.org

w4 – To learn more about the European Space Agency, visit: www.esa.int

w5 – For more details about the European Molecular Biology Laboratory, see: www.embl.org

w6 – More information about the European Southern Observatory is available here: www.eso.org

Contestants exchanging ideas

Image courtesy of the Portuguese Youth Foundation, Host Organiser of EUCYS 2010

Images courtesy of the Portuguese Youth Foundation, Host Organiser of EUCYS 2010

Dancing the quadrille

Dinner in the refectory of the Mafra monastery

w7 – For more information about the Institut Laue-Langevin, see: www.ill.eu

w8 – To learn more about the European Synchroton Radiation Facility, visit: www.esrf.eu

w9 – The EUCYS 2010 website includes information about all participants, their projects and the contest, along with many pictures and videos: www.lisboa.eucys2010.eu

Further movies are available on the EUCYS YouTube channel. See: www.youtube.com/user/EUCYS2010

w10 – The slides of Claus Habfast's and Maximos Tsalas's lectures can be downloaded from the *Science in School* website: www.scienceinschool.org/2011/issue18/eucys2010#resources

w11 – Learn more about the 2011 edition of EUCYS in Helsinki and enter their slogan competition. See: http://eucys2011.tek.fi

Resources

For more information on EUCYS, see the European Commission website: http://ec.europa.eu/research/youngscientists

To find out more about the national competitions and to contact your national organiser, see: http://ec.europa.eu/research/youngscientists (under 'who is involved?')

Read about how last year's winners enjoyed their EIROforum visits:

Williams C (2011) Young scientists at the cutting edge. *Science in School* **18**: 10-12. www.scienceinschool.org/2011/issue18/eucys2009

To learn more about energy, the topic of the EIROforum lectures at EUCYS, see the *Science in School* series of energy articles: www.scienceinschool.org/energy

Learn more about EIROforum and the research performed at its organisations here:

EIROforum (2010) EIROforum: introducing the publisher of *Science in School*. *Science in School* **15**: 8-17. www.scienceinschool.org/2010/issue15/eiroforum

If you enjoyed reading this article, take a look at the full collection of event reports published in *Science in School*. See: www.scienceinschool.org/eventreports

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

Image courtesy of the Portuguese Youth Foundation, Host Organiser of EUCYS 2010

Contestants from the Czech Republic analysed the habitat preferences of black (right) and common (left) redstarts. Unlike the males, females (middle) are very similar in both species

To learn how to use this code, see page 1.

Battle of the birds: interview with Tim Birkhead

Tim Birkhead tells **Karin Ranero Celius** about promiscuous birds and teaching science students.

Tim Birkhead

Image courtesy of John Smith

Biology
Evolution
Animal Behaviour
Ages 16+

If "nothing in biology makes sense except in the light of evolution" (Theodosius Dobzhanky, 1900-1975) this article will be appealing and enjoyable for all biology teachers. It focuses on Professor Tim Birkhead, his life and his research, but also introduces another interesting topic – animal promiscuity and sexual selection – which is probably new for many readers and uncommon in teaching evolution at school.

The article is based on an interview, so the style is pleasant and witty; moreover some difficult points (sperm competition and sperm choice) are explained in a clear and vivid way (for instance, in the synthesis of the battle of sexes, as "maximum fertilisation versus best fertilisation").

The story of Birkhead's life and career is interesting and inspiring for young students attracted by the study of animal behaviour and evolution; his personal methodology in teaching the history of science will also provide science teachers with new and stimulating ideas.

Finally, this article shows that the study of evolution is an ever charming and surprising adventure.

Giulia Realdon, Italy

REVIEW

"Be thou like the dunnock – the male and female impeccably faithful to each other," said Reverend Frederick Morris in 1853. In an attempt to preach fidelity, he encouraged his parishioners to behave like dunnocks (*Prunella modularis*) – small, brown, rather plain-looking birds. Far from being monogamous, however, the dunnocks – from a Victorian point of view – have shockingly lax morals, with the female often mating with several males. What would Reverend Morris have made of the scandalous truth?

Tim Birkhead, professor of behavioural ecology and the history of science at Sheffield University, UK, has

Skomer Island's most famous resident: the puffin

Image courtesy of Julie Langford; image source: Wikimedia Commons

Image courtesy of Wenkbrauwalbatros; image source: Wikimedia Commons

The ever-faithful dunnock

devoted nearly 40 years to the study of promiscuity in birds. From Darwin's time up to the late 1960s it was thought that male animals competed for female partners, with the strongest and most attractive males impregnating the most females, and that females sought only the security of monogamy, copulating with multiple partners only when forced. The unladylike truth that gradually emerged, however, is that females of most species actively seek multiple partners to mate with, an evolutionary strategy to get the very best sperm to fertilise their eggs.

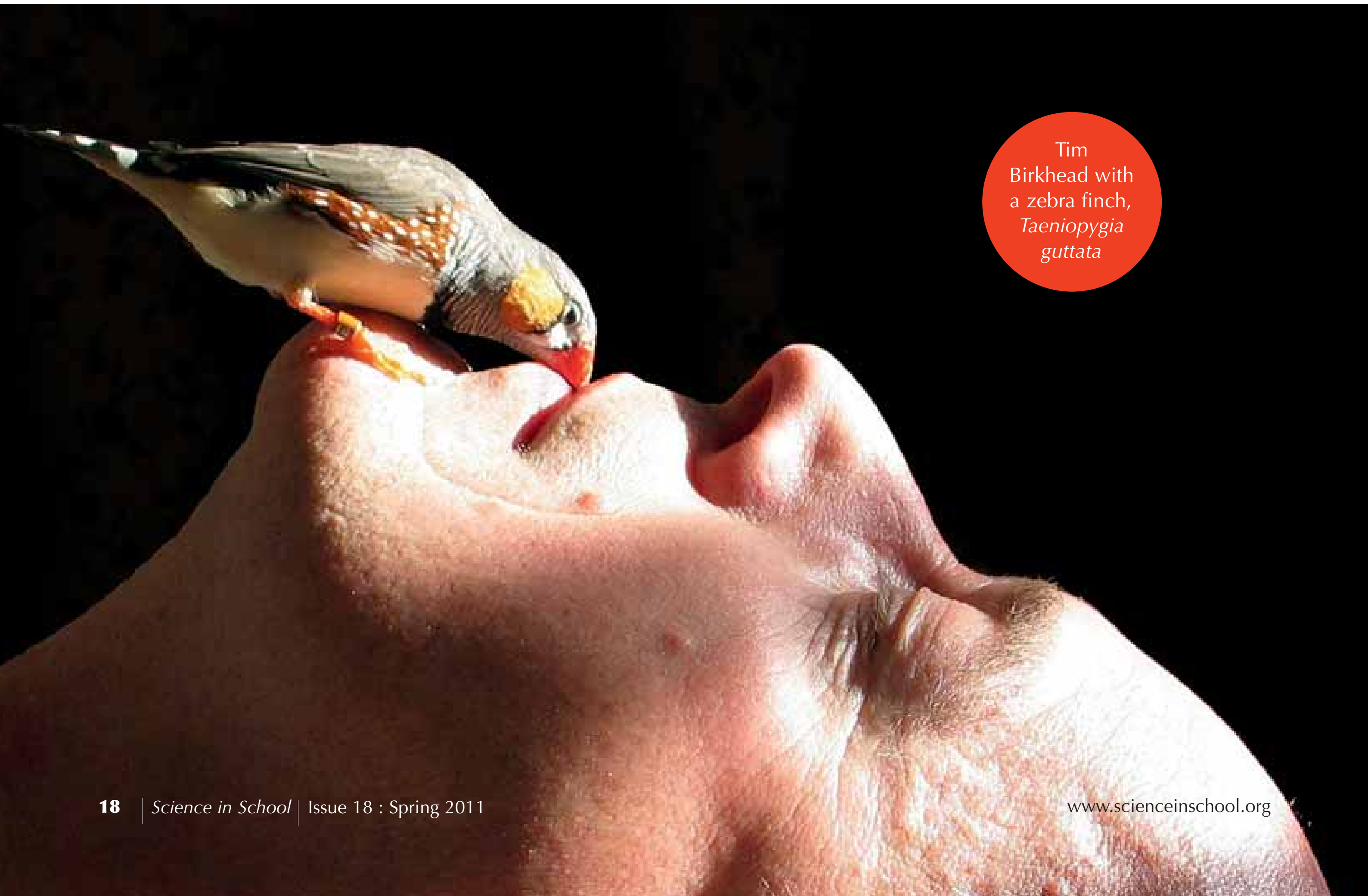
Indeed, rivalry between males and discrimination by females extends beyond the sexual act itself. Inside the female, the sperm of different males fight for supremacy – this is sperm competition. At the same time, the female may be able to select the sperm that are best for her – this is sperm choice. This is the true battle of the sexes. The males and females of each species are permanently locked in a struggle to out-evolve each other, as their reproductive anatomy and behaviour change to achieve their conflicting aims: maximum fertilisation versus best fertilisation.

These radical ideas were just beginning to emerge when Tim Birkhead graduated from university in 1972. "I just feel incredibly fortunate to have been the right age, at the right place and the right time," he says.

Tim's initial interest was in sea birds. In 1972, he started a project to monitor guillemots on Skomer Island, a nature reserve in Wales: he looked at the adult and immature survival rates and the age of the first breeding and reproductive success, as well as assessing the effects of oil pollution and climate change on the population. Although the project continues and he returns to Skomer Island regularly, the focus of his research gradually moved towards sex. In particular, post-copulatory sexual selection.

Tim Birkhead's research has helped to re-shape our understanding of bird mating systems. Why should a bird or an individual copulate with more than one partner? What determines which male fertilises the female's eggs when she has mated with several

Image courtesy of Francesca Birkhead



Tim Birkhead with a zebra finch, *Taeniopygia guttata*

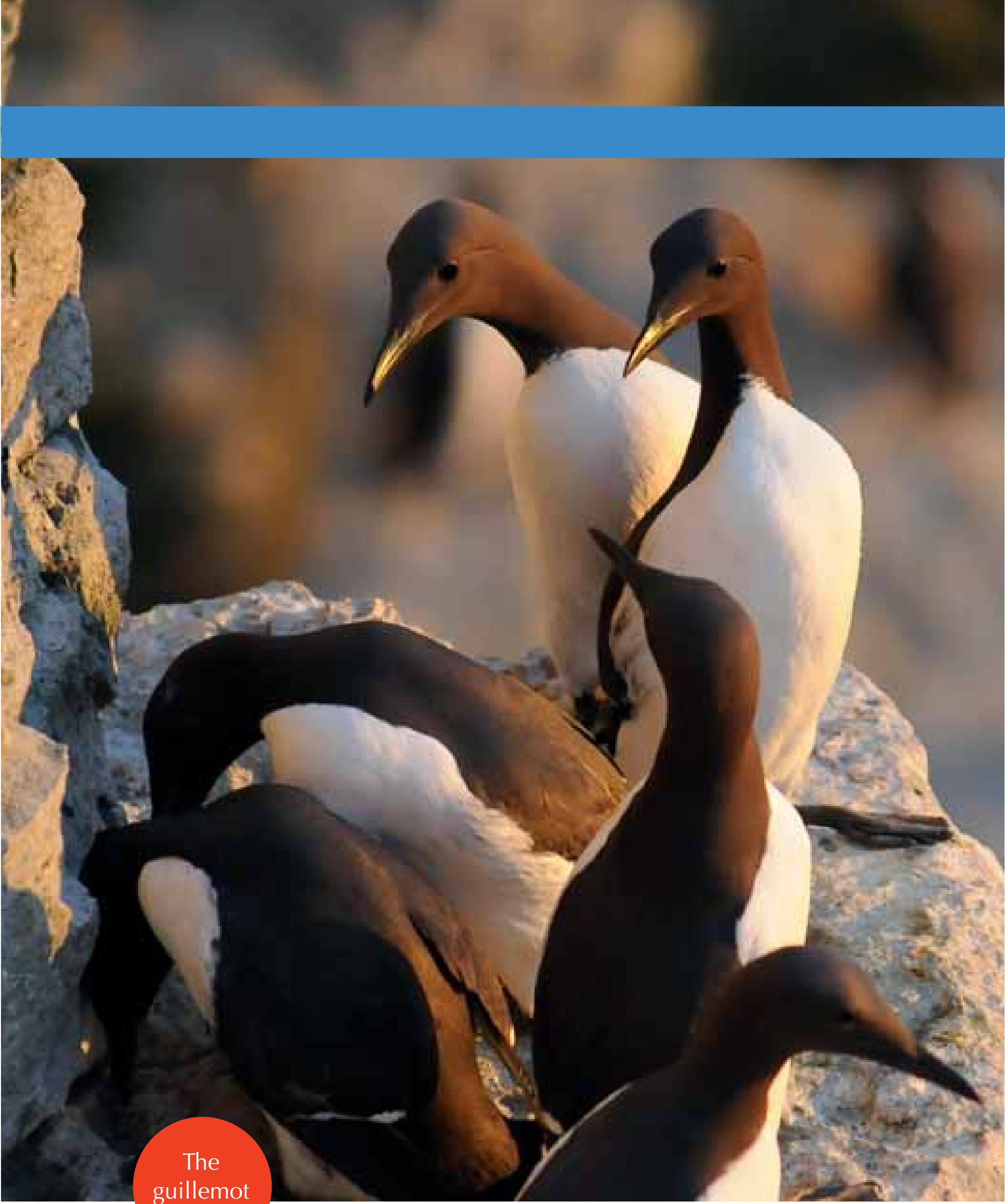


Image courtesy of davthy / iStockphoto

partners? And how are sexual conflicts resolved? His research involves finding out what happens to the sperm of the male inside the female's reproductive tract and investigating the importance of sperm competition and sperm choice in determining which male fertilises the eggs.

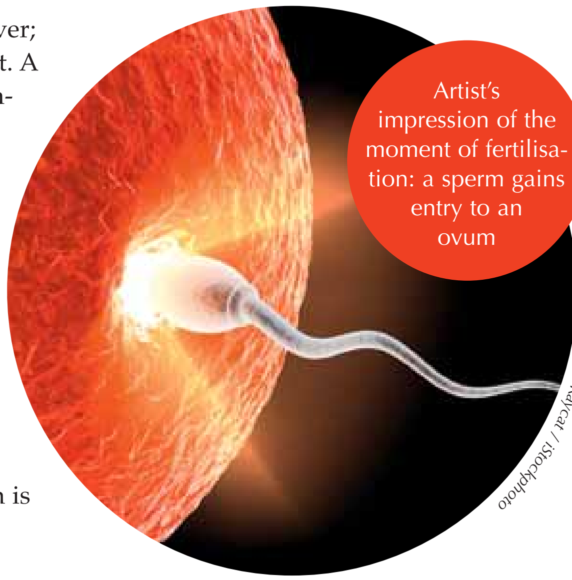
In his ongoing quest to explore the nature of sexuality, Tim Birkhead could be considered a paparazzo of nature – travelling to remote islands and bearing extreme discomfort in the hope of catching birds mating, and when they do, splashing their most intimate details and pictures over the pages of science journals.

Tim's passion for birds goes way back – to when he was 11. "On one memorable holiday in Wales, my father took me to a little island called Bardsey Island – one of the most beautiful places in the world, with lots of wonderful birds. As we walked back at the end of the day, a young man sat looking through a telescope with a notebook and my dad just looked at me and said: 'You could do something like that when you get older'." And he did.

But Tim is not always the observer; often, he is the one in the spotlight. A good scientist must be able to communicate his research and engage audiences by making it relevant and Tim does just that: he illustrates science with many stories, and he's clever, funny, persuasive and very clear. In fact, he is one of those teachers whose lectures should be scheduled early in the morning to make it worth the students' while to get out of bed. What makes his lessons so special? His enthusiasm is surely part of the answer.

Field courses and tutorials are Tim's preferred teaching methods. "I think intellectual development hinges very strongly on personal exchange. Tutorials are important for students to hear *us* talking to *them*, and for *them* to answer so that we can help shape their arguments. In field courses, similarly. I love teaching field courses because you can see the kids grow in that week. I teach a field course that takes place in June. The first day is appalling, but by the end of the week they are fantastic. However, they have trouble retaining that knowledge and enthusiasm, so when they come back in September it's as if nothing has happened. I feel we ought to be doing four or five field courses, and by the end of that time a lot of the information and enthusiasm and way of doing science would have stuck."

Doing science is important, but so is understanding science itself. "The history of science course that I teach is about doing science and what it means to be a scientist. I try to teach it in an unconventional way: I don't let my students take notes because I want them to listen, to be inspired by what I tell them and then go off and do the necessary reading. For one of the major assessments, I take them to a place where, based on their reading and a quote I give them, they have to organise a conference for the day. It's



Artist's impression of the moment of fertilisation: a sperm gains entry to an ovum

Image courtesy of Raycat / iStockphoto

up to them entirely how they interpret it, and how they give the presentation, and everybody does it very differently. They learn about the history of science by listening to their peers."

Tim also enjoys sharing his enthusiasm for science with school students. "Two or three weeks ago I gave a talk at a school where the students were incredibly mature. As I said, most of my research is on sexual selection and reproduction, and I was a bit apprehensive about telling 16- and 17-year-olds about reproduction, but they were fantastic. They asked really innovative questions, and there wasn't any silly giggling. I think with a group like that, you could really get across what science is, although with other types of kids it might be a bit difficult."

What would Reverend Morris have made of that talk, I wonder? Perhaps he too would have concluded that he would have been better preaching to the dunnock about the virtuous ways of the human.

This article is based on an interview with Tim Birkhead, as well as his lecture 'Darwin and post-copulatory sexual selection' at the 11th EMBL / EMBO Science and Society Conference: The Difference between the Sexes – From Biology to Behaviour, on 5-6 November 2010.

Resources

To learn more about Tim Birkhead, see: www.sheffield.ac.uk/aps/staff/acadstaff/birkhead.html

To see one of Tim Birkhead's talks, see: www.thedolectures.co.uk/speakers/speakers-2009/tim-birkhead

Another talk by Tim Birkhead ('The early birdwatchers') can be watched on TED, an online collection of lectures: www.ted.com/talks/tim_birkhead_the_wisdom_of_birds.html

To learn more about research into dunnock promiscuity, see:

Davies, NB (1983) Polyandry, cloaca-pecking and sperm competition in dunnocks. *Nature* **302**: 334-336. doi: 10.1038/302334a0

Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2011/issue18/birkhead#resources), or subscribe to *Nature* today: www.nature.com/subscribe

Haubold B (2007) Review of *The Selfish Gene* and *Richard Dawkins: How a Scientist Changed the Way We Think*. *Science in School* **5**: 84-85. www.scienceinschool.org/2007/issue5/selfish

Dawkins R (2006) *The Selfish Gene*, 3rd edition. Oxford, UK: Oxford University Press. ISBN: 9780199291151

To see all previously published feature articles in *Science in School*, see: www.scienceinschool.org/features

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Karin Ranero Celius obtained a bachelor's degree in physics and psychology, and then an MSc in museum studies. Her passion for educating others about the wonders of science led her to become a science communicator, concentrating mainly on outreach and education, first at the IAC (*Instituto de Astrofisica de Canarias*) in the Canary Islands, Spain, and then at the European Southern Observatory in Munich, Germany. While writing this article, she was based at the European Molecular Biology Laboratory in Heidelberg, Germany, and she now works for EJR-Quartz in Leiden, the Netherlands.

To learn how to use this code, see page 1.

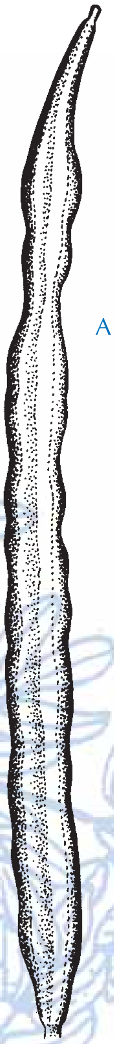
Bardsey Island, North Wales

Image courtesy of AlasdairJames / iStockphoto

Moringa: the science behind the miracle tree

Moringas have long been known as miracle trees. Now scientists are investigating their properties in depth, as **Sue Nelson** and **Marlene Rau** report.

A flower from a moringa tree



A moringa pod

Moringa leaves

In the foothills of the Himalayas grow trees, five to ten metres tall, with clusters of small oval leaves and delicately perfumed cream-coloured flowers. These are *Moringa oleifera* – the most widely cultivated of the 14 species of the genus *Moringa*, known as 'miracle trees'.

"It is called a miracle tree because every part of the tree has benefits," says Balbir Mathur, president of Trees for Life International[w1], a US-based non-profit organisation that provides developmental aid through planting fruit trees, moringas among them. "The roots, leaves, bark, parts of the fruits and seeds – everything. The list is endless."

Reports in the press about the miraculous nature of the tree may be exaggerated, but it does have some truly impressive properties. Native to northern India but now found widely in Asia, Africa and Latin America, moringas have been used in villages in developing countries for hundreds of years, their uses ranging from traditional medicine, food and cooking oil, to natural pesticide, domestic cleaning agent, and – the latest addition – biofuel.

Moringas are extremely hardy, known in parts of Africa as nebedies, meaning 'never-die trees', because they grow on marginal soils, regrow after being chopped down, and are one of the few trees that produce fruit during a drought.

It is yet another useful property of *Moringa oleifera*, though, that is exciting scientists: when crushed, moringa seeds can help purify dirty water. This could save lives: the World Health Organization estimates that unsafe water, poor sanitation and inadequate hygiene cause about 1.6 million deaths a year globally.

Water purification is mainly a two-step process: initially, water is clarified, removing particles such as minerals, plant residues and bacteria. However, since not all particles readily sink to the bottom, coagulating agents are added to help clump the particles together; these clumps can then be removed by filters or sedimentation. The second step is disinfection, to kill those pathogens that still remain, using chlorine compounds, ozone, hydrogen or ultraviolet light.

Moringa oleifera can help with the first purification step – not only in the developing world but also in the developed world. In industrial water treatment plants, the most prevalent coagulating agents used today are aluminium salts. Most particles that need to be removed from water are charged, so coagulating agents are usually ions; because the coagulating efficiency increases with the square of the coagulating agent's ionic charge, polyvalent ions such as aluminium are very efficient. However, there is concern – albeit controversial – that long-term exposure to aluminium may be associated with the develop-

The *M. oleifera* tree

REVIEW

- **Biology**
- **Chemistry**
- **Biochemistry**
- **Physics**
- **Personal, social and health education**
- **Ages 7-18**

This is a thought-provoking article that uses theoretical science (binding abilities of ions, neutron reflection techniques) to explain a real-life situation (using seeds to purify water).

Ideas from this article could be used with students of all ages to carry out some innovative practical work, with appropriate risk assessments. *M. oleifera* seeds can be bought via the Internet, if you are not lucky enough to have them grow locally, and their effects on clarifying water can be compared to those of other seeds. Are *M. oleifera* seeds really much better? Younger students could have a lot of fun grinding up different seeds and coming up with different ways of measuring how clear their dirty water becomes.

Older students could take this further and carry out investigations linked to using different parts of the seeds and relating this to seed biochemistry, or compare seeds treated in different ways, e.g. dried versus fresh. Researching the scientific basis of the seed-driven clarification process would certainly be challenging for the most able students.

The article fits well into a number of curricular topics: biology of seeds / biochemistry of extracts; chemistry of water purification / physical behaviour of the salts; physics – perhaps something to do with investigating density of layers – and looking at alternative methods. The idea could form the basis of a cross-curricular project with social science lessons, because of the good links with sustainability and renewable resources.

The article is suitable as a comprehension exercise for students aged 16 and older. Possible questions to ask in a biology lesson include:

- *Moringa oleifera* is just one of 14 species of the 'miracle tree'. Which part of the scientific name gives the genus, and which the species?
  (Answer: genus: *Moringa*; species: *Moringa oleifera*)
- In this article, a variety of uses are given for the moringa, including medicine, food, and cooking oil. Suggest which parts of the tree might be used for which of the given uses in the article. (Answers need not be correct, as students are not expected to know, but they should be reasonable suggestions, e.g. oil from seeds; medicine from any part; food from fruit; pesticide from leaves; cleaning agent from roots.)
- Moringas 'regrow after being chopped down' and are also described as being 'one of the few trees that will produce fruit during a drought.' Suggest what adaptations these trees might possess in order to do this.
  (Answer: again, students would not be expected to know the answer, but could come up with possible ideas such as new trees growing from seeds that were dispersed before the tree was cut down, or the chopping down acting as a kind of coppicing, causing more branches to grow. Being able to produce fruit during a drought could be due to an extensive root system (deep and / or wide, like those of cacti), to leaves that reduce the transpiration rate, or to mechanisms for absorbing dew, such as shallow roots.)

The article can also form the basis of discussion. Possible topics include:

- The evidence for / against aluminium being implicated in neurodegenerative diseases
- The more unusual uses of plants
- The role of the media in scaremongering the public on flimsy scientific basis (such as the drop in sales of aluminium saucepans, after it was proposed that they may be harmful)
- Citizenship topics and / or theme days based on water availability around the world.

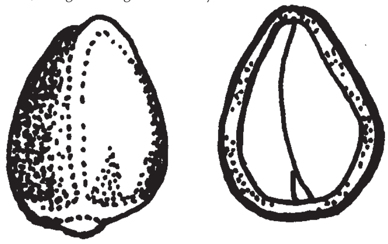
Sue Howarth, UK

ment of neurodegenerative diseases. Iron salts are an alternative, but they are more difficult to use, as their solubility changes with pH.

Further kinds of coagulating agents include synthetic polymers, but, as with the other coagulants, the sludge formed in the clarification process needs to be disposed of: so even though synthetic polymers solve the problem of the putative link to neurodegenerative diseases, their lack of biodegradability is an issue.

Since *M. oleifera* is both non-toxic and biodegradable, and reported reductions in the cloudiness, clay and bacterial content of water after the application of *M. oleifera* seeds rival the efficiency of aluminium salts (see Ghebremichael et al., 2005), it seems to be a viable alternative.

In certain rural areas of Sudan, women already use *M. oleifera* to purify water: when collecting water from the River Nile, they place the pow-



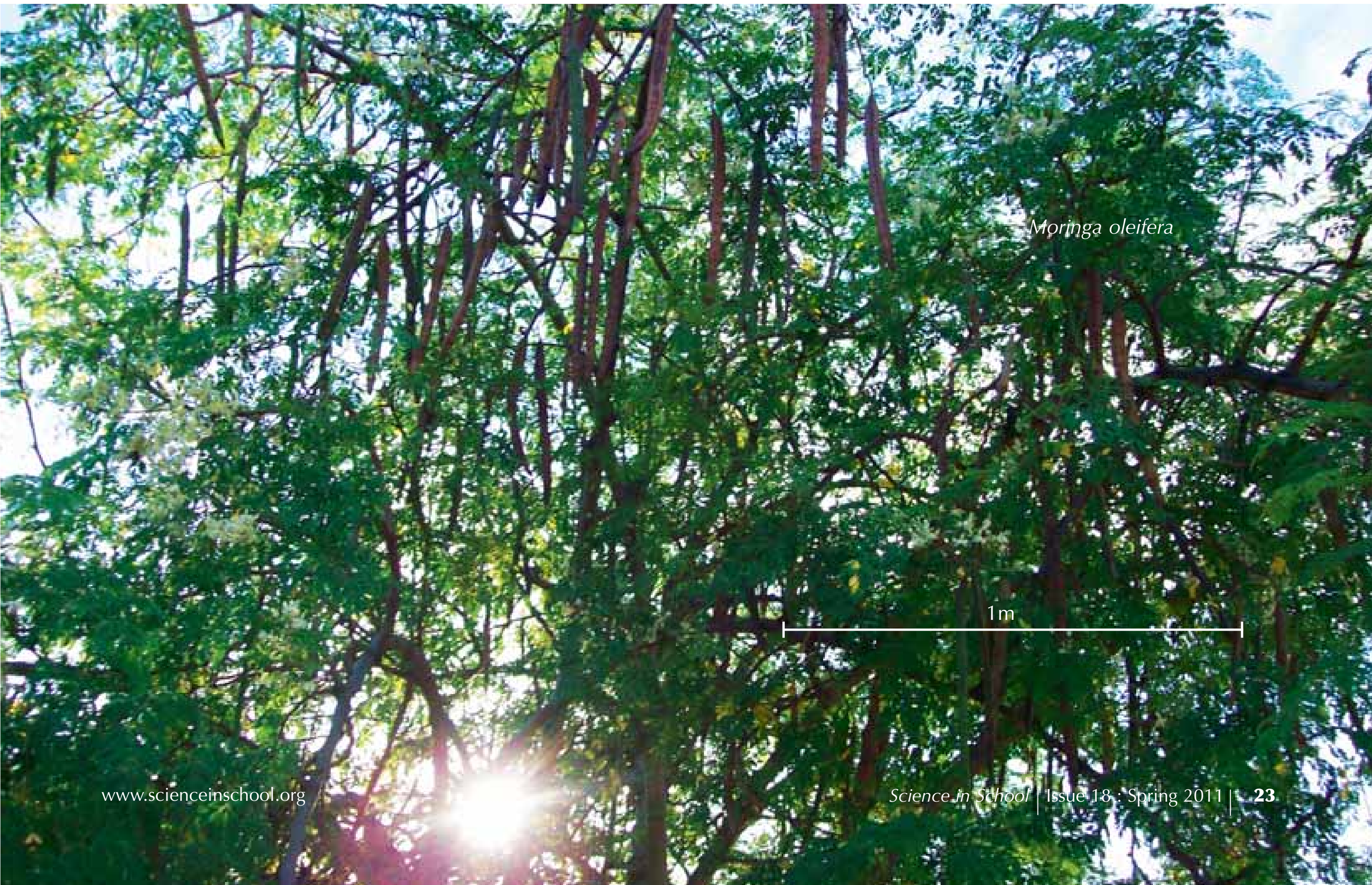
Moringa seeds: whole (left) and cut open (right)

dered seeds in a small cloth bag with a thread attached. This is then swirled around in the bucket of turbid water, until the fine particles and bacteria clump together with *M. oleifera* powder, sinking and settling to the bottom. For drinking water though, the water needs to be purified further – by boiling, filtering through sand or placing it in direct sunlight in a clear bottle for a couple of hours (solarising; see Folkard et al., 1999). You can try a similar technique yourself in class (see box on page 24).

Although a successful pilot study was performed at Thyolo water treatment works in Malawi in 1989-1994 (see Folkard & Sutherland, 2002), developing future industrial treatment methods from *M. oleifera* relies on knowing exactly what processes take place during the purification. Researchers already know that the active ingredient in the seeds is protein, which accounts for 30-40% of the seeds' weight. There are at least two proteins that may be active: they are water-soluble and quite small, about 6-16 kDa, so they can readily diffuse out of the cloth bags. At higher concentrations, they aggregate even in solution due to their substantial hydrophobic regions. The protein adsorbs on to contaminant particles, which then clump together and can be separated and extracted.

But how exactly does this clumping work? Scientists from the University of Uppsala, Sweden, and the

Image courtesy of Dr Majority Kwaambwa, University of Botswana



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M. oleifera seeds are ground to a powder before use

University of Botswana in Gaborone, Botswana, set out to investigate further (see Kwaambwa et al., 2010). They produced a purified extract of all the water-soluble protein from the seeds to study how the protein adsorbs onto an interface between water and silica (silicon dioxide, SiO_2) as a model for the interface between water and mineral particles.

The team used a neutron beam at the Institut Laue Langevin[w2] in Grenoble, France, in a technique called neutron reflectometry, to measure the thickness, density and coarseness of the forming protein layer.

Dried *Moringa oleifera* seeds

Image courtesy of Dr Majority Kwaambwa

How does this technique work? When you see a layer of petrol on a puddle, you can see a variety of iridescent colours: light bounces off both the top and bottom of the petrol layer. The reflected light waves will be slightly out of phase, and depending on the thickness of the petrol layer, will either add up or cancel each other out, resulting in different colours. Many more materials are

CLASSROOM ACTIVITY

Cleaning water with moringa seeds

Seeds of the *Moringa oleifera* tree are cheaply available online, as the tree is grown for decorative purposes.

Water will require different amounts of *M. oleifera* powder to purify it, depending on the impurities present. Around 50-150 mg of ground seeds treat one litre of water: as a rule of thumb, powder from one seed will be sufficient for one litre of very turbid or two litres of slightly turbid water. Experimenting with small amounts of water in a jar will help you work out the correct amount of powder and the optimal stirring times.

You may want to compare the water quality achieved with *M. oleifera* seeds to that achieved with other methods (see Mitchell et al., 2008, for an example of a different water purification method), and run a competition for the most efficient method of water purification.

1. Remove the seeds from the dried pods, if still present, and shell them, leaving a whitish kernel. Discard any kernels with dark spots or other signs of damage.
2. Crush the seed kernels to a fine powder and sieve them (0.8 mm mesh or similar).
3. Add the powder (approximately 2 g) to one cup of clean water, pour into a bottle and shake for 5 minutes.
4. Filter the mixture through a clean cloth into a bucket of dirty water that is to be treated.
5. Stir the water quickly for 2 minutes and slowly for 10-15 minutes (do not use metal implements, since this may re-introduce unwanted metal ions removed by *M. oleifera*). During the slow mixing, the fine particles and bacteria will begin to clump together and sink and settle to the bottom of the bucket.
6. Cover the bucket and leave it undisturbed until the water becomes clear and the impurities have sunk to the bottom. This may take up to an hour.
7. The clean water may be siphoned or poured off the top of the bucket or filtered through a clean cloth. The process removes at least 90% of the bacteria and other impurities that cause turbidity.

Notes:

Both the seeds and the seed powder can be stored, but the paste (made in step 4) should be freshly made every time water is to be purified.

For safety reasons, water purified in class must not be used as drinking water.

Images courtesy of Dr Majority Kwaambwa, University of Botswana

The mother of moringa researcher Dr Kwaambwa demonstrates how the seeds are treated for water purification

transparent to neutrons than to light, and neutron wavelengths are also about one thousand times shorter (0.2-2 nm) than those of light (about 0.5 μm), which is why a neutron beam can be used to measure layers of protein a single molecule thick.

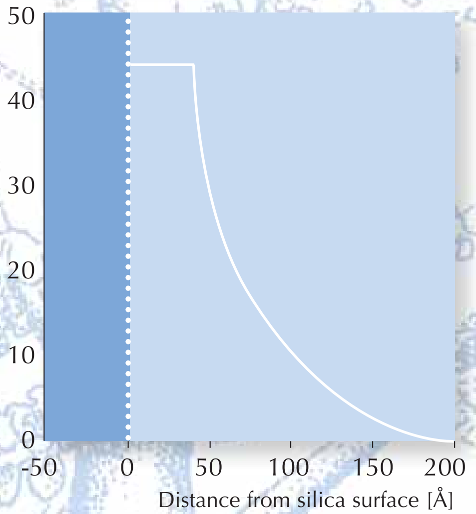
The 'white' neutron beam is shone onto the sample, and reflectivity is measured as a function of neutron 'colour' (i.e. wavelength), telling scientists how many molecules thick the layer is, how densely packed the molecules are, and how rough the surface of the layer is.

In the *M. oleifera* experiment, the scientists found that the seed protein forms dense layers thicker than a single molecule even at concentrations as low as 0.025 wt% – so the binding is very efficient. The surface of the layers is remarkably smooth, but the array of *M. oleifera* protein is not uniform: further away from the silica surface, the number of water molecules among the protein increases, which can be seen as a change in density, as measured by neutron reflection (see diagram, left).

This suggests that the clumping is so efficient because *M. oleifera* protein has a strong tendency to bind both to mineral surfaces and to other *M. oleifera* protein molecules, even at very low protein concentrations, due to hydrophobic regions and to the fact that, even when the overall protein is electrically neutral, different subgroups of opposite charge will be ionised.

Work on *M. oleifera* proteins continues to develop a non-toxic, biodegradable water purification treatment for which materials are available locally and at a much lower cost than aluminium salts. Questions being addressed include how much seed protein is needed, whether other proteins or biopolymers are suitable, and if other impurities in water, such as natural detergents, affect the action of the process.

Mathur welcomes the scientific scrutiny. "We feel that the moringa tree is very important and needs to be brought to the attention of scientists who can do further research," he says. "It is not widely known in the Western world yet because it doesn't grow there." In the future, the miracle tree could live up to its name. "The moringa could save millions of lives around the world for years to come," states Mathur. "I cannot emphasise enough how important it is."



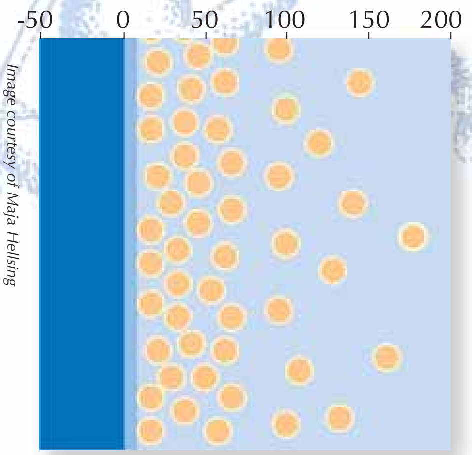


Image courtesy of Maja Hellsing

Closest to the silica surface, *M. oleifera* protein is packed very densely, in a layer about two molecules thick (50 Å). Then, with increasing distance from the silica surface, the concentration of adsorbed protein decreases rapidly

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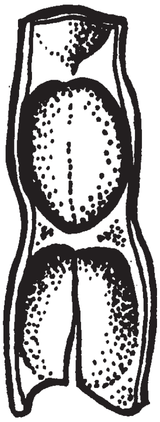
The *M. oleifera* tree



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Section of a moringa pod

Web references

w1 – Trees for Life International provides an international forum on beneficial trees and plants, and has been promoting the moringa tree for many years, sending literature and information to universities, embassies and heads of state, as well as producing educational material for schools. See: www.treesforlife.org

w2 – To learn more about the Institut Laue-Langevin, see: www.ill.eu

Resources

If you enjoyed reading this article, take a look at other *Science in School* articles about research done at ILL. See: www.scienceinschool.org/ill

Sue Nelson is an award-winning UK science broadcaster and writer. A physics graduate, Sue also studied space science and astronomy at the University of Michigan as a Knight Wallace journalism fellow in 2002 and recently completed a one-year Nesta Dream Time fellowship writing science-based dramas. Her reports have appeared on all the BBC's national TV and radio news bulletins. Co-author of the popular science book *How to Clone the Perfect Blonde*, Sue has written for *The Sunday Times*, *The Observer*, *The Guardian* and *The Independent* and has contributed opinion columns on science for *The Times*.

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

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Uracil in DNA: error or signal?

Uracil is well known as one of the bases used in RNA, but why is it not used in DNA – or is it? **Angéla Békési** and **Beáta G Vértessy** investigate.

Image courtesy of spxChrome / iStockphoto and Nicola Graf

Endopterygotes such as ants lack the enzyme capable of removing uracil from their DNA

Thymine versus uracil

Our genetic information is stored in the form of DNA, using a four-letter alphabet. The four 'letters' correspond to the four chemical bases that each building block of DNA – called a nucleotide – can have: adenine (A), thymine (T), cytosine (C) and guanine (G; see Figure 1 on page 28). As James Watson and Francis Crick famously discovered, DNA forms a double helix in which the four bases always pair up the same way, through specific hydrogen bonds: adenine binds to thymine, and guanine to cytosine (see Figures 2 and 3).

There is an alternative fifth letter, though: uracil (U), which forms the same pattern of hydrogen bonds with adenine (see Figure 4). But although

REVIEW

- Biology
- Genetics
- Immune system
- Insect development
- Cell proliferation
- General cytology
- Enzyme pathways
- Cancer research
- Ages 16+

This article demonstrates that science never sleeps, shaking up the dogma that uracil only exists in RNA. As the article explains, this is not always the case. And even when it is, why should that be?

To help the students understand the article, guiding questions could be:

1. Describe the bonding structures between the two complementary base pairs in DNA.
2. Which of the bases is replaced in RNA?
3. Describe and draw a graph of the repair enzyme pathway triggered when uracil is found in DNA.
4. The ratio of which molecules could be adjusted to stop cancerous cells from growing and dividing?
5. Why is uracil 'tolerated' in RNA?
6. Which living organisms use uracil DNA and how?

Friedlinde Krotscheck, Austria

Figure 1

The key components of a nucleotide, the basic building block of DNA. The sugar deoxyribose and the phosphate group are invariant, whereas the organic base can be of one of four types: A, T, G and C

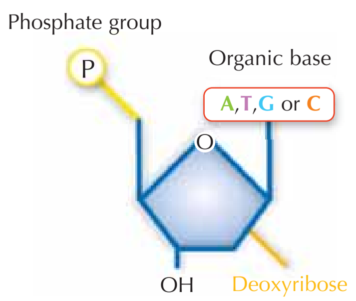


Image courtesy of Nicola Graf

Figure 2

The chemical structure of DNA, showing the base-pairings A-T and G-C. The hydrogen-bonded bases link together the two sugar-phosphate backbones

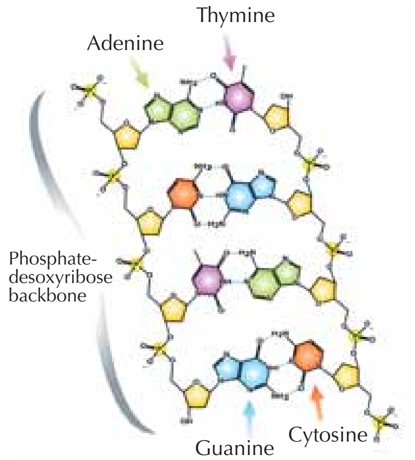


Image courtesy of Madeleine Price Ball; image source: Wikimedia Commons

Figure 3

The double helix structure of DNA

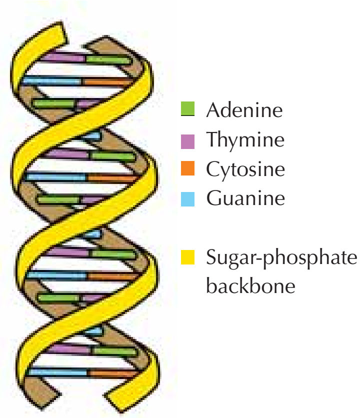


Image courtesy of Forluvoft; image source: Wikimedia Commons

uracil is commonly used in RNA, this is not the case in DNA, where thymine is used instead. Why might this be?

Chemically, thymine is a uracil molecule with an extra methyl group attached. What would be the advantage, in evolutionary terms, of using this more complex building block in DNA? The answer may lie in how cells correct damage to DNA.

Cytosine can spontaneously turn into uracil, through a process called hydrolytic deamination (see Figure 4). When this happens, the guanine that was initially bound to that cytosine molecule is left opposite uracil instead (remember that uracil normally binds to adenine). When the cell next replicates its DNA, the position opposite this uracil molecule would be taken up by an adenine instead of the guanine that should be there, altering the message that this section of DNA encodes (see Figure 5). This process of cytosine deamination is one of the most common types of DNA damage, but is normally corrected effectively. How does the cell do this?

Cells have a repair system that can detect when a uracil is sitting where a cytosine should be, and correct the mistake before it is replicated and passed on. The complex machinery to do that consists of several enzymes: first uracil-DNA glycosylases recognise the uracil, and cut it out of the DNA. Then several enzymes contribute to the elimination and re-synthesis of the damaged part of DNA, during which the abasic ('empty') site in the DNA is replaced with a cytosine (see Figure 6).

However, the most common form of uracil-DNA glycosylase cannot tell which base the uracil is paired with, i.e. whether the uracil was intended to be there (if bound with adenine) or if it is a mutated cytosine (and is opposite guanine); instead, it would recognise and cut out both types of uracil. Clearly, this would cause prob-

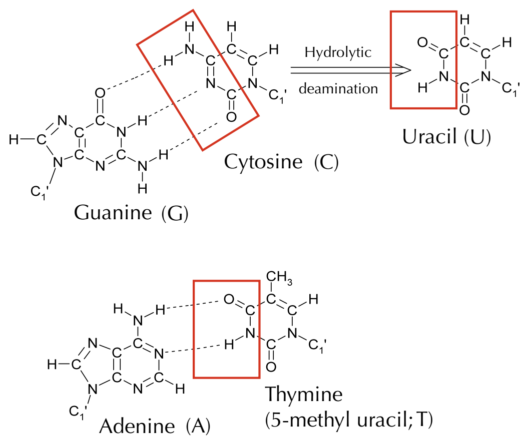


Image courtesy of Angéla Békési

Figure 4

Guanine and cytosine form a base pair stabilised by three hydrogen bonds, whereas adenine and thymine bind to each other through two hydrogen bonds. The red frames highlight the functional groups of cytosine and thymine that are responsible for forming the hydrogen bonds. Cytosine can spontaneously undergo hydrolytic deamination, resulting in a uracil base with the same capability for hydrogen bond formation as thymine

Image courtesy of taramol / iStockphoto

Figure 5

Hydrolytic deamination of cytosine can change the amino acids encoded by the sequence

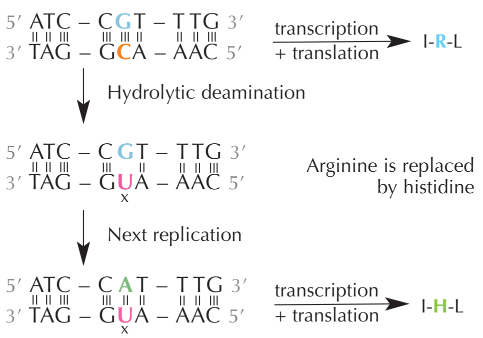
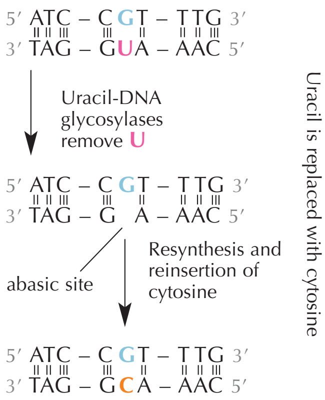


Image courtesy of Nicola Graf

Figure 6

Repair of hydrolytic deamination



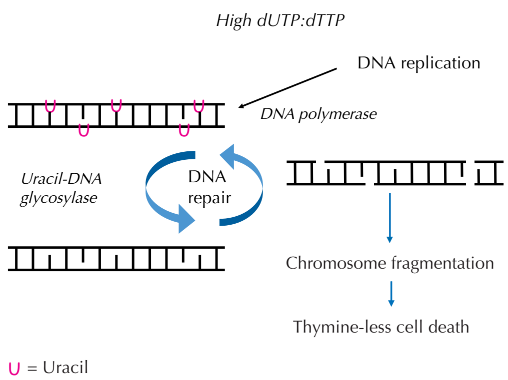
lems. The solution to this potential problem is thought to have been the evolution of a mechanism in which 'correct' uracils (paired with adenine) were labelled with a methyl group – resulting in thymine. This way, if the cell machinery found a uracil, it cut it out and repaired it, but if it found a uracil with a methyl label – a thymine (see Figure 4) – it left it. Over time, therefore, thymine in DNA became the standard instead of uracil, and most cells now use uracil only in RNA.

Why was uracil retained in RNA? RNA is more short-lived than DNA and – with a few exceptions – is not the repository for long-term storage of genetic information, so cytosine molecules that spontaneously turn into uracils in RNA do not present a great threat to the cell. Thus, there was probably no evolutionary pressure to replace uracil with the more complex (and presumably more costly) thymine in RNA.

Figure 7

Image courtesy of Angéla Békési

If dUTP:dTTP increases, DNA polymerase frequently incorporates uracil instead of thymine during both replication and repair. Uracil-DNA glycosylase removes the uracil and initiates further repair involving DNA strand breaks in an intermediate step. Repair synthesis, however, may reintroduce uracil, leading to a futile DNA repair cycle. Eventually, the system is overloaded and chromosome fragmentation occurs, leading to cell death



Thymine-less cell death

When DNA is synthesised, the DNA polymerase enzymes (which catalyse the synthesis) cannot discriminate between thymine and uracil. They only check whether the hydrogen bonds form correctly, i.e. whether the base pairs are matched properly. To these enzymes, it does not matter whether thymine or uracil binds to adenine. Normally, the amounts of deoxyuridine triphosphate (dUTP, a source of uracil) in the cell are kept very low compared to levels of deoxythymidine triphosphate (dTTP, a thymine source), preventing uracil incorporation during DNA synthesis.

If this strict regulation is perturbed and the ratio of dUTP to dTTP rises, the amount of uracil that is incorrectly incorporated into DNA also increases. The repair system – which, unlike DNA polymerases, can distinguish uracil from thymine – then attempts to cut out the uracil with the help of uracil-DNA glycosylase and to re-synthesise the DNA, which involves temporarily cleaving (cutting) the DNA backbone. However, if the ratio of dUTP to dTTP is still elevated, this re-synthesis may again incorporate uracil instead of thymine. This cycle eventually leads to DNA strand breaks and chromosome fragmentation, when these temporary cuts in the DNA happen one after the other and too close to each other (see Figure 7). This results in a specific type of programmed cell death, called thymine-less cell death.

The process of thymine-less cell death can be deliberately exploited in the treatment of cancer. Because cancer cells proliferate at such a high rate compared to normal cells, they synthesise a greater amount of DNA per given time period and therefore require large amounts of dUTP. By raising the ratio of dUTP to dTTP, these cancer cells can be selectively targeted and eliminated.

Uracil DNA still exists

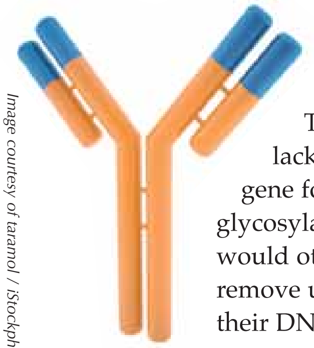
Although most cells use uracil for RNA and thymine for DNA, there are exceptions. Some organisms have uracil instead of thymine in all their DNA, and other organisms have uracil in only some of their DNA. What could be the evolutionary advantage of that? Let's take a look at some examples.

Uracil in viral DNA

Two species of phage (viruses that infect bacteria) are known to have DNA genomes with only uracil and no thymine. We do not yet know whether these phages are representatives of an ancient life form that never evolved thymine DNA, or whether their uracil-substituted genomes are a newly evolved strategy. Nor do we know why these phages use uracil instead of thymine, but it may play an essential role in the life cycle of these viruses. If that is the case, it would make sense for the viruses to ensure that the uracil in their DNA is not replaced with thymine. And one of these phages has in fact been shown to have a gene that encodes a specific protein to inhibit the host's uracil-DNA glycosylase, thus preventing the viral genome from having its uracil 'repaired' by the host enzymes.

Programmed cell death in insect life cycles

Uracil-DNA also appears to play a role in the development of endopterygotes – insects that undergo pupation during their life cycle (ants and butterflies do; grasshoppers and termites do not). These insects lack the main gene for uracil-DNA glycosylase, which would otherwise remove uracil from their DNA.



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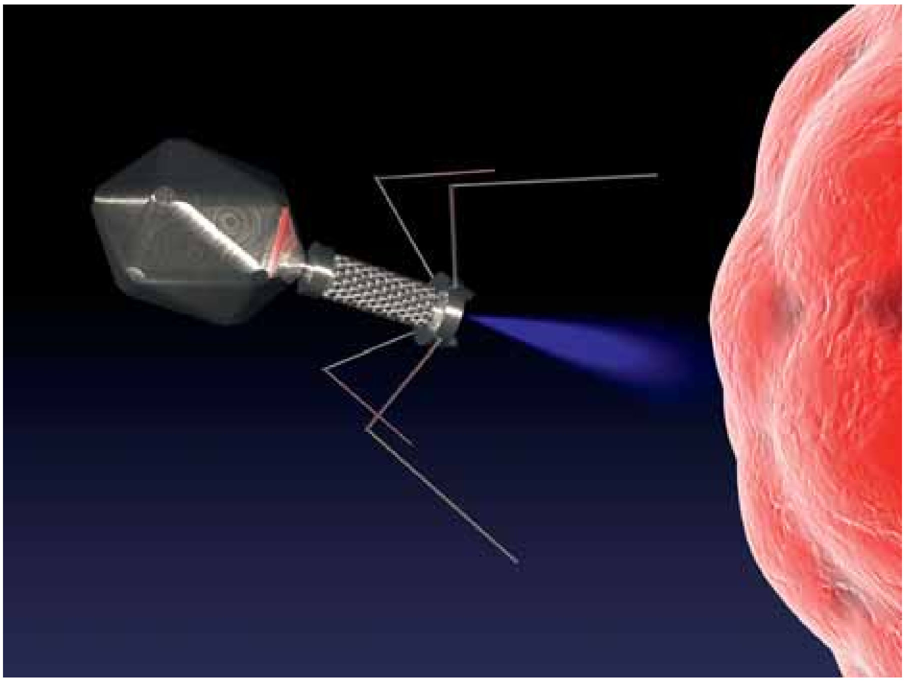

Artist's impression of a phage virus infecting a bacterial cell

Moreover, our own research has shown that, in larvae of the fruit fly *Drosophila melanogaster*, the ratio of dUTP to dTTP is regulated in an unusual manner: in all tissues that will not be needed in the adult insect, there are much lower levels of the enzyme that breaks down dUTP and generates a precursor for dTTP production. Consequently, significant amounts of uracil are incorporated into these tissues during DNA synthesis.

So during the larval stages, uracil-DNA is produced and seems not to be corrected in tissues that are to be degraded during the pupal stage. As these insects lack the main uracil-DNA glycosylase enzyme, at the pupal stage, additional uracil-DNA-specific factors may recognise this accumulated uracil as a signal to initiate cell death. We have already identified an insect-specific protein that seems to be capable of degrading uracil-DNA, and we are investigating whether this enzyme is used to initiate programmed cell death.

Beneficial errors: the vertebrate immune system

Uracil in DNA, however, can also be found closer to home – in the immune system of vertebrates like us. Part of our immune system, the adaptive immune system, produces a large number of different antibodies that are trained to protect us from specific pathogens. To increase the number of different antibodies that can be created, we shuffle the DNA sequence in the regions that code for them, not only by recombining the existing sequences in the cells but also by creating new ones through vastly increased mutation rates, known as hypermutation.

Hypermutation starts with a specific enzyme (an activation-induced deaminase) that changes cytosine into uracil (see Figure 4) at specific DNA loci, eliciting an error-prone repair response, which the organism uses to its advantage: 'errors' generate new sequences that can be used to make different antibodies. This system is very strictly regulated, however, as if it got out of hand, it would lead to cancer.

When considering the question of why uracil or why thymine, we need to consider the evolutionary context. Living organisms have evolved in a continuously changing environment, facing a dynamic set of challenges. Thus, a solution that avoids mistakes being incorporated into DNA is advantageous to most organisms and most cells, which explains why thymine-DNA became the norm. Under certain circumstances, however, 'mistakes' themselves can be beneficial, which is why some cells still use uracil in their DNA.

Resources

To find out more about the work of Beáta Vértessy's research group, see: www.enzim.hu/~vertessy

To download a summary of Villő Muha's PhD thesis, which was written under Beáta Vértessy's supervision and focuses on uracil-DNA in *Drosophila melanogaster*, use the link: http://teo.elte.hu/minosites/tezis2010_angol/v_muha.pdf

The complete thesis is available here: http://teo.elte.hu/minosites/ertekezes2010/muha_v.pdf

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Angéla Békési was born 1977 in Kaposvár, Hungary. In 2001, she graduated in chemistry from the Eötvös Loránd University of Sciences, and in theology from the Pázmány Péter Catholic University (both in Budapest, Hungary), having joined the lab of Beáta Vértessy in 2000 as an undergraduate student. In 2001, she began a PhD on the regulation of uracil-DNA repair and uracil processing in pupating insects. She identified a new protein candidate for a novel type of uracil-DNA sensor and received her PhD in structural biochemistry from Eötvös Loránd University of Sciences in 2007. She is continuing her work as a postdoctoral scientist, and was a school ambassador in the SET-Routes programme (www.set-routes.org/school/profiles/bekesi_en.html).

Beáta G Vértessy was born in Budapest, Hungary and was trained in the biological sciences. She has an MSc from the University of Chicago, USA, a PhD / CSs from the Eötvös Loránd University in Budapest, Hungary, and the Hungarian Academy of Sciences, and a DSc from the Hungarian Academy of Sciences. Since 2000, she has been the head of a laboratory focusing on genome metabolism and repair at the Institute of Enzymology, Budapest, Hungary. The lab's current research aims to understand the prevention, recognition and repair of uracil in DNA from the perspectives of structural and cell biology.

To learn how to use this code, see page 1.

The presence of uracil in antibody gene sequences elicits a DNA repair response, which has the effect of increasing antibody protein diversity. An extensive antibody pool increases the chance of the immune system recognising unwanted invaders

A neural switch for fear

Image courtesy of EMBL Photolab

Cornelius Gross

When something frightens us, should we freeze, or should we investigate? **Sarah Stanley** describes how scientists from the European Molecular Biology Laboratory are probing the mysteries of the brain, seeking to understand our response to fear.

Image courtesy of EMBL Photolab

Flee, fight or freeze? For an animal overcome with fear, that is the essential question. The answer often depends on the amygdala – a major emotion-processing hub nestled deep in the brain. In both mice and humans, it affects how we behave in response to certain types of fear, and helps to form long-term memories of frightening experiences. However, very little is known about how cells in the amygdala communicate with other brain cells to produce specific fear-induced behaviours.

A recent study narrows this gap in knowledge, thanks to the innovative work of scientists at the European Molecular Biology Laboratory[w1] (EMBL) in Monterotondo, Italy, and GlaxoSmithKline[w2] in Verona, Italy. The scientists focused on one of many different types of fear processed by the amygdala. They used new techniques to understand the interactions between the areas of the brain involved in reactions to that specific type of fear. In the course of their work, they identified a switch that toggles between two different fear responses: freezing and, surprisingly, an alternative to the flee, fight or freeze options, known as active risk assessment. This active response involves behaviours like rearing, digging and exploring.

Mice conditioned to associate a tone with an uncomfortable shock usually freeze in fear upon hearing the sound, even if it is not accompanied by discomfort. Neurons called type 1 cells, which are found in the amygdala, are known to control the freezing response. When type 1 cells are prevented from sending signals to other cells, mice no longer freeze in fear. But, it seems, type 1 neurons are more than just an on / off switch.

In a pioneering approach that uses both pharmacology and genetics, EMBL scientists engineered mice so that their type 1 cells could be turned off without disrupting other cells. The mice were made to produce certain drug-sensitive proteins (receptors) exclusively in their type 1 cells. When the mice were injected with the drug, it bound to those receptors, setting off chemical reactions that disrupted the cells' electrical charge. Thus, these neurons could no longer send electrical signals to surrounding brain regions.

Before treatment with the drug, the mice had been conditioned to fear a certain tone. After their type 1 cells were blocked, they were subjected to the tone, and their behaviours were observed and analysed.

"When we inhibited these neurons, I was not surprised to see that the mice stopped freezing, because [freezing] is what the amygdala was thought to [control]. But we were very surprised when they did a lot of other things instead, like rearing and other risk-assessment behaviours," says Cornelius Gross, who led the research at EMBL. "It seemed that we were not blocking the fear, but just changing their responses from a passive to an active coping strategy. That is not at all what this part of the amygdala was thought to do."

To better understand the connections between brain cells – the neural circuitry – involved in the switch from passive to active fear behaviours, the scientists looked at activity in different brain regions using a type of brain scan called functional magnetic resonance imaging (fMRI). In small animals like mice, fMRI measures local blood volume as an indica-

Image courtesy of EMBL Photolab

REVIEW

- Biology
- Genetics
- Pharmacology
- Physiology
- Behaviour
- Ages 16+

In this article, several experiments are carried out with mice (in which both the behaviour and the activity of the brain were analysed) to understand the details of their response to fear. Such research is very important to ultimatly improve our knowledge about how the human brain works.

This article can be extremely useful for giving students some insight into how research is done in scientific laboratories. Teachers can get their students to read the article and then think about how respond to fear, perhaps even designing and performing an experiment. Furthermore, students can think about the evolutionary benefits of these reactions for our ancestors, and how useful they are in modern life. Moreover, the students can try to find out about animals with different responses to fear and try to relate their behaviour to their environment.

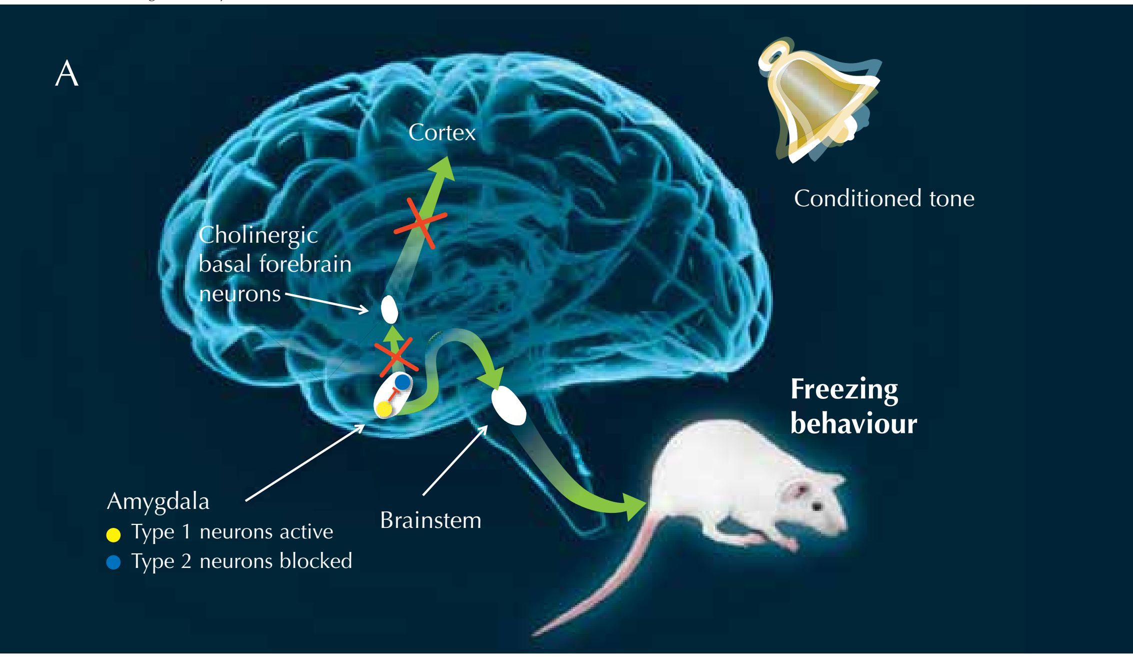
The use of new research techniques such as pharmacogenetics and functional magnetic resonance imaging (fMRI) is also reported in this article. Students aged 16 and over can try to find more information about how these techniques work and their importance in research.

Finally, this article could also be used as a starting point for discussing research on animals. Students can think about how the results obtained from animals can be applied to humans, and they can also discuss alternatives to animal testing.

Mireia Guell Serra, Spain

Image courtesy of Nicola Graf, Cornelius Gross and Marlene Rau

When mice hear a tone that they have been conditioned to associate with an uncomfortable shock, the amygdala is activated and relays information to the brainstem, making the animal freeze (A).
However, in mice in which type 1 amygdala neurons have been switched off, these neurons no longer suppress the surrounding type 2 amygdala cells. Type 2 neurons now activate the cortex via the cholinergic basal forebrain, blocking freezing and promoting risk-assessment instead (B)



tor of brain activity: the more blood there is in a particular area of the brain, the more active those neurons are. This study marks the first use of fMRI to map neural circuitry in mice, using a new technique developed by GlaxoSmithKline scientist Angelo Bifone and his team.

The brain scan yielded another unexpected result. Scientists previously thought that the amygdala managed fear behaviours by simply relaying information to the brainstem, which links the brain to the spinal cord. But Cornelius, Angelo and their colleagues found that in mice with blocked type 1 cells, the outer layer of the brain – the cortex – was highly active, indicating that it too plays a role in determining how mice react to fear. Activity was also observed in a region of the brain called the cholinergic basal forebrain, which is known to influence cortex activity.

Like all brain scans, fMRI requires the subject to remain very still, so it can only be performed on mice that have been anaesthetised. But the scientists wanted to confirm the association between the cortex and fear behaviours in conscious mice. As they could not observe brain activity while the mice were awake and therefore capable of displaying fear behaviour, the scientists took a different approach. They used the drug atropine to block cortex activity in mice whose type 1 cells were blocked, and found that the animals no longer showed any risk assessment behaviours.

Thus, the scientists infer, the amygdala normally inhibits the cholinergic basal forebrain, while it signals the brainstem to control the passive fear response: freezing (see image above, A). When type 1 neurons are blocked, however, the amygdala releases its hold on the cholinergic basal forebrain, leading to cortex activity and an active reaction to fear: risk assessment (see image on page 35, B).

"This is a powerful demonstration of the ability of functional MRI to resolve brain circuits involved in complex tasks, like processing of emotions and control of behavioural responses," says Angelo, now at the Italian Institute of Technology[w3] in Pisa.

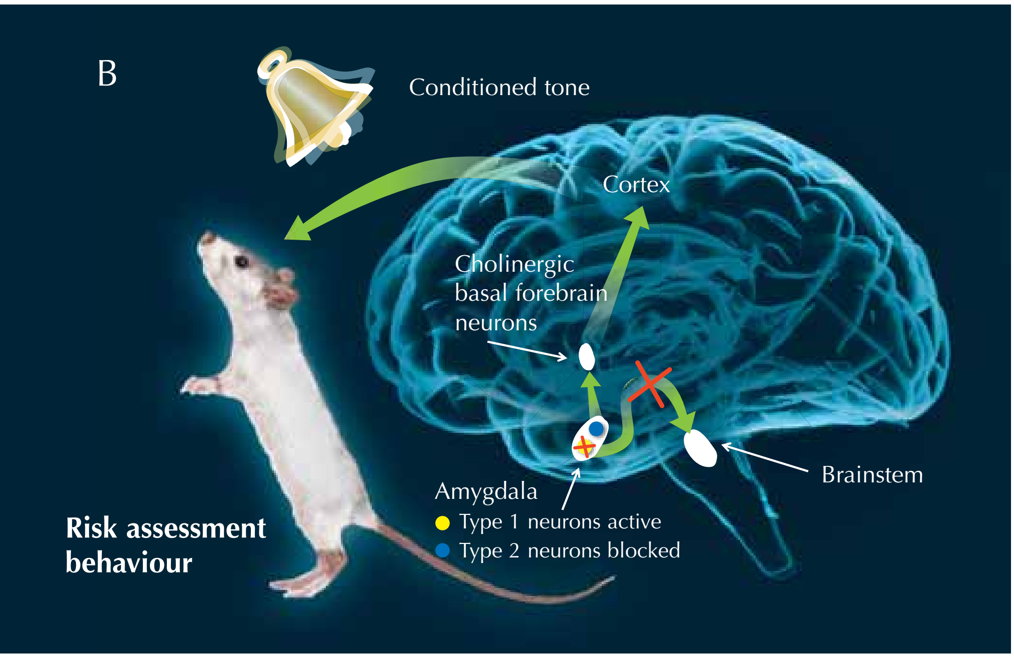
Taken together, the results of the array of techniques used to explore the freezing fear response in mice indicate that the amygdala plays a more complex role in fear processing than previously thought. Instead of merely passing on information about external threats, the amygdala makes decisions about how to respond.

It is important to note that the type of fear explored in this study – conditioned fear of a painful shock – is very specific. The results cannot necessarily be applied to behavioural responses to other types of fear in mice.

"There are multiple, parallel fear circuits that handle different types of fear information. For example, one part of the [mouse] brain is often used to process fear of a predator, such as a cat, while another part usually responds to aggressive behaviour by another mouse," Cornelius says. "We thought there was a simplistic fear circuit that is either on or off, but that doesn't seem to be true."

Also, scientists are not yet sure whether wild mice ever use risk assessment behaviours in response to threatening stimuli. Blocking of type 1 cells was performed artificially in this study, and there may or may not be situations when the neurons would naturally be inhibited, leading the mouse to engage in investigative behaviours to learn more about a perceived threat.

If the active response *is* found naturally in mice, what kinds of external



sensory cues are necessary to activate it? Previous studies have shown that animals located farther away from a perceived threat are more likely to freeze in fear than run or fight. But scientists cannot yet say whether use of an active risk assessment response is a function of distance. Cornelius emphasises that it is important not to assume that risk assessment would be used in place of freezing in a situation perceived as less threatening.

Nonetheless, the study has significant implications. The pharmacogenetic and fMRI techniques used by the scientists will likely prove invaluable in many other studies of neural circuits in mice. Indeed, Cornelius and his team have already used a pharmacogenetic approach to reveal cells that act as an input for another brain region, the hippocampus, relaying information that enables a mouse to gauge an appropriate level of anxiety in an uncomfortable circumstance.

Furthermore, we humans also show freezing and risk assessment responses to fear. We possess a region of the amygdala that is analogous to the one housing the active / passive switch in mice. Patients who have suffered lesions to this region are unable to develop conditioned fear responses, though they have normal reactions to fear in other situations. Thus, it is likely that the results of this study could apply directly to humans, Cornelius says.

Though much remains to be discovered about how humans process fear in different situations, studying fear brings scientists ever closer to developing more effective treatments for fear-based illnesses – such as anxiety disorders and post-traumatic stress disorder. In the words of two-time Nobel Prize-winning chemist Marie Curie, "Now is the time to understand more, so that we may fear less."

References

Gozzi et al. (2010) A neural switch for active and passive fear. *Neuron* **67(4)**: 656-66. doi: 10.1016/j.neuron.2010.07.008

Web references

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

w2 – For information about GlaxoSmithKline in Verona, Italy, see: www.gsk.it

w3 – To find out more about the Italian Institute of Technology, see: www.iit.it

Resources

For an introduction to the 2010 article by Gozzi et al., see:

Pape HC (2010) Petrified or aroused with fear: the central amygdala takes the lead. *Neuron* **67(4)**: 527-529. doi: 10.1016/j.neuron.2010.08.009

As part of an exhibition (Goose Bumps! The Science of Fear), the Museum of Science, Boston, USA, devised some scary activities for the classroom. See the museum's website (www.mos.org) or use the direct link: http://tinyurl.com/65savzz

For another example of research using fMRI, see:

Hayes E (2010) The science of humour: Allan Reiss. *Science in School* **17**: 8-10. www.scienceinschool.org/2010/issue17/allanreiss

If you enjoyed this article, you may like to browse the other cutting-edge science articles in *Science in School*: www.scienceinschool.org/cuttingedge

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Sarah Stanley graduated in biology from the University of California, Santa Barbara, USA. At the time of writing this article, she was a science writing intern at the European Molecular Biology Laboratory. Currently, she is an intern at *Discover Magazine*.

Image courtesy of EMBL Photolab

To learn how to use this code, see page 1.

The resourceful physics teacher

Physics teacher **Keith Gibbs** shares some of his many demonstrations and experiments for the physics classroom.

During more than 30 years of teaching physics, I have come across many interesting demonstrations and teaching ideas – often suggested by relatives, friends, colleagues and past students. In 2000, I began to gather these ideas together – this was the basis of the Schoolphysics website and CD-ROM collection. Over time, I added more explanation and background for teachers whose specialism was not physics.

Below are four ideas from the collection. I hope that you will find at least one of them new, challenging, informative and fun, and that the ideas go some way towards popularising the subject and making people realise that physics can be interesting and fun.

Boiling water under reduced pressure

Age range: 13-15

This simple experiment demonstrates that the saturated vapour pressure of water depends on the temperature. It is best performed as a teacher demonstration, with a safety screen between the apparatus and the students.

Materials

- A round-bottomed flask
- A bung with two holes
- A glass tube, with an external diameter to fit the hole in the bung
- A rubber tube with a diameter to connect to the glass tube
- A thermometer to fit the hole in the bung
- A Bunsen burner
- A retort stand and clamp
- A safety screen
- A tray
- Water

Procedure

1. Fit the rubber tube onto the end of the glass tube.
2. Fit the thermometer and glass tube into the holes in the bung, pour cold water into the flask until it is just less than half full. Then seal the flask with the bung.
3. Fit the clamp onto the rubber tube but do not close the clamp.

Image courtesy of aristotoo / iStockphoto

REVIEW

- Physics
- Chemistry
- Thermodynamics
- Circular motion
- Electromagnetism
- Gravitational fields
- Inertia
- Boiling points
- Ages 13-19

The four experiments described in this article are innovative and use items that are easily available in school laboratories. The aim, materials, procedure and diagram for each experiment make it very straightforward for teachers and students to understand the processes and theories involved. It is also interesting to read about the author's experiences and the results that he obtained from these experiments.

Teachers could use the experiments for a wide array of physics topics and adapt them to different age groups, depending on how much theory the teacher chooses to explain. They can be performed as a pre-topic experiment to introduce the students to the theory or else while the theory is being explained, to consolidate concepts with facts. A discussion can be held with students during the experimental investigations to prompt them to make predictions and explain the outcomes.

The activities can be used with students of different ages, depending on the emphasis. The boiling water activity could be used with students aged 13-15 to discuss the boiling point of water; for students aged 16-19, it could be used in a lesson about gas laws. The coat-hanger experiments could be used with 16- to 18-year-olds to introduce circular motion, centripetal force and centripetal acceleration. For 10- to 13-year-olds, the electromagnetic separator activity could be used in general science lessons or to discuss magnetic materials; for students aged 14+, it could be used in magnetism lessons. Finally, the experiment with the falling jar could be used for students aged 16+ to teach simple harmonic motion, gravitation and inertia.

These types of demonstration are ideal for students who are visual learners and who will understand and remember theory better when they see it applied in practice.

Catherine Cutajar, Malta

4. Use the Bunsen burner to heat the water to boiling.
5. Close the clamp and turn off the Bunsen burner.
6. Invert the flask and pour cold water over it.

Steam will condense inside the flask, reducing the pressure and allowing the water to start boiling again. When the water stops boiling, pour more water over the flask. How low can you get the temperature and still observe the water boiling? You should be able to get the water to boil at 40 °C – I once observed the water boiling at body temperature (37 °C)!

Safety note: wear safely goggles. Although unlikely, it is possible that the glass flask could shatter, so keep a safety screen between the experiments and the students. If possible, stand behind the screen yourself.

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

Theory

The explanation is that the saturated vapour pressure of water depends on the temperature: the lower the temperature, the less water vapour the air can hold (see Table 1). When the water condenses, it lowers the pressure in the flask – and this, of course, allows water to boil at less than 100 °C.

An alternative method

A simpler method is to partly fill (about 20%) a syringe with 50-60 °C warm water. Then pull on the plunger of the syringe. This lowers the pressure in the syringe, causing the water to boil at well below 100 °C.

Temperature	Saturated vapour pressure
37 °C	0.06×10^5 Pa
60 °C	0.19×10^5 Pa
75 °C	0.38×10^5 Pa
85 °C	0.57×10^5 Pa
100 °C	10^5 Pa

Table 1: Dependence of saturated vapour pressure of water on temperature

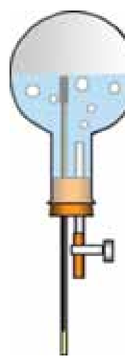

Image courtesy of Keith Gibbs

Image courtesy of Floortje / iStockphoto

The wire coat hanger and circular motion

Age range: 14-18

This is a simple demonstration of centripetal force.

Materials

- A wire coat hanger with the end filed to a point
- A metal file
- A small coin

Procedure

1. Bend the wire coat hanger until it forms a square.
2. File the tip of the hook flat and then bend the hook until it points towards the opposite corner of the square (see diagram).

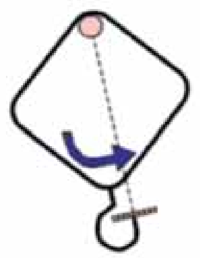

Image courtesy of Keith Gibbs

3. Balance a small coin (try a UK one-penny piece or a 5 or 10 Euro-cent coin) on the hook.
4. Place one finger in the corner of the square opposite the hook and spin the coat hanger in a vertical circle. The coin should remain in place.

Theory

The force of the hook on the coin provides the centripetal force, and this always acts towards the centre of rotation.

How many coins can you balance on the swinging coat hanger? My record is five one-penny pieces. With only one penny and with great care, I have once even been able to bring the coat hanger to rest without the coin falling off.

Electromagnetic separator

Age range: 16-18

This is a small-scale simulation of the type of electromagnetic separator that is used industrially to separate non-ferrous metals from other non-metallic scrap, and is suitable as a teacher demonstration.

Materials

- A U-shaped electromagnet with an iron core to give a high field intensity
- An AC (alternating current) power supply
- Aluminium scraps (e.g. kitchen foil)
- A piece of thin card
- Some scraps of paper

Procedure

1. Place the card on top of one arm of the electromagnet and put a few scraps of aluminium and paper onto the card.
2. Connect the electromagnet to an AC supply and turn on the current. The aluminium scraps will be ejected from the magnetic field.

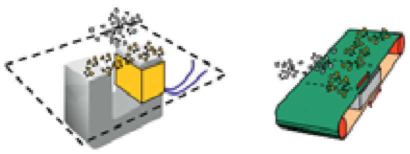

Image courtesy of Keith Gibbs

Theory

The AC electromagnet induces eddy currents within the aluminium scraps. These turn the scraps into tiny electromagnets that are then repelled by the large electromagnet and so fly off the card. With non-metallic scraps there are no induced currents and so these scraps remain on the card.

In a moving-belt version of this experiment, mixed metal and non-metal scraps are passed along a belt over an AC electromagnet. This induces eddy currents in the metal scraps, which are then repelled by the field and fly off sideways while the remaining non-metal scraps continue along the belt. Schools might be able to construct such a version for demonstration use, using a mixture of paper and aluminium.

A floating block in a falling jar

Age range: 11-18, depending on the treatment of the theory.

This is a very useful demonstration of one of the ideas of general relativity, using a wooden block floating in a jar of water that is suspended from a spring.

Fairground ride-goers should be grateful to centripetal force

Image courtesy of inabeanpod; image source: Flickr

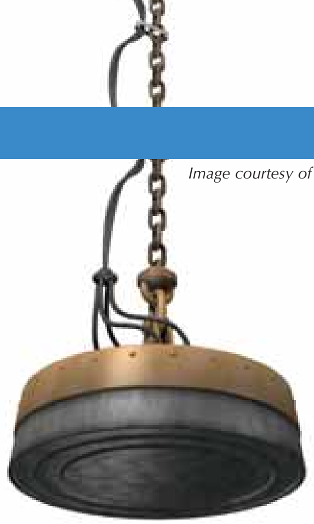

Image courtesy of ZargonDesign / iStockphoto

Artist's impression of a large electromagnet, of the type used for separation in an industrial setting

Materials

- A helical spring tied with string to a plastic jar
- A wooden block or straw loaded with modelling clay (e.g. Plasticine®)
- Water

Procedure

1. Half fill the jar with water, add the wooden block or straw, and suspend the apparatus from the spring.
2. Support the jar, then let it fall, suspended from the spring. The jar and contents will then oscillate in a vertical plane (up and down) but the water level will stay at the same position in the jar and the block or straw will float at the same level in the water as it falls and rises.

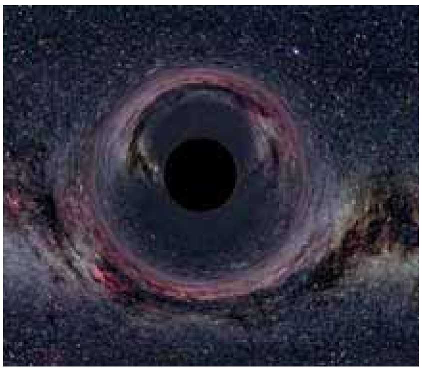

Image courtesy of Ute Kraus; image source: Wikimedia Commons

Computer-simulated image of the night sky, were it to feature a black hole with a mass ten times that of the Sun, and seen from a distance of 600 km. Einstein's theory of general relativity allows details of a black hole's structure to be calculated. Black holes are thought to be distortions in space and time, consisting of zero volume and infinite density.

Theory

The depth at which the wooden block or straw floats depends on both its weight (not its mass) and the upthrust on it. The upthrust depends on the weight of water displaced. Thus, as the acceleration of the jar and the block changes, the weight of the block and the upthrust on it change in direct proportion to each other; as a result, the depth at which the block floats remains unchanged as the apparatus oscillates.

Objects undergoing acceleration behave in the same way as they would in a gravitational field. As the jar and its contents oscillate, they have an acceleration that is due to both the constant gravitational field of Earth and the simple harmonic motion of the oscillation.

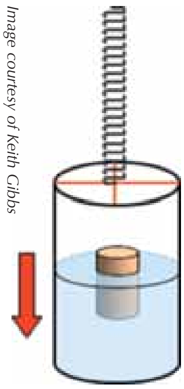

Image courtesy of Keith Gibbs

As the jar moves upwards, its net acceleration is greater than that of Earth's gravitational field and as it falls, its acceleration is less than that of Earth's field. On the downward part of the motion, it is as if the jar were on the Moon, where the gravitational acceleration is less than on Earth.

This is a very useful demonstration of the equivalence of gravitational and inertial fields.

Acknowledgements

The editors of *Science in School* would like to thank Catherine Cutajar and Gerd Vogt for their help in selecting the experiments to include in this article.

Web reference

w1 – To view more (free) teaching material collected by Keith Gibbs or to purchase the CD-ROMs, see: www.schoolphysics.co.uk

Resources

If you enjoyed this article, you might like to browse the rest of the teaching activities on the *Science in School* website. See: www.scienceinschool.org/teaching

If you prefer to concentrate on physics, here is a list of all physics-related articles in *Science in School*: www.scienceinschool.org/physics

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After graduating from University College London, UK, with a degree in physics, Keith Gibbs took a PGCE teacher training course at Cambridge University, UK. He subsequently taught physics in four different schools across the UK for 36 years, retiring in 2002.

The ideas in this article are just a few of more than 700 ideas and experiments that Keith Gibbs has collected and devised over the years, available on CD-ROM (currently £10). These, as well as explanations suitable for 11- to 19-year-old students, animations, lesson plans, images and much more, are available on a further CD-ROM which, once bought (currently £35), can be copied within the school and made available via the school's intranet. See the Schoolphysics website[w1].

Keith has written and contributed to a number of physics textbooks. Recently, he has worked with Pearson Education on animations for advanced-level physics courses, and practical projects for younger physics students.

Keith also travels extensively, demonstrating his collection of experiments. If you are interested in a visit, contact him via the Schoolphysics website[w1].

To learn how to use this code, see page 1.

Breeding dragons: investigating Mendelian inheritance

Mendelian inheritance can be a tricky topic to teach, but **Pat Tellinghuisen**, **Jennifer Sexton** and **Rachel Shevin's** memorable dragon-breeding game makes it easier to understand and remember.

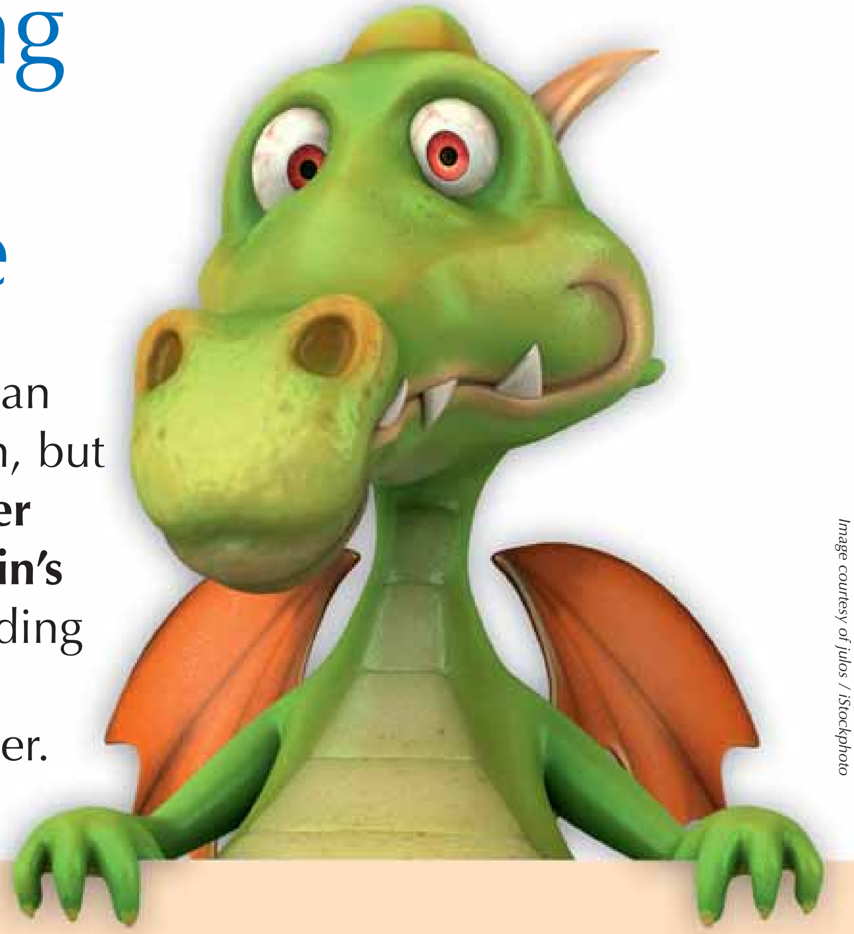


Image courtesy of julos / iStockphoto

REVIEW

- **Biology**
- **Ages 10-15**

As a secondary-school biology teacher I had never come across the idea of teaching genetics using mythical creatures, but after my initial surprise, I realised that using the genetics of dragons was perfectly coherent with the scientific facts... and really good fun! The idea of randomly choosing genes and looking for the resulting traits of baby dragons is ingenious and effective at the same time.

Even if they aren't real, dragons can help to raise interest in a topic generally considered boring (at least by students) and can convey scientific concepts as well as real organisms like Mendel's peas do.

I recommend this article to primary- and lower-secondary school biology teachers willing to address the basics of Mendelian genetics (genes, alleles, genotype and phenotype, dominance, meiosis and breeding) in a novel and playful way. The activity could be carried out very easily in the classroom with practically no equipment.

Suitable comprehension questions include:

1) Dragons have:
   a) seven chromosomes
   b) seven genes
   c) seven pair of chromosomes
   d) seven alleles.
2) When you breed dragons, the number of chromosomes of their offspring:
   a) is divided into half
   b) remains the same
   c) is doubled
   d) depends on their sex.

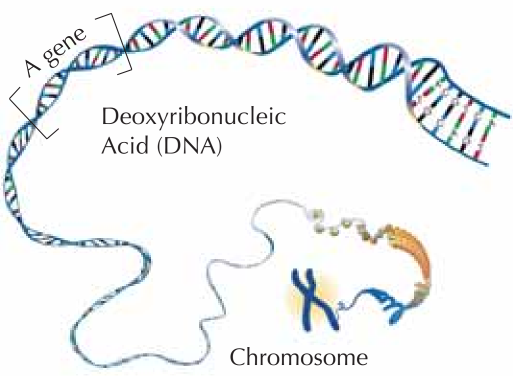
Giulia Realdon, Italy

Image courtesy of Alexsey / iStockphoto

Dragons may be mythical animals, but they can still be good tools for investigating Mendelian inheritance. In the following activity, students will 'breed' baby dragons, using paper chromosomes to determine the genotype and phenotype.

The activity has been tested with students aged 12-13, and generally takes one lesson – about 45 to 60 minutes.

Image courtesy of Darryl Leja, NHGRI / NIH



How DNA is packaged into chromosomes (not to scale)

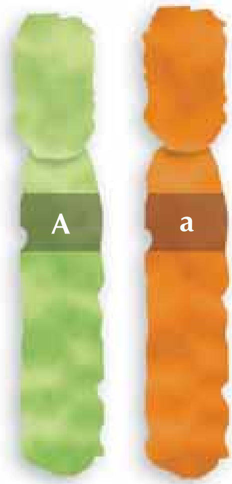


Image courtesy of Nicola Graf

Different alleles of the same gene (not to scale)

Materials

For the whole class

- A DNA model
- A picture of a chromosome

For each student

- A set of chromosome strips in two colours (14 pink strips for the mother and 14 blue strips for the father)
- A student worksheet
- Crayons (at least four colours)

The chromosome strips, Tables 1-3 from the worksheet and the basic dragon drawing can be found on pages 42/43 or downloaded from the *Science in School* website[w1].

Procedure

Using the information below, introduce the dragon story and the required background for the activity to the students. Then hand out the materials and let the students follow the instructions on the student worksheet. Tables 1–3 can also be downloaded from the *Science in School* website[w1].

The story

Dragons are a curious type of creature. Amazingly, though, their genetics is very similar to that of humans – or even guinea pigs. Many schools keep pet guinea pigs, but wouldn't it be much more exciting to keep a herd of dragons? Unfortunately, dragons are very expensive, so your school can only afford two – one of each sex. The purpose of this activity is to determine what kinds of dragon you could have in your herd when (or if) your two dragons decide to mate.

Background for the students

Each cell in all living organisms contains hereditary information that is encoded by a molecule called deoxyribonucleic acid (DNA): show students the DNA model. DNA is an extremely long and skinny molecule, which when all coiled up and bunched together, is called a chromosome: show students the picture of a chromosome. Each chromosome is a separate piece of DNA, so a cell with eight chromosomes has eight long pieces of DNA.

A gene is a segment of the long DNA molecule. Different genes may be different lengths and each gene is a code for how a certain polypeptide should be made. One or more polypeptides form a protein, which can generally be sorted into two different types: those that run the chemical reactions in your body (enzymes), and those that are the structural components of your body (structural proteins). How an organism looks and functions is a result of the cumulative effect of both these types of protein.

Any organism that has 'parents' has an even number of chromosomes, because half of the chromosomes come from the 'father' and the other half from the 'mother'. For example, in plants, a pollen grain is the paternal contribution and an ovule is the maternal contribution. These two cells combine to make a single cell, which will grow into a seed (the offspring).

Humans have 46 chromosomes, sorted into 23 pairs. One chromosome in each of the 23 pairs is from the person's father, the other from his or her mother. Since chromosomes come in pairs, genes do too. One gene is located on one member of the chromosome pair; the other gene is in the same location on the other chromosome. The gene 'pair' is technically referred to as a 'gene', as both members of the pair encode the same trait. For any gene, a variety of different forms – known as *alleles* – may exist, but each person can have a maximum of only two alleles (one from the mother, and one from the father). The two copies of the gene that a person has may be the same or different alleles.

Our dragons have 14 chromosomes in seven pairs, and we will look at only one gene on each of the pairs. We will be investigating seven different traits (e.g. the ability to breathe fire), each of which is controlled by a single gene – we say that such a trait is *monogenic*. Each of the seven genes has two alleles.

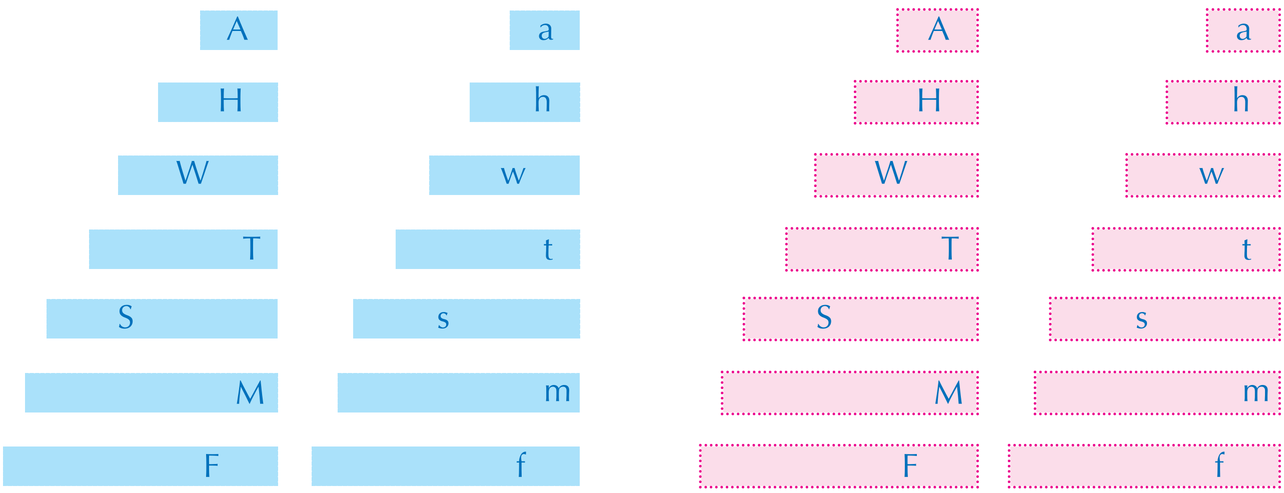
Student worksheet

One set of 14 strips represents the chromosomes from the mother (female) dragon. The other, differently coloured set, represents the chromosomes from the father (male) dragon.

Each chromosome strip has a letter, which may be either upper or lower case. The upper-case letters represent dominant alleles, and the lower-case letters represent recessive alleles. Each pair of letters codes for a trait. If at least one dominant allele (upper-case letter) is present, the dominant trait will occur (e.g. the dragon can breathe fire); the recessive trait (e.g. inability to breathe fire) will only occur if the dragon has two copies of the recessive allele.

1. Sort the chromosomes so that they are matched into pairs of the same length and letter of the alphabet. You should have seven chromosome pairs for each colour (blue for male, pink for female).

   The traits encoded by the letters are as follows:
   - F and f represent whether or not the dragon breathes fire
   - M and m represent the number of toes
   - S and s represent the number of tail spikes
   - T and t represent the colour of the tail
   - A and a represent the colour of the body
   - W and w represent the colour of the wings
   - H and h represent whether or not the dragon has a horn.
2. Take the longest pair of male chromosomes (blue) and the longest pair of female chromosomes (pink) and place them face down on your desk so that you cannot see the letters.
3. Without turning the chromosomes over, pick one of each colour and put them together to form the chromosome pair for the baby dragon. Discard the remaining pair of chromosomes.
4. Repeat steps 2 and 3, moving from the longest to the shortest chromosomes, until you have seven new chromosome pairs, each consisting of one pink and one blue strip.
5. Turn over the seven pairs of chromosomes of the new baby dragon. For each pair, record the letter on the blue chromosome in the 'Male gene' column in Table 1 and the letter of the pink chromosome in the 'Female gene' column. Be sure you copy the letters exactly, noting whether they are upper or lower case.
6. Return all the chromosomes to their proper bags.
7. Record which alleles (letters) your dragon has for each trait, and enter them in the second column of Table 2. We refer to the two alleles inherited for a particular gene as the *genotype* (e.g. TT). The observable traits of an individual (e.g. a red tail) are known as the *phenotype*.
8. Refer to Table 3 to determine which alleles are dominant or recessive for each trait, then enter the phenotype of your dragon in Table 2.
9. Now you are ready to draw your baby dragon: colour and add the relevant body parts to the basic dragon picture (which can also be downloaded from the *Science in School* website[w1]). See Table 3 for suggestions as to how the additional body parts can be drawn.

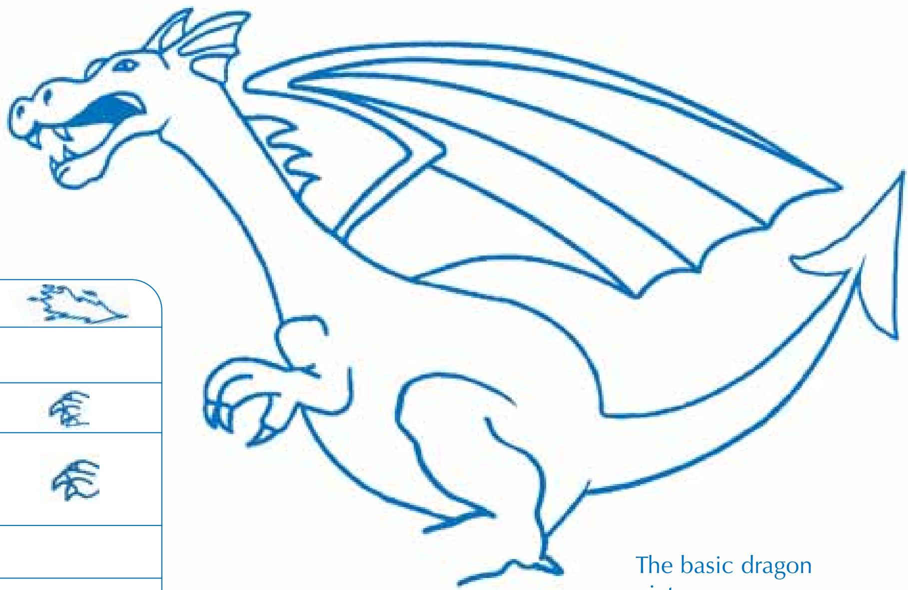


Male gene (blue)	Female gene (pink)

Table 1: The genes your dragon has inherited from its parents

Trait	Genotype	Phenotype
Fire/No fire (F/f)		
Toes (M/m)		
Spikes on tail (S/s)		
Tail colour (T/t)		
Wing colour (W/w)		
Horn/no horn (H/h)		
Body colour (A/a)		

Table 2: Genotype and phenotype of your baby dragon



The basic dragon picture

Genotype	Phenotype	
FF or Ff	Breathes fire	
ff	Does not breathe fire	
MM or Mm	Four toes	
mm	Three toes (all dragons have at least three toes)	
SS or Ss	Five spikes on tail	
ss	Four spikes on tail (all dragons have at least four tail spikes)	
TT or Tt	Red tail	
tt	Yellow tail	
WW or Ww	Red wings	
ww	Yellow wings	
HH or Hh	Horn	
hh	No horn	
AA or Aa	Blue body and head	
aa	Green body and head	

Table 3: Translating the dragon genotype into the phenotype

Variations

Codominance

To introduce the concept of codominance, you can extend the activity by swapping the relevant materials concerning the body colour trait (genotype Aa) for the following ones with the genotypes A/Ä/a, where A and Ä are codominant and a is recessive:

Genotype	Phenotype
AA or Aa	Blue body and head
ÄÄ or Äa	Black body and head
AÄ	Stripy blue and black body and head
aa	White body and head

Table 1a: Translating the dragon genotype into the phenotype (extension for codominance example)

Trait	Genotype	Phenotype
Body colour (A/Ä/a)		

Table 2a: Genotype and phenotype of your baby dragon (extension for codominance example)

Chromosome set 1

For the father	A	Ä
For the mother	A	Ä

Chromosome set 2

For the father	a	Ä
For the mother	A	A

Other variations

Instead of drawing dragon parts, you could have your students draw other mythical creatures, or even build them, for example from marsh

Acknowledgements

This activity is based on an idea by Patti Soderberg, adapted with permission from *The Science Teacher* (see Soderberg, 1992). Her reebops lesson was then adapted by the authors. Credit for the chromosome strips goes to Nancy Clark[w2], and Marlene Rau, editor of *Science in School*, included the codominance example.

References

Soderberg P (1992) Marshmallow meiosis. *The Science Teacher* **59(8)**: 28-31. The article can be freely downloaded from the *Science in School* website, with kind permission from *The Science Teacher*. See: www.scienceinschool.org/2011/issue18/dragons#resources

Web references

w1 – The chromosome strips, tables and the basic picture for this activity can be downloaded from the *Science in School* website. See: www.scienceinschool.org/2011/issue18/dragons#resources

w2 – Retired US science teacher Nancy Clark's collection of classroom resources can be found online: www.nclark.net

w3 – Find out more about the Vanderbilt Student Volunteers for Science here: http://studentorgs.vanderbilt.edu/vsvs

Resources

The Scottish 'Gene jury' project proposes a 'make a baby' game, focusing on pre-implantation diagnostics and genetics. See the Gene jury website (www.biology.ed.ac.uk/projects/GeneJury) or use the direct link: http://tinyurl.com/6edlhnq

To learn more about genetic diseases, and the research into them, see:

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

For our two-part article on molecular evolution and the genetics behind positive selection of certain alleles, see:

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

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

Staying with the subject of genetics and evolution, a simple way to teach the Hardy-Weinberg principle in class is described here:

Pongsophon P et al. (2007) Counting Buttons: demonstrating the Hardy-Weinberg principle. *Science in School* **6**: 30-35. www.scienceinschool.org/2007/issue6/hardyweinberg

Try the UK Science museum's online game 'Thingdom' to learn about genetics while creating your own fictional organism. See: www.sciencemuseum.org.uk/WhoAmI/Thingdom.aspx

If you enjoyed this article, why not browse our full collection of biology articles? See: www.scienceinschool.org/biology

Patricia Tellinghuisen is the Director of the Vanderbilt Student Volunteers for Science (VSVS)[w3] and Faculty Advisor at Vanderbilt University, Nashville, Tennessee, USA. Jennifer Sexton and Rachel Shevin were undergraduate laboratory assistants at the VSVS.

To learn how to use this code, see page 1.

The heat is on: heating food and drinks with chemical energy

Have you ever longed for a hot drink or meal but had no fire or stove to hand? **Marlene Rau** presents two activities from the *Lebensnaher Chemieunterricht* portal that use chemical reactions to heat food – and to introduce the topic of exothermic reactions.

Image courtesy of Martin Müller / pixelio

Heater meals

Heater meals – originally developed for military use – are ready-made self-heating meal packs. They can be heated in many ways – by pressing a button on the packaging, unwrapping and shaking the pack, or pouring the contents of one bag into another and waiting for a few minutes – all of which use exothermic chemical reactions. These meals can be used to motivate students to study such reactions relatively safely and without the use of a burner. Plus there is the added value of discussing the negative ecological aspects of disposable meals.

For the following experiment, we use the Crosse & Blackwell heater-meal system, which relies on the reaction of magnesium and salt water to produce hydrogen:

$$Mg\ (s) + 2H_2O\ (l) \rightarrow Mg^{2+}\ (aq) + H_2\ (g)\uparrow + 2OH^-\ (aq)$$

s: solid; l: liquid; g: gaseous; aq: in solution; the vertical arrow indicates that gas is released.

This reaction is very slow, due to passivation, so to speed it up, iron and salt are added. Passivation is the process by which a material is made less reactive, usually by the deposition of a layer of oxide on its surface: if you place a strip of magnesium into cold water, its surface will oxidise to magnesium hydroxide ($Mg(OH)_2$), and this coating will prevent further reaction.

Therefore, in the heater meal, iron is added to the magnesium, leading to the production of a local cell – small-scale corrosion that happens where two metals of different reactivity are in contact under humid conditions – which speeds up the exothermic reaction. Because the electron potential of magnesium is lower than that of iron (the less reactive metal), electrons will pass from the magnesium to the iron, and only from there into the water. Although magnesium cations (Mg^{2+}) and hydroxide anions (OH^-) continue to be formed, they are separated by the iron and cannot combine to form magnesium hydroxide. As a result, the magnesium does not become passivated by a coating of magnesium

Images courtesy of Gregor von Borstel

The heater-meal pack: the meal (silver bag), heater bag into which the meal is placed (orange), salt-water bag (see-through), magnesium/iron mixture (white bag, taken out of the orange bag), spoon

hydroxide, which would lower the reactivity.

Because the differently charged magnesium and hydroxide ions are mobile, in pure water they would soon form magnesium hydroxide, the charge would be equilibrated and the reaction would slow down again. To prevent this, sodium chloride is added to the water, so that the sodium (Na^+) and chloride (Cl^-) ions from the salt can move to the magnesium and hydroxide ions instead, equilibrating the charge.

The experiment can be used to introduce and discuss the topics of electron transfer, local cell, passivation, sacrificial anodes, corrosion and the composition of water (covalent bonds, polarity and oxidation numbers). It takes about 45 minutes plus discussion time and has been successfully tested with 14-year-olds to study electron transfer reactions and corrosion, as well as with older students to work on electrochemistry.

Materials

Demonstration materials

- A magnesium strip
- Cold (unheated) saturated sodium chloride solution (salt water)
- Phenolphthalein solution
- A Crosse & Blackwell heater-meal pack (available from a range of suppliers)[w1]
- A heat-resistant glass
- A laboratory thermometer

Materials per group

- An empty tea bag
- A small amount (a few grains, covering the tip of a spatula) of the magnesium / iron powder mixture taken from a Crosse & Blackwell heater-meal pack. Mixing magnesium and iron powder yourself tends not to work since it is already partly oxidised. The powder mixture in the heater meal packs is vacuum-sealed.
- A 50 ml syringe
- 10 ml saturated sodium chloride solution
- A 20 ml syringe
- A three-way stopcock
- A small beaker
- A plastic tube fitting on the valves of the stopcock (about 10 cm long)
- A bowl filled with water
- A burning candle
- A test tube
- Phenolphthalein solution <1% per weight

REVIEW

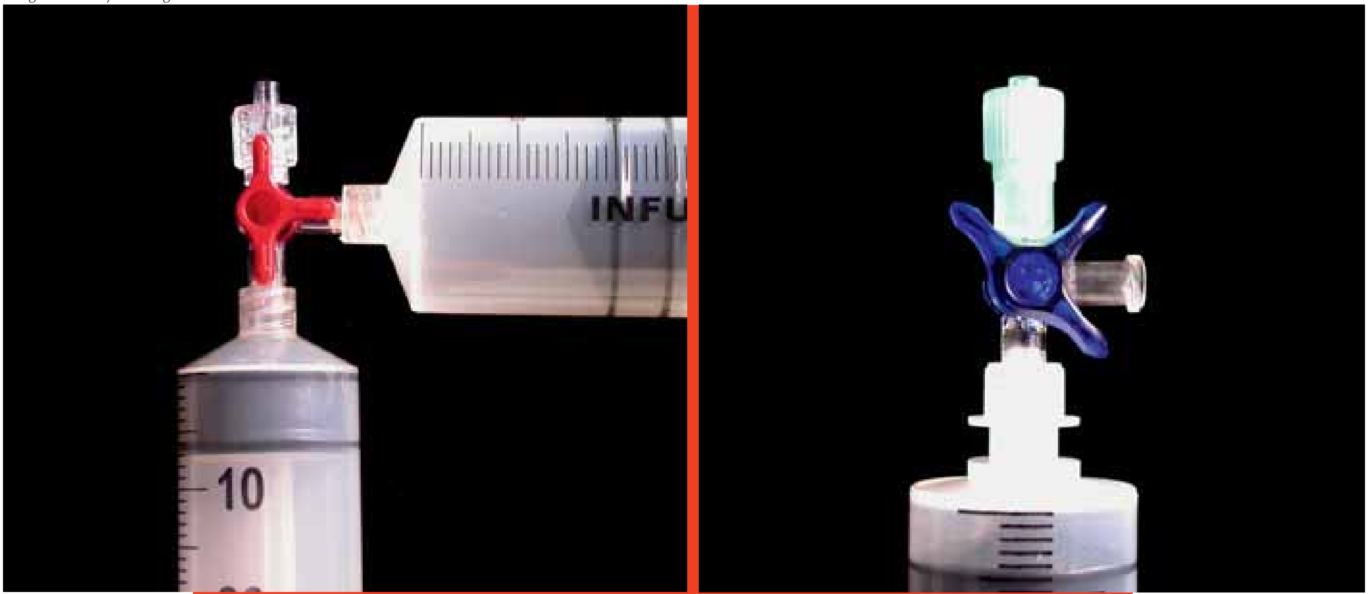
- Chemistry
- General science
- Energy
- Ages 8-19

This article allows students to discover the link between classroom science and the real world. With experiments that have a wow factor – often missing from practical lessons – students can develop and build skills and knowledge.

The main subject addressed is chemistry, but the teacher could adapt the lesson to include discussions of energy from other subjects, for example keeping warm, survival in cold climates, and treatment of sports injuries. The experiments could also be used to trigger a discussion of how science works.

Nick Parmar, UK

Images courtesy of Gregor von Borstel



A closed and an open three-way stopcock

The plastic materials required for the experiment can be ordered as part of the ChemZ[w2] kits, which were developed in collaboration with the *Lebensnaher Chemieunterricht* (LNCU)[w3] project, but are also available from most medical and chemical lab suppliers.

Procedure

1. Show a film about the heater meal[w4].
2. Show the heater meal to the students.
3. Pour the contents of the heater-meal pack into a heat-resistant glass with a thermometer and observe the reaction – it heats up and bubbles are produced.

   Note: if you use the contents of only two of the four packages of magnesium / iron mixture, you can save the contents of the other two for the students' experiments – it will be sufficient for about 20 student groups. Even with only two of the packages for the demonstration, the heater meal will reach a temperature of 100 °C after about one minute.
4. Discuss: why does this work? What is happening? What kind of gas is produced?
5. Explain the reaction of magnesium – ignore the iron and salt for the moment.
6. Demonstrate that a magnesium strip shows a weak reaction with cold saturated salt solution (which is what is added in the heater meal): a few gas bubbles are visible, and adding a droplet of phenolphthalein solution gives a light pink colour.
7. Before starting, demonstrate how to perform the oxy-hydrogen test: hold the top of a test tube close to a flame, allowing the gas in the tube to combust. There are two possible positive results:
   a) If the tube contains both hydrogen and oxygen, the hydrogen will combust with a 'squeaky pop'. Under normal lab conditions, this is the usual result, as the tube will also contain oxygen from the air.
   b) If the tube is completely filled with hydrogen, there will be no sound, but the gas combusts with colourless flame and the resulting water will fog the test tube. Furthermore, the exothermic reaction will heat the tube. Students often mistake this for a negative result (no hydrogen).
8. Place the students into groups of three to perform the heater-meal experiment. Because of the resulting heat, the reaction speeds up, so should only be performed on a small scale (as suggested).

   At the local cell, magnesium hydroxide is produced. If desired, this can be detected using phenolphthalein (see below).
9. Hand out the worksheet (see page 49 or download it from the *Science in School* website[w5]) describing how to carry out the heater-meal experiment. The students will now be ready to start.

Student worksheet

Safety note: Wear safety goggles. The reaction creates highly flammable gas – be careful. See also the general safety note on the *Science in School* website (www.scienceinschool.org/safety) and on page 65.

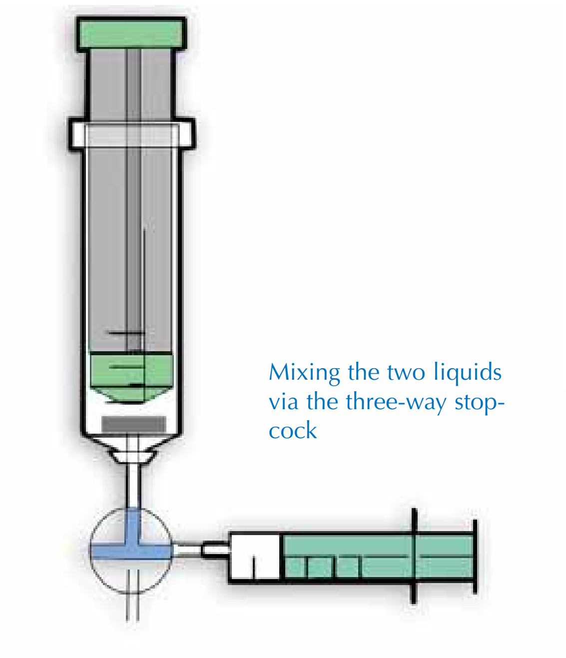
1. Put the metal powder mixture into an empty tea bag and stuff this into a 50 ml syringe (without the tea bag, the powder could block the syringe). Press out the air.
2. Fill the 20 ml syringe with salt water and connect it to the large syringe using a three-way stopcock.
3. Turn the stopcock's valve to let the two materials flow together in the closed system.

   As the reaction proceeds, gas will collect in one of the syringes.
4. As soon as more than 25 ml of gas has collected, open the stopcock and let the salt water flow out, collecting it in a beaker.

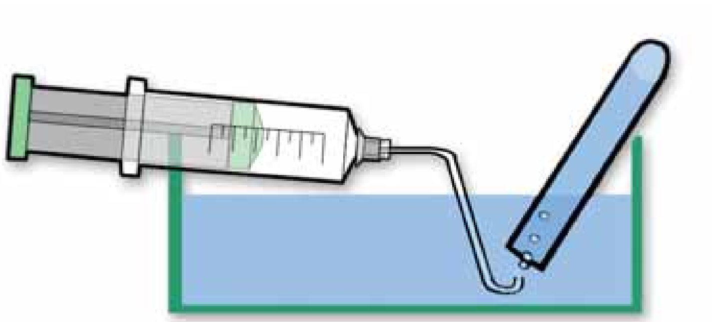
   Safety note: because of the resulting heat, the reaction speeds up (chain reaction). Keep a careful eye on it, to make sure you let the water out of the syringe before the gas that is produced pushes the piston out of the syringe.
5. Once you have released the water, close the valve to keep the gas in the syringe, and attach the plastic tube to the valve. If gas continues to be produced, leave the valve open.
6. Press the piston of the syringe to push the gas into a test tube through a pneumatic trough (use the plastic tube, bowl of water and test tube as in the diagram).
7. Perform the test for hydrogen by holding the mouth of the test tube in a flame (see diagram below), making sure you hold the top of the tube close enough to the flame. The test should be positive.

Optional: add one droplet of phenolphthalein solution to the water you collected in the beaker. What happens? Why?

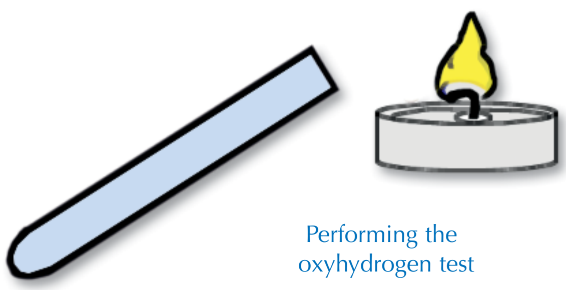
Health and safety note: the remaining liquids can be disposed of in the sink. Clean the plastic materials with water and leave them to dry.



Mixing the two liquids via the three-way stop-cock



Collecting the gas



Performing the oxyhydrogen test

Images courtesy of Gregor von Borstel

Discussion

Other reactions commonly used in heater meals include the oxidisation of iron, the reaction of anhydrous calcium chloride with water (see below) or, for cooling, the reaction of ammonium nitrate fertiliser with water.

Further experiments such as making your own heat and cold packs, or determining the oxygen content in the air with the aid of the iron oxidation reaction used in heat packs, are described on the LNCU website[w3].

This activity can also form part of a lesson in which the students develop a script for a TV science programme to answer a viewer's question on the function of heater meals. The English version of this worksheet is available on the *Science in School* website[w5], the German one on the LNCU website[w3].

A quick cup of hot coffee

In this activity, students heat coffee using anhydrous calcium chloride and water. The activity works well as part of a teaching unit on dissolving salts in water, to introduce the energetic aspects of this process. Students should already be familiar with ionic and covalent bonds. The activity works well with groups of three students aged 14 and over.

One possibility is to discuss lattice energy, using as an example from everyday life cold packs that rely on an endothermic reaction triggered by bending a metal plate. The following activity can then be used to introduce the notion of hydration energy and to demonstrate that the reaction by which some salts dissolve is an exothermic reaction.

The activity is relatively safe – the most dangerous aspect is the possibility of breaking glass by not handling it carefully.

Materials per group

- About 10 g anhydrous calcium chloride
- Different sizes of beakers
- Water
- Styrofoam / polystyrene (use reasonably large pieces as smaller pieces are a nuisance when they become charged and 'stick' everywhere)
- Two laboratory thermometers
- Soluble coffee powder
- Further items to awaken the students' imagination, such as rubber bands, foil, batteries, etc.

Student worksheet

1. Using the materials provided, how can you achieve the highest possible temperature change when making coffee?

   You have 5 minutes to discuss your experimental approach in the group. Before you put your plan into action, check the safety (not the feasibility) of it with your teacher.

   You then have 10 minutes to perform the experiment. If you want to change your procedure part way through, check with your teacher.

2. Before you start, record the starting temperature of the air and the coffee, and note the amount of coffee (in ml) you are making.

3. During the experiment, measure the air and coffee temperatures and note down the maximum temperature you achieve.

Safety note: Wear safety goggles; do not drink the coffee.

BACKGROUND

The source of the activities: *Lebensnaher Chemieunterricht*

In 2003, four German chemistry teachers joined forces to create a web portal to share their best teaching ideas: *Lebensnaher Chemieunterricht*[w3] (LNCU, chemistry lessons relevant to everyday life). Their collection has grown steadily, and they offer a wide selection of activities for all age ranges from primary to upper-secondary school, linking to major curricular topics in chemistry, such as the periodic table, titration, and air and water, plus biology and physics activities for the youngest students.

Their German-language materials are freely available as downloadable PDFs and Word® documents, with both instructions for teachers and worksheets for students. In addition, the website offers a range of videos on the activities and a list of more (German and English) websites with teaching ideas and relevant materials for the science classroom.

Potential approaches

Two problems the students often face are adding too little calcium chloride to the water (the more they use, the more heat will be produced) and forgetting to insulate their beakers.

A common solution to the task is to improvise a small water bath by placing water and calcium chloride in a large beaker, and fixing styrofoam around the beaker with sticky tape. The coffee can then be heated in a smaller beaker in the improvised water bath.

The best result within the context of the LNCU project (see box) was achieved by filling a small beaker with water and placing it in a larger beaker with a layer of styrofoam inbetween for insulation. The students then placed the calcium chloride, to which they had added very little water, in a small film canister. Attaching a string to it and a stone for weight, they let it hang into the water. The temperature of 50 ml of coffee changed from 20 to 44 °C in less than a minute.

Heating coffee with calcium chloride

Image courtesy of Gregor von Borstel

Discussion

Discuss the apparent contradiction between the behaviour of cold packs in previous experiments and the experiment you have just performed – in this case, the solution process is not endothermic. In the cold packs, more energy is required to destroy the salt's molecular lattice (lattice energy) than is released when water molecules surround the ions (hydration energy). The required energy is drawn from the surroundings, so the solution cools down. In the coffee experiment, in contrast, the hydration energy is higher than the lattice energy, so the process as a whole is exothermic. Hydration and lattice energy are fixed characteristics of an individual salt.

Further experiment

To follow this up, the students could try to achieve the lowest possible temperature using anhydrous calcium chloride, sodium chloride and ice. They may be surprised to find that the addition of anhydrous calcium chloride to ice (rather than water) does not increase the temperature. This is because the hydrogen bonds in the ice crystals first have to be broken, which requires energy, so that the full process is endothermic.

Web references

w1 – To order Crosse & Blackwell heater meals online, see: www.heatermeals.co.uk, www.aapnespis.no or www.dauerbrot.de

w2 - The ChemZ kits were developed in close collaboration with the LNCU project, and offer a range of plastic materials normally used in medicine for use in school labs. For more information and to order materials, see: www.chemz.de

w3 – The LNCU project is run by German chemistry teachers Andy Bindl, Andreas Böhm, Gregor von Borstel and Manfred Eusterholz. For more information (in German) and to access all materials, see: www.lncu.de

w4 – Videos of the heater meals (albeit an older version in which the packs were in deep plates rather than today's aluminium sachets) are available on the Dauerbrot website (www.dauerbrot.de) or via the direct link: http://tinyurl.com/6ewkvhw

as well as here www.aapnespis.no/Norsport1_0/show.htm

You can also find a photo demonstration of how the heater meals are prepared here: www.mlaltd.co.uk/store

w5 – To download the English worksheets of the main heater-meal and the heater-meal science TV show activities, see: www.scienceinschool.org/2011/issue18/lncu#resources

Resources

For some microscale chemistry experiments using disposable materials, from kindergarten to secondary-school level (in English and German), see: http://www.micrecol.de/

If you find the idea of microscale chemistry experiments appealing, you may also like:

Kalogirou E, Nicas E (2010) Microscale chemistry: experiments for schools. *Science in School* **16**: 27-32. www.scienceinschool.org/2010/issue16/microscale

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

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

To learn how to use this code, see page 1.

Biomimetics: clingy as an octopus or slick as a lotus leaf?

Astrid Wonisch, Margit Delefant and **Marlene Rau** present two activities developed by the Austrian project 'Naturwissenschaft und Technik zum Angreifen' to investigate how technology is inspired by nature.

In 2004, Alice Pietsch from the University of Teacher Education Styria[w1], Austria, was inspired by a simple but very visual demonstration at a science museum. A retired science teacher was using bellows to pump air into a pair of sheep's lungs, rhythmically inflating and deflating them. The crowd around him was much larger than around many of the more high-tech exhibits – which is what prompted Alice to create an interactive science museum.

In 2008, her dream came true. Over five months, Styrian students of all ages developed 50 different activities for other students. The exhibition *Naturwissenschaft und Technik zum Angreifen* ('Science and technology to touch') took place in 2009 at the *Haus der Wissenschaft* ('House of science') in Graz, Austria, where the students and their teachers helped the visitors with each activity. It was a huge success.

Most of the activities from the exhibition are suitable for the science classroom; here we present two activities about biomimetics – the application of principles from nature to engineering and technology. Velcro, which mimicks the hooked seeds of burdock, and boat hulls that mimic the

Image courtesy of chang / iStockphoto

Octopus suction pads

REVIEW

- Biology
- Chemistry
- Physics
- Ages 5-19

Get stuck in! Or rather, give your students an opportunity to get stuck in with the activities described in the article.

The stickiness of tree frogs' feet and of octopus tentacles prompts students to explore how this works using suction pads. Younger students will enjoy drawing around their feet and the noises that the suction pads make as they 'slurp off' when pulled. Older students can appreciate the physics and explain what is happening using calculations.

The stickiness of honey makes an appearance in the second activity, along with ketchup, cinnamon and curry powder – what student will not enjoy being let loose with these ingredients? Investigating non-stick lotus leaves and nasturtiums leads on to investigating novel self-cleaning liquids. This could lead to some interesting debates, as well as practical work that ranges from simple tasks for young students (rolling water off leaves) to much more complex work for older students, working with sprays and using scanning electron micrographs to explain phenomena.

The first activity covers physics (pressure) and the second activity, chemistry (surface interactions), both linking to biology with the idea that nature got there first – which could be taken further and investigated by the students. If different varieties of leaf are investigated, taxonomy can be introduced as well.

Here are some suggestions for questions you could ask your students after the activities:

1. Draw a diagram to show a suction pad before and after it is pushed onto a surface. Annotate it to show areas of high, low and equal pressure.
2. The article reminds you that force = area x pressure. Here this is used to calculate the force of a suction pad. Can you think of some other contexts in which this equation could be used?
3. It is very annoying (and noisy) when a shower tray attached by suction pads to a tiled shower wall falls down. Explain what might make the suction pads 'fail' and cause the crash.
4. The article mentions that "dung beetles crawl out of cowpats". What might dung beetles be doing inside cowpats and why might they be crawling out? This might take some research!
5. A scanning electron microscope is mentioned in the discussion of the second main activity. What is a scanning electron microscope? How does it differ from a transmission electron microscope?
6. The bumps on a lotus leaf are up to 20 micrometres (μm) high. Express this height in a) nanometres (nm) and b) millimetres (mm).
7. Explain, in your own words, what is meant by
   - Hydrophobic
   - Hydrophilic
   - Surface tension
   - Pollutant
   - Inorganic

You could also get your students to carry out a risk assessment for one or both of the activities. Some countries insist on these. Although it is the teacher's role to provide a risk assessment, it is thought that if students are involved in creating their own risk assessments, they are likely to be much safer as they will have thought through the dangers themselves. Below are some suggested responses, although any valid responses or alternatives could be accepted. For some activities, the likelihood of incidents may vary with the age of the students.

Image courtesy of midlander1231; image source: Flickr

Risk assessment

Danger	Explanation of danger	Likelihood (1 = very likely, 5 = very unlikely)	Severity (1 = very severe, 5 = minor inconvenience)	Prevention or reduction
Fretsaw	Cut skin	4	3	Train students how to use the saw safely and how to store it when not in use. Hold the pole in a vice if possible while cutting the grooves.
Plants	Some may be toxic	5	2	Only bring plants into school that are known to be safe Warn students, especially younger ones, not to eat the plants or put their fingers in their mouths
	Some students may be allergic to some plants or parts of plants such as pollen	3	3	Ask students about any known allergies Check any medical records for younger students

Sue Howarth, UK

A tree frog

Image courtesy of Nickodemo; image source: Flickr

thick skin of dolphins are common examples. The activities below investigate suction pads and superhydrophobicity, both seen in nature. The activities were developed for younger secondary-school students (aged 10-15), but can easily be adapted for students of virtually any age and are a good opportunity for integrating physics, chemistry and biology. Depending on the level of detail you go into, the activities can each take anything from five minutes to over an hour.

The full collection of activities from the exhibition is available in print in German from Birgit Muhr (birgit.muhr@phst.at) for €19 plus postage.

Adhesion on flat surfaces: negative pressure

Household suction pads were inspired by the soles of tree frogs' feet and the tentacles of octopuses, whose suction power was already known to the ancient Greeks.

We use these pads on flat surfaces – to attach hooks to bathroom tiles or make kitchen machines more stable, and on rubber mats in the shower or toy arrows. But why do they stick?

If you look at a suction pad closely, you will notice that it is slightly curved. Could this curvature be important for the pad's adhesive power? And why do you need to wet suction pads before using them? Let's investigate.

Materials

- 4 suction pads (make sure you can attach a string to them)
- A small fretsaw
- A 50 cm pole, about 3-4 cm in diameter (the students should be able to wrap their fingers around it easily)
- Four 50 cm pieces of strong string
- A pair of scissors
- A plastic board (about 1 x 1 m)
- A permanent marker pen

Procedure

1. Using the fretsaw, make four equidistant grooves in the pole.
2. Tie a piece of string to each of the four suction pads.
3. Tie the other ends of the string to the four grooves on the pole. Make sure the four lengths of string are exactly the same length.
4. Put the plastic board on the ground, and use the permanent marker pen to draw four circles for the suction pads in a straight line. On either side of the line, draw a footprint (see image on page 55).
5. Press the suction pads onto the four circles.

A fretsaw

Image courtesy of PHSt Archiv

The setup for the adhesion activity. Alternatively, a single suction pad and a shorter piece of wood can be used (see back of the image)

6. What happens to the curvature of the suction pads when they are stuck to the plastic board?
7. Stand on the footprints and try to pull the suction pads off the plastic by pulling on the pole.
8. Repeat the experiment, wetting the suction pads before sticking them to the plastic board. What do you observe?

Discussion

When you press the suction pad onto the plastic board, you reduce the pad's curvature, thereby reducing the volume of the space between the pad and the board, and causing some of the air between the pad and the board to escape. When you stop applying pressure, the elastic pad tends to resume its original, curved shape. The volume in the cavity between pad and board is increased again, but there is less air in it, and therefore also a lower air pressure. The higher pressure of the air outside the pad is what keeps the pad stuck to the board.

You can calculate the force of a suction pad as:

$F = AP$, where F: force; A: area; p: pressure.

The area will be πr^2 where r is the radius of the pad. The pressure inside the cavity between pad and board is negligible when compared to atmospheric pressure, which is about 100 000 Pa. So:

$F = \pi r^2$ (100 000 Pa)

The time it takes for the pad to come undone by itself (without applying additional force) will depend on how porous and flat both the rim of the pad and the underlying surface are, which determines how fast the air leaks back in and equilibrates the pressure.

Water, saliva and other liquids work well to seal the pad, making it more airtight and ensuring that air leaks back in less easily. Therefore, you need even more strength to pull the suction pads off if you moisten them before applying them to a surface.

Self-cleaning effects: hydrophobicity in nature

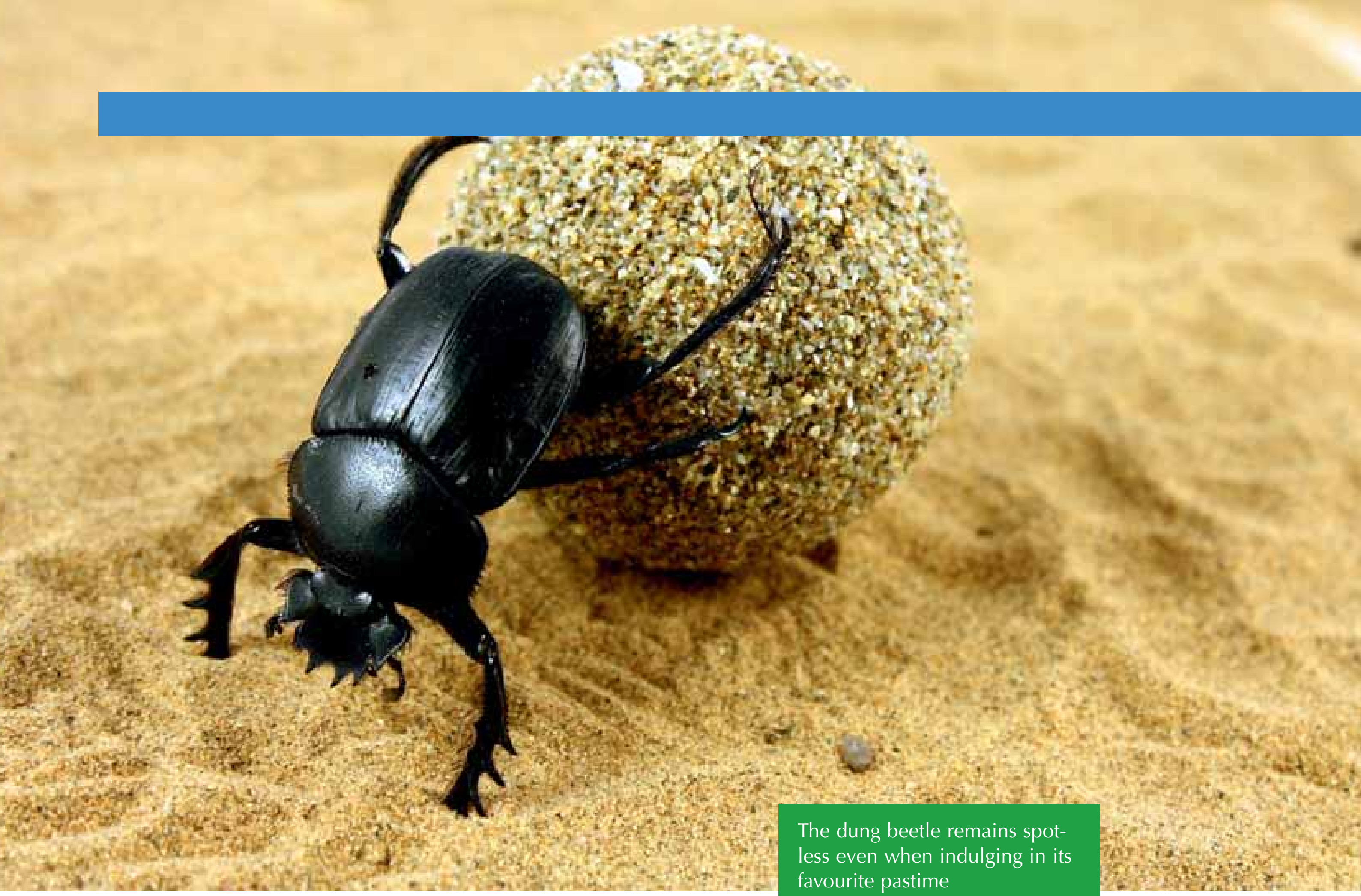
Nature has some real cleanliness fanatics: dung beetles crawl out of cowpats looking spotless, you rarely find a dirty butterfly or dragonfly, and some plants are very successful at shedding filth. The Indian lotus, for example, grows in muddy waters, yet no dirt clings to its leaves; in fact, in Buddhism, the lotus is a symbol of purity. You can find this lotus effect closer to home, too: nasturtium leaves

Image courtesy of Professor Edith Stabentheiner, Karl-Franzens-Universität Graz

A scanning electron microscopy image of a nasturtium leaf showing the complex wax structures on the epidermis cells; these structures are responsible for the superhydrophobicity

Image courtesy of tanakawho; image source: Flickr

A lotus leaf showing off its hydrophobic properties



The dung beetle remains spotless even when indulging in its favourite pastime

Image courtesy of vendys / iStockphoto

and flowers look clean enough to eat, even without washing (rinse them anyway, just in case). How do they manage without soap?

Humans have replicated this self-cleaning effect for many purposes, for example, in self-cleaning plastics, roof tiles, windowpanes, ceramics, wood and car varnishes, and façade paint. You can also create dirt-repellent clothes by impregnating them with a special spray.

How does it work? Let's find out.

Materials

- Parts of different plants with self-cleaning properties, such as nasturtium (*Tropaelum majus*), lotus leaves (*Nelumbo nucifera*), cabbage leaves (*Brassica oleracea*), and tulip leaves (*Tulipa spp.*)
- Parts of different plants with hydrophilic leaves, such as leaves of the common beech (*Fagus sylvatica*) or the Southern magnolia (*Magnolia grandiflora*)
- Water, runny honey and / or liquid glue
- A Pasteur pipette and bulb, and some small spoons
- Ketchup, ground cinnamon and curry powder
- Newspaper, kitchen roll and textiles
- Impregnation spray (e.g. for waterproofing suede), self-cleaning nano-based façade paint, nano-coating for wood or glass
- Optional: a nano-sealed roof tile

Procedure

1. Wet the self-cleaning plants with water, honey or glue and cover them with ketchup, cinnamon or curry powder (to simulate dirt). What do you observe?
2. Repeat the experiment with the hydrophilic leaves. What do you observe?
3. Now investigate the self-cleaning properties of artificial materials. Spray textiles, kitchen roll and newspaper with different types of nano-sealing treatments (e.g. impregnating spray, paint or nano-coating). Either compare the effect of the same type of treatment on different materials, or of different types of treatment on the same material.
4. Use these and other nano-coated materials (e.g. tiles) to repeat the experiments, wetting and dirtying them. What do you observe?

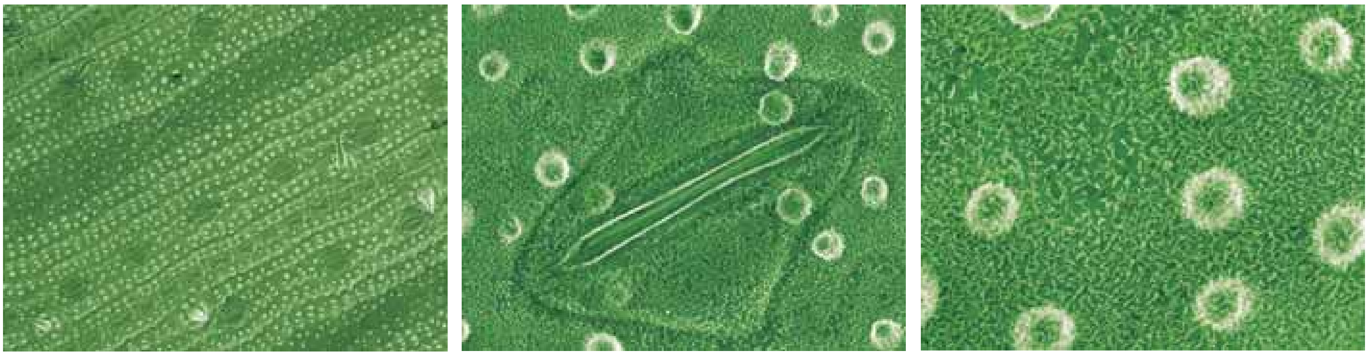
Safety note: Some students may be allergic to some plants or parts of plants such as pollen. When using nano-coating, impregnation spray, etc., carefully read the instructions on the package. They may require the use of gloves or a well-ventilated space. See also the general safety note on the *Science in School* website (www.scienceinschool.org/safety) and on page 65.

Discussion

If you drop water or honey onto a lotus leaf, it will roll off very quickly. A close look under a scanning electron microscope reveals why: large numbers of tiny wax-covered bumps on the surface. These bumps are

Image courtesy of midlander1231; image source: Flickr

Images courtesy of Sarah Perfect / Syngenta



Scanning electron microscopy images (at magnifications of 300x, 2500x and 3000x) showing the wax structures on the surface of a rice leaf, similar to those on nasturtium or lotus leaves. The first image shows the waxy bumps amongst the stomata; the second image shows a stoma close up; the third image shows the papillate surface of the leaf and the fine detail of the wax structures

about 10-20 μm high and 10-15 μm apart from one another.

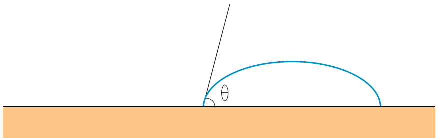
How does this structure help the lotus leaf to remain clean? First, the surface of the lotus leaf is hydrophobic (water-repellent). The hydrophobicity of a surface can be quantified as the contact angle between the surface and the drop of water: the higher the contact angle, the more hydrophobic the surface (see image to the right). Surfaces with a contact angle <90° are called hydrophilic ('water-loving'); those with a contact angle >90°, hydrophobic. Some plants, which are known as *superhydrophobic*, achieve contact angles of up to 160°, with only 2-3% of the drop's surface in contact with the surface of the leaf. However, the lotus leaf is not only superhydrophobic but also covered in the aforementioned waxy bumps. These reduce the contact surface of the water droplet still further (imagine the drop sitting on the points of the bumps), with the result that the drop barely touches the leaf (only 0.6% surface contact) and runs off easily.

We have seen how the water flows off, but how do the leaves get rid of dirt particles? Plants are exposed to a variety of pollutants, many of which are inorganic (dust or soot), although others are of biological origin (e.g. fungal spores, conidia, honeydew or algae). On unwettable leaves such as those of the lotus, it is not only the adhesion of water to the surface that is reduced – dirt is also simply washed away by the water. This is not as obvious as it seems, though: there are two different types of dirt particles – hydrophilic and hydrophobic ones. Hydrophilic particles such as silt are taken up in the water droplet and cannot escape again. A track is visible on the leaf where the drops have taken up the particles and washed them away.

But what about the hydrophobic particles? You might expect them to stick to the hydrophobic leaf surface, but in fact a drop of water will remove these particles too. How does this happen? The particles only touch the outermost tips of the wax structures, and since this contact surface is tiny, so are the adhesive forces between particle and leaf. They are so low that even the small adhesive forces between the water-repellent particle and water are stronger. So unlike the hydrophilic particle, which is taken into the drop, the hydrophobic particle sticks to the surface of the drop. The end effect is the same, though – it is washed off the plant.

Superhydrophobicity is not limited to lotus plants: other plants have self-cleaning properties thanks to mats of

The contact angle Θ of a water droplet on a surface



Public domain image; image source: Wikimedia Commons

Droplets of fluid on a surface, demonstrating different levels of hydrophobicity

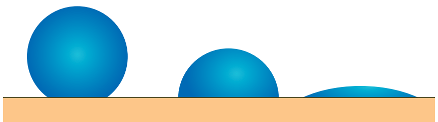
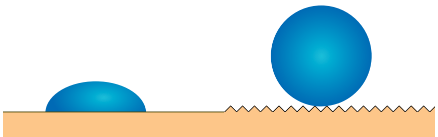


Image courtesy of MesserWoland; image source: Wikimedia Commons

On a superhydrophobic surface, a drop will be almost spherical and have a very low contact angle



Public domain image; image source: Wikimedia Commons

hair covering their leaves, butterfly wings have tiny ratchets that direct raindrops away from the insect's body no matter whether the wing is tilted up or down, and the cuticle of dung beetles has embossed geometrical textures that make it hydrophobic.

What is the advantage of these self-cleaning surfaces? For sedentary

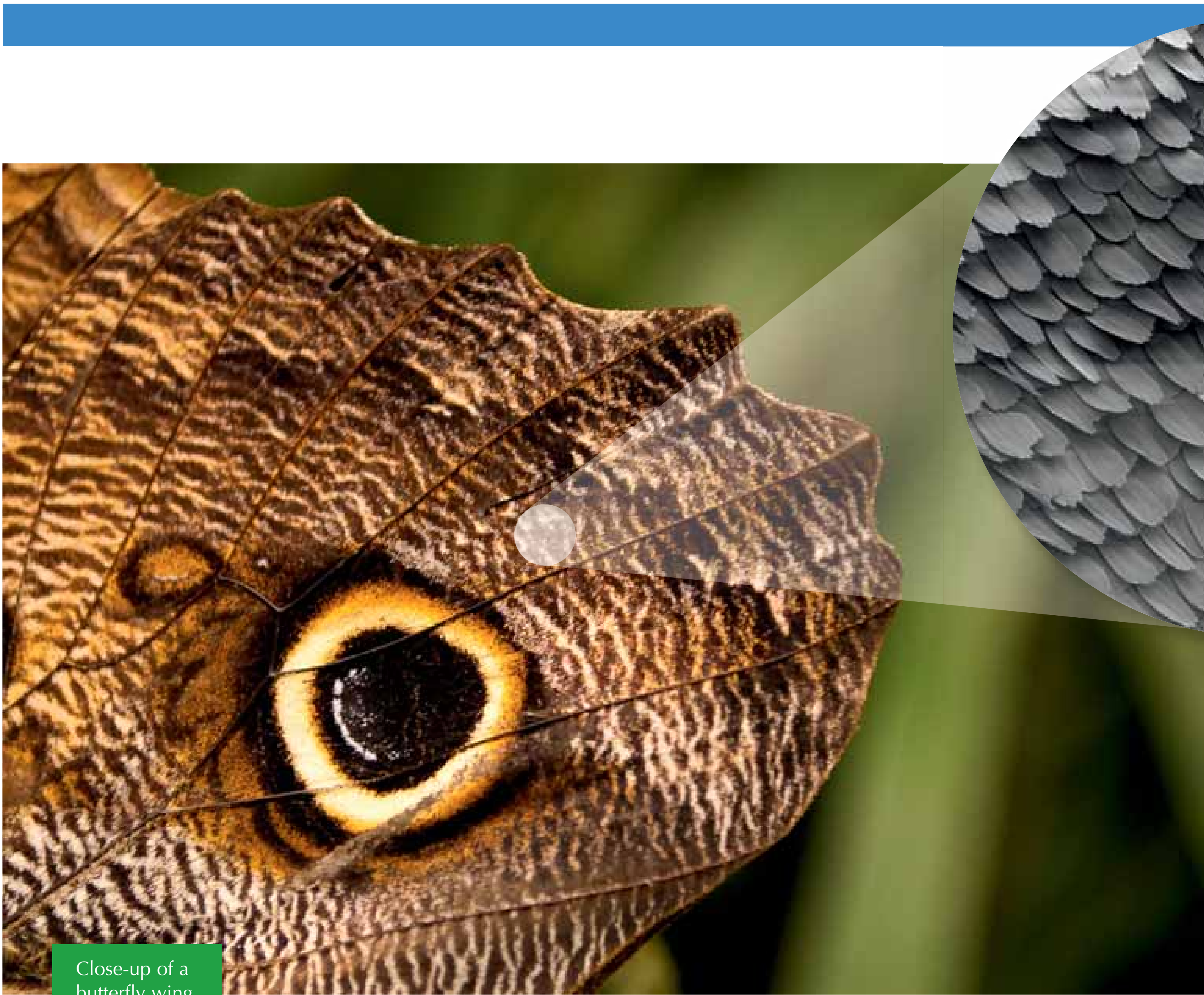


Image courtesy of Sebastian; image source: Flickr

Close-up of a butterfly wing

plants, they are a way of protecting themselves against micro-organisms, such as fungi, bacteria or algae. Most plants fight these enemies chemically through a large range of secondary metabolites, but preventing them from settling in the first place is potentially even more effective. In addition, if leaves are covered in dirt, this reduces the surface available for photosynthesis. The self-cleaning wings of butterflies have the advantage of not retaining water and becoming heavy, which would prevent the insects from flying.

Humans have developed many types of technology that emulate these hydrophobic effects. Impregnation sprays, for example, cover the material with a wax-like coating that makes the materials hydrophobic. Some façade paints go even further, forming tiny bumps when they dry. These bumps are as water-repellent as the lotus's wax structures with the result that the painted surface becomes superhydrophobic.

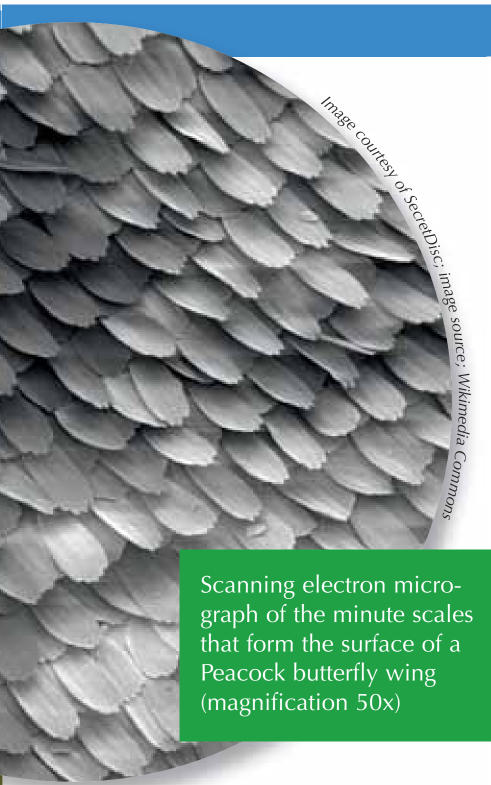
Illustration of the lotus effect

Image courtesy of William Thielicke; image source: Wikimedia Commons

Acknowledgements

The two activities in this article were developed in the context of a workshop led by Astrid Wonisch for students of the Karl-Franzens-Universität Graz who were training to become biology teachers, and included in the 2008 exhibition *Naturwissenschaft und Technik zum Angreifen*.

Biology students Steffen Böhm and Karin Edlinger worked together with students from the combined 7th and 8th grade (aged 17-19) biomimetics class at the secondary school BG / BRG Petersgasse, Graz, a secondary school with a science and maths focus, and the school's biology teachers, Renate Rovan and Ruth Unger, on 'Adhesion



Scanning electron micrograph of the minute scales that form the surface of a Peacock butterfly wing (magnification 50x)

on flat surfaces: negative pressure'.

Biology students Anna Freudenschuss and Ingo Fuchs worked together with students from a 4th grade (aged 14-15) class at the secondary school BG / BRG Fürstenfeld, Fürstenfeld, on 'Self-cleaning effects: hydrophobicity in nature'.

Web reference

w1 – To learn more about the University of Teacher Education Styria, see: www.phst.at

Resources

The German TV channel SWR has produced a series of short videos on suction pads in nature and technology, with accompanying teaching materials (in German). See their education website Planet Schule (www.planet-schule.de) or use the direct link: http://tinyurl.com/6gey6tg

The following website offers a wealth of information on the lotus effect in English and German, including a small collection of videos: www.lotus-effekt.com

For primary-school teaching activities on hydrophobicity and the surface tension of water, see:

Kaiser A, Rau M (2010) LeSa21: primary-school science activities. *Science in School* **16**: 45-49. www.scienceinschool.org/2010/issue16/lesa

For a more in-depth overview of bio-inspired design, comparing the achievements of nature and technology, see:

Vincent J (2007) Is traditional engineering the right system with which to manipulate our world? *Science in School* **4**: 56-60. www.scienceinschool.org/2007/issue4/biomimetics

For more information on biomimicry, see the Ask Nature website: www.asknature.org

For further teaching activities on superhydrophobicity and nano-waterproofing for different age ranges, see:

The EGFI website: http://teachers.egfi-k12.org/nano-waterproofing

The Nanoyou website (http://nanoyou.eu) or use the direct link: http://tinyurl.com/6d88zmd

The NanoEd resource portal (www.nanoed.org) or use the direct link to the PDF: http://tinyurl.com/6dwxo2b

For more nanotechnology-related resources for the classroom, see:

Harrison T (2006) Review of *Nano: the Next Dimension* and *Nanotechnology*. *Science in School* **1**: 86. www.scienceinschool.org/2006/issue1/nano

Hayes E (2010) School experiments at the nanoscale. *Science in School* **17**: 34-40. www.scienceinschool.org/2010/issue17/nano

Mallmann M (2008) Nanotechnology in school. *Science in School* **10**: 70-75. www.scienceinschool.org/2008/issue10/nanotechnology

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

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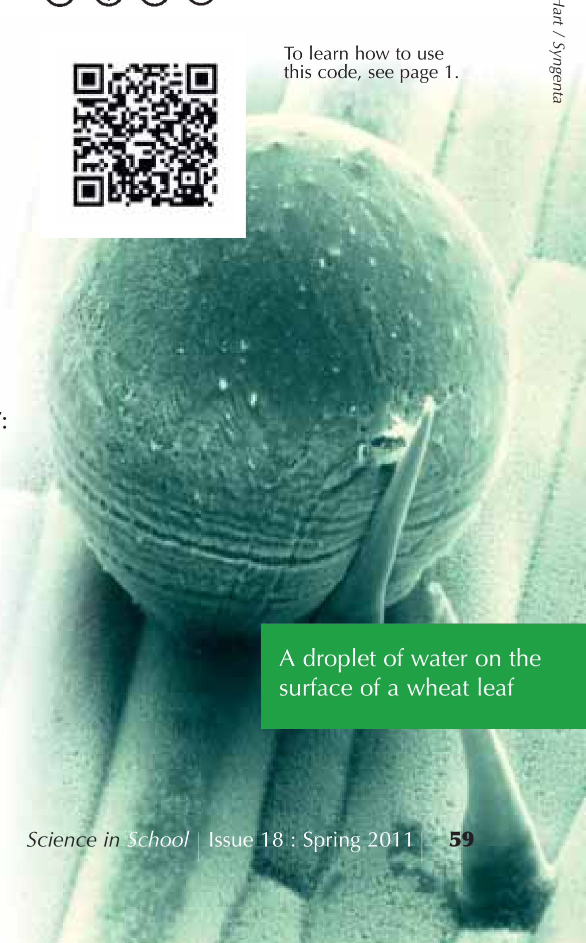
Margit Delefant is the deputy director of the regional didactics centre for biology and environmental science in Styria, Austria. She splits her time between teaching at the secondary school BG / BRG Fürstenfeld and at the Karl-Franzens-Universität Graz, where she teaches didactics to future biology teachers.

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

To learn how to use this code, see page 1.



A droplet of water on the surface of a wheat leaf

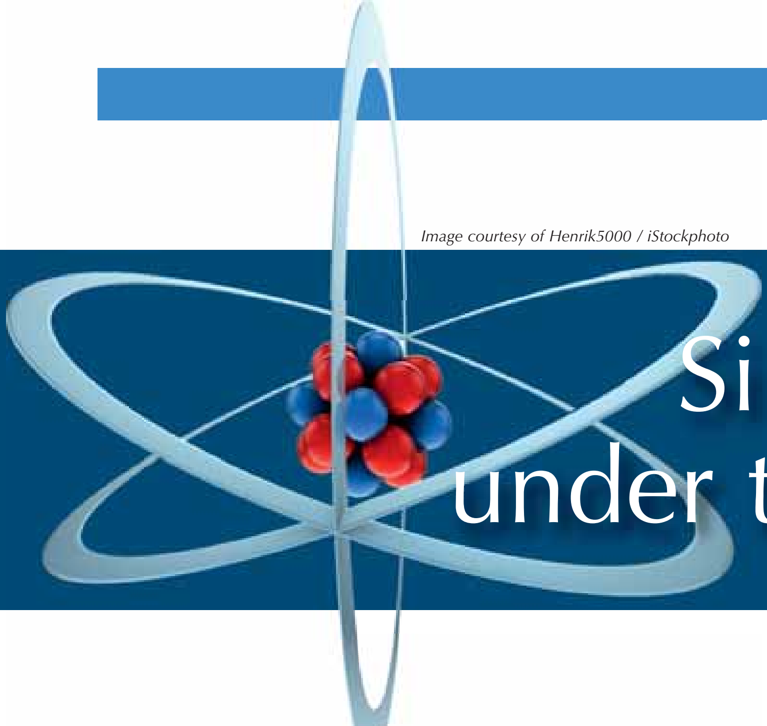


Image courtesy of Henrik5000 / iStockphoto

Single molecules under the microscope

The idea of looking at single molecules or atoms has fascinated scientists for over a hundred years. This ambitious goal was first achieved in 1981 with the invention of scanning tunnelling microscopy, for which Gerd Binnig and Heinrich Rohrer at the IBM Research Laboratory in Rüschlikon, Switzerland, were awarded the Nobel Prize in Physics some time later, in 1986[w1]. This microscope has a severe limitation though: it works only on electrically conducting objects, so many interesting materials including biomolecules could not be studied.

Binnig and his colleagues continued to search for better solutions, and in 1986, presented the atomic force microscope (AFM), which can be used to image both conducting and non-conducting materials.

The instrument works not unlike a record player, in which a sharp needle scans a vinyl record to reproduce sound (see image on page 62). The AFM 'feels' the atoms, rather than 'seeing' them: the structure of a surface is scanned with a very sharp cone (typically of silicon or silicon nitride) at the end of a flexible cantilever that can follow even the smallest details of the surface. When the tip, consisting of a single atom, comes close to the sample surface, it is deflected through forces between the two: these can be mechanical contact forces, van der Waals forces, capillary forces, chemical bonding, electrostatic forces, magnetic forces, Casimir forces, solvation forces or others, depending on the nature of the specimen.

Because this variety of forces can be measured with the AFM, it is very versatile and has led to an explosion in the number of scientists using the instrument – mostly but not only for material sciences and biology. In each case, the force causing the deflection is tiny and proportional to the tip's distance from the surface.

How can these tiny deflections be measured? The inventors used a clever trick: a laser spot is shone onto the top of the cantilever, from where it is reflected onto a position-sensitive light detector. The change in the laser spot's position on the detector (see diagram on page 61, ΔH) due to a deflection of the cantilever (see diagram on page 61, Δh) is proportional

Image courtesy of lovestruck; image source: Flickr

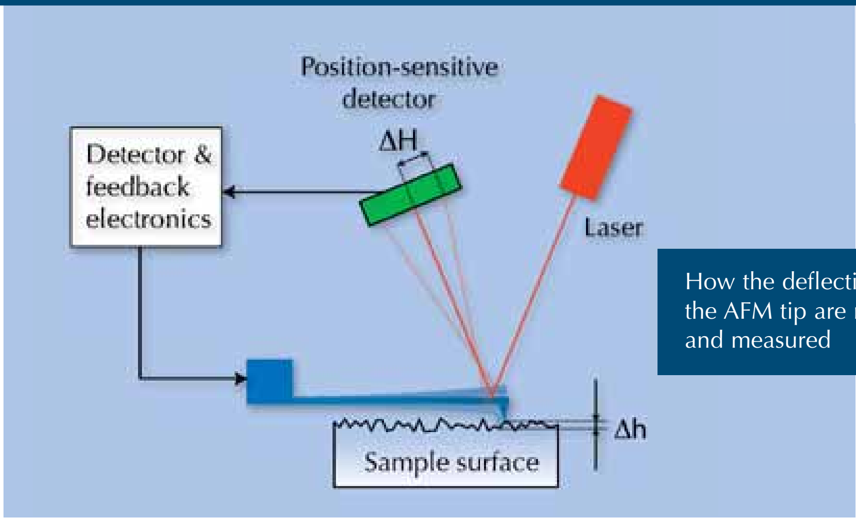
Boats suffering from biofouling

Would it not it be fascinating to observe and manipulate individual molecules? **Patrick Theer** and **Marlene Rau** from the European Molecular Biology Laboratory explain how, with an atomic force microscope, you can do just this. You could even build your own.

to the distance between the detector and cantilever. With large enough distances between them, even tiny deflections can be measured, making it possible to study the structure of surfaces atom by atom.

The applications of the AFM are myriad. Let us take a brief tour of just a few of them.

Originally, AFM was developed to observe and analyse surface struc-



How the deflections of the AFM tip are magnified and measured

Image courtesy of Patrick Theer

REVIEW

- Physics
- Biology
- Medicine
- Physiology
- Ages 14-19

This article would be suitable for a wide range of science lessons – not only in physics but also when considering animal physiology or biomedical sciences, for example.

Students can research atomic force microscopy and its uses further, as there is plenty of material on the Internet about the advantages and disadvantages of various microscopy techniques. They could also look up the group of scientists who invented the atomic force microscope (having won a Nobel Prize for a previous invention) and find out more about them and their work.

Potential comprehension questions include:

1. What was the limitation of scanning tunnelling microscopy?
2. What microscope was developed to overcome the problems of scanning tunnelling microscopy?
3. Explain how AFM is like a vinyl record (please note that some students may not be familiar with vinyl records).
4. Explain the term biofouling.
5. Why is biofouling a problem?
6. Give examples of potential uses of AFM.
7. What would you like to investigate if you had an AFM?

The article could be used with groups of older students or those most able to think creatively, perhaps for an extended writing task in conjunction with the film Honey I Shrunk the Kids (about a scientist working on a top-secret machine that miniaturises objects and – accidentally – people), to get the students to think about looking at single molecules. What would they like to use AFM for? Would they use their images as art or for scientific research? Would they want to use their knowledge to cure diseases or to see how beautiful science can be at this level?

Jennie Hargreaves, UK

tures in minute detail – not only is this interesting for research purposes, but it can have direct economic benefits: biofouling is the undesirable accumulation of micro-organisms, plants, algae and / or animals (such as barnacles, Cirripedia) on wet structures. On ship's hulls, high levels of fouling can increase water resistance and thus substantially increase fuel consumption, but it is also an issue in membrane bioreactors, cooling water cycles of power stations and certain oil pipelines. Scientists use AFM to measure the degree of biofouling and thus compare the anti-biofouling activity of different substances, to identify the ideal material (Finlay et al., 2010).

Similarly, AFM has its uses in agriculture: pineapple plants often suffer from a fungal disease called fusariosis. Scientists compared the surface structure of cells from pineapple cultivars that are resistant to this disease with those of susceptible cultivars, and found that they have different mechanical properties. This can now be used to select and improve resistant cultivars that have the required mechanical properties (de Farias Viégas Aquije et al., 2010).

Is surface structure relevant to human health, too? The answer is yes: AFM studies are often used in dentistry, for example to compare the effectiveness of different methods to remove plaque and stains; to measure the surface roughness of braces and see how this influences the effectiveness with which the teeth are pulled into shape; or to quantify the erosion of tooth enamel caused by acid in soft drinks and test the efficacy of various toothpastes in repairing this damage (Kimyai et al., 2011; Lee et al., 2010; Poggio et al., 2010).

Other medical applications include the development of new biomaterials in regenerative medicine: their surface properties such as wettability, roughness, surface energy, surface charge, chemical functionalities and composition can determine the behaviour of the cells they will come into contact with. Thus AFM can be used, for example, to help design biomaterials that are tolerated by the body and can be used for medical implants such as artificial hips (Al-Ahmad et al., 2010; Kolind et al., 2010; Padial-Molina et al., 2011).

The needle is poised over a vinyl record, ready to begin scanning its surface to produce sound

Image courtesy of arbobo; image source: Flickr


Image courtesy of Frantysek / iStockphoto

Another major field of application for AFM in medical biology is the misfolding and aggregation of proteins such as α-synuclein, insulin, prions, glucagon and β-amyloid. These phenomena have long been implicated in degenerative diseases such as type II diabetes, Parkinson's, spongiform encephalopathy ('mad cow disease'), Huntington's and Alzheimer's. Here AFM has already provided important information on the nanoscale structure of the aggregates, and it is hoped that scientists will be able to use AFM to identify why the protein misfolds in the first place, and how it encourages surrounding proteins to adopt the same misfolded structure (Lyubchenko et al., 2010; for an explanation of prion misfolding, see Tatalovic, 2010).

Further biological interactions that have been studied with AFM include how human trophoblasts (cells forming the outer layer of a blastocyst which provide nutrients to the embryo and develop into a large part of the placenta) interact with epithelial cells of the uterus – the basis of successful embryo implantation (Thie et al., 1998).

It was only a small step from using AFM for observations to using it to manipulate atoms, molecules or other

The European Synchrotron Radiation Facility has developed an atomic force microscope especially for use on X-ray beamlines. One possible use is positioning nano-sized objects accurately in the X-ray beam. This is not a trivial task if both the object under study and the X-ray beam measure 100 nm or less across

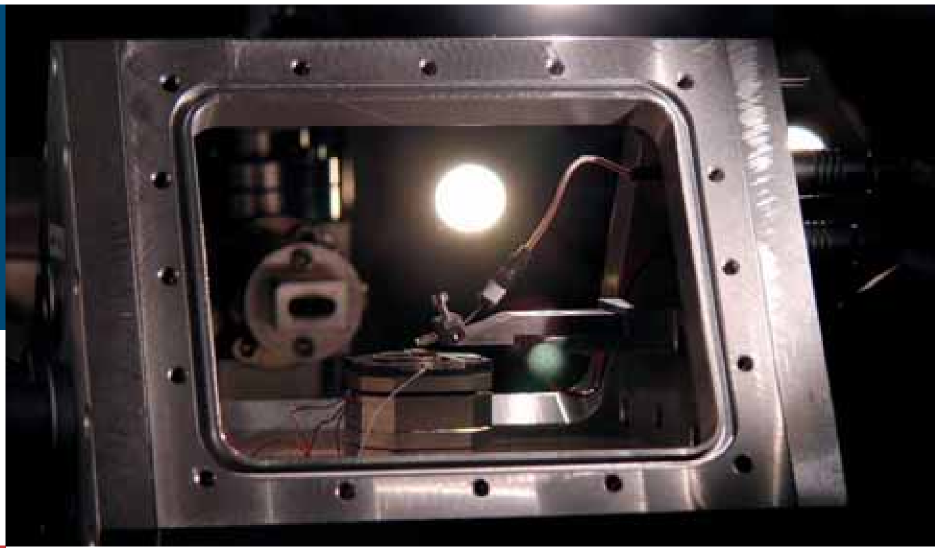


Image courtesy of ESRF / Small Infinity

AFM has a full set of tooth-related applications

Image courtesy of webking / iStockphoto

nanoscale structures. For example, using the tip as nano-tweezers, precise regions of the cell's plasma membrane can be examined; individual protein loops can be removed to reveal the protein structure inside the molecule; and single molecules can be stretched into novel conformations to determine their elasticity. The next big step will be using AFM for nanosurgery: introducing or extracting individual molecules from the cytoplasm of individual cells, to study cellular homeostasis or for subcellular drug delivery (Lamontagne et al., 2008; Müller et al., 2006).

Modified AFM tips can also be used as drills or pens: nano-milling removes material in the form of long curled chips (Gozen & Ozdoganlar, 2010), whereas dip-pen nanolithography is the controlled delivery of molecular or liquid 'ink'. In chemistry and the life sciences, such technology is used to produce nanoscale sensors or, by the deposition of metallic, semiconductor and metal oxide nanostructures, functional nanocircuits or nanodevices (Basnar & Willner, 2009). This, combined with using the AFM tip to physically push nanometre-sized particles to a desired position, should pave the way for the miniaturisation of electronic circuitry and other structures.

Despite its vast number of applications – these are just a small sample – the possibilities of AFM are not yet exhausted. Future trends involve optimised tips and combinations with other techniques, for example to simultaneously determine surface structure and fluorescence or electrical properties (Müller et al., 2006). Speed is another issue: recently, an AFM has been developed with which biological processes such as chromosome replication and segregation, phagocytosis and protein synthesis can be imaged in real time, up to 1000 times faster than was previously possible (Ando et al., 2008).

Are you now itching to come up with your own applications for AFM? Then you might want to try and follow Philippe Jeanjacquot's instructions[w2] for building your own instrument at school. It is a time-consuming project, but he and his students managed to create a feasibly low-cost microscope. There is one important catch though: you will need a vibration-free environment to set it up, such as a quiet cellar. If you can find that, your enthusiasm and ingenuity are the only limitations.

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w1 – To learn more about the discovery of the scanning tunnelling microscope, which won Gerd Binnig and Heinrich Rohrer the Nobel Prize in Physics in 1986, see: http://nobelprize.org/nobel_prizes/physics/laureates/1986

w2 – To download the instructions for building your own AFM at school, see: www.scienceinschool.org/2011/issue18/afm#resources

Resources

Swiss scientists have developed the first AFM for planetary science, which forms part of NASA's Phoenix mission to Mars. For a video introduction, see the Azonano website (www.azonano.com) or follow the direct link: http://tinyurl.com/6yguvb9

'Universe today' reports on the instrument's success in the mission. See their website (www.universetoday.com) or follow the direct links: snow on Mars (http://tinyurl.com/6kp3rym) and Martian dust grains (http://tinyurl.com/64z6xrb)

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Dr Patrick Theer is a physicist who has spent most of his career developing microscopy techniques. After studying medical physics in Berlin, Germany, in Toronto, Canada, and in Guildford, UK, he delved into the field of non-linear optics for a PhD at the University of Heidelberg, Germany, studying the imaging depth limit in two-photon microscopy – an optical sectioning method that can provide information from very deep within scattering tissues. For his postdoctoral work, he moved on to the University of Washington in Seattle, USA, studying voltage-sensitive dyes using second harmonic generation microscopy. Currently, he works as a senior research assistant at the European Molecular Biology Laboratory in Heidelberg, developing a light-sheet-based fluorescence microscope for the study of embryonic development.

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

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

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Teacher solidarity: a UK-Rwandan physics project

Thanks to the determination of UK physics teacher David Richardson, increasing numbers of students in Rwandan schools are experiencing the delight of practical work. **Vienna Leigh** reports.

Mention Rwanda and, even now, people are most likely to think of its troubles; the Rwandan genocide, 1994's mass killing of 800 000 people, is not something that can – or should – be easily forgotten. Today, though, this east-central African country is one of the continent's success stories, with an efficient government, notable economic growth and even a flourishing tourism industry. But when, in 2004, physics teacher David Richardson visited a colleague who was doing voluntary work at a secondary boarding school, Apred Ndera, about 5 miles from the capital Kigali, it was the education system that caught his attention.

"Students there are usually well-motivated and have a strong desire to do well, knowing that the way to move on is to get a good education," says David, who works at Clifton College[w1], a boarding school in Bristol, UK. "Unfortunately, though, discussion forms no part of the way they are taught. Often they just copy the work

Image courtesy of Zach Harden; image source: Wikimedia Commons

Image courtesy of Green Lane; image source: Wikimedia Commons

Clifton College in Bristol, UK

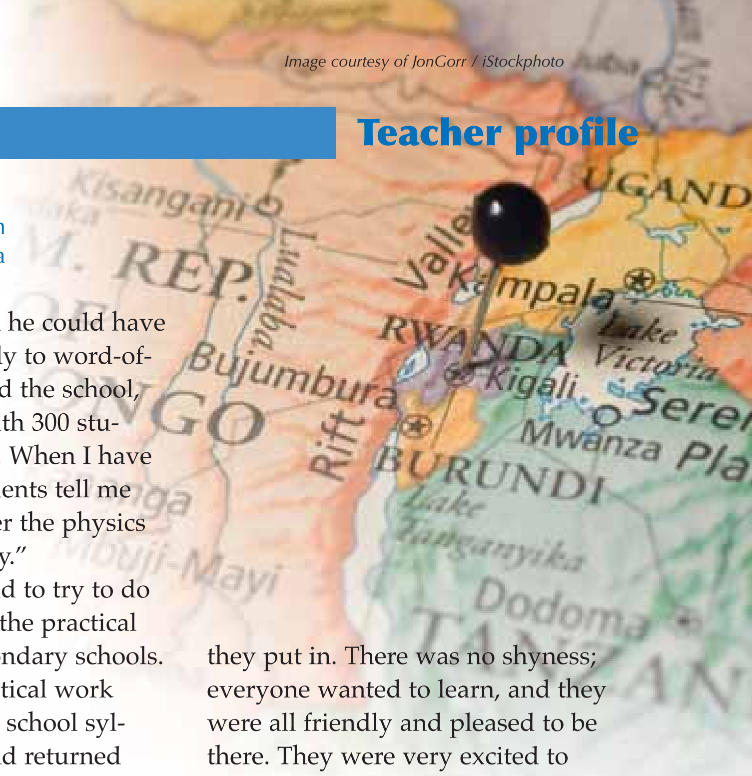

Image courtesy of JonGorr / iStockphoto

Rwanda is located in east-central Africa

from the board and try to understand it later. Teachers aren't valued in society and aren't well paid, with many having more than one job to make ends meet. They can also simply decide to leave one school to go and work elsewhere with no warning, meaning students are suddenly left with no teacher."

During his visit, David taught the senior 5 maths and physics class – 17-year olds – in their free periods. "Practical work isn't common in Rwandan schools, particularly in physics, mostly due to a lack of apparatus," he says. "Any equipment they have is often incomplete or broken, or they simply don't know how to use it. They hadn't even seen simple electric circuits, and none could connect up a battery pack to bulbs when I brought these into the lesson."

The flag of Rwanda

David was inspired to put together a one-hour show covering the school's physics syllabus. "I spent two weeks collecting together apparatus to demonstrate standing waves, oscillations in a pipe, Doppler and other wave effects," he explains. The results were more than he could have hoped for. "Thanks only to word-of-mouth publicity around the school, the hall was packed with 300 students! It was great fun. When I have been back to visit, students tell me that they still remember the physics they witnessed that day."

This persuaded David to try to do something to improve the practical work in Rwandan secondary schools. He looked at how practical work could be fitted into the school syllabus. "I made a list and returned home with a mission to find a way to get the necessary equipment to students in Rwanda," he explains.

During the following year, he approached the international department of the UK-based Institute of Physics[w2] (IOP) to see if they would fund his idea. "My aim was to take enough apparatus to allow five schools to carry out demonstrations in waves, dynamics, optics, electronics and modern physics," he says. "I planned to take four colleagues with me in the summer holidays, to work with ten local teachers, training them to use the apparatus and giving them the confidence to use it with their own classes."

The IOP agreed to the funding, and in August 2005, David, accompanied by IOP network coordinator David Grace, and a team from Gordano School, Portishead – head of physics Paul Crossthwaite, teacher Paul Welch and 18-year-old Adam Aziz, selected from among many student applicants – travelled back to Kigali. "Training the teachers was an amazing experience," says David. "I was impressed with the hard work that they put in. There was no shyness; everyone wanted to learn, and they were all friendly and pleased to be there. They were very excited to know what was in the first box!"

Even at mealtimes, the conversation often turned to physics. "It was interesting to hear about the politics of the education system, and how teachers worked within this at their schools," says David.

David began by showing them circuit apparatus. "They performed the experiments with care and precision, making careful notes, and were delighted that they would be able to take the apparatus away with them," he recalls.

The teachers repeatedly came up with further ideas about equipment that they would like to be able to show their students. "You really appreciate how privileged we are in the UK when you see a teacher looking forward to the chance to use bulbs, batteries and ammeters with their classes for the first time," says David.

The project did not stop there. When David repeated the exercise in the summer of 2006, the IOP funding allowed the number of schools receiving the apparatus to be increased from five to ten. In addition,

Students at Ada Senior High School and Asi Daahey International Junior High School in Ada, Ghana

Image courtesy of Ernest Nanor

Images courtesy of Ernest Nanor

Students at Ada Senior High School and Asi Daahey International Junior High School in Ada, Ghana

Rwandan teachers who had been trained in 2005 carried out the training instead of their British counterparts. "I felt that this was important, so that the Rwandan teachers felt they were sharing what they had learned with other colleagues from across the country," he says. "It was encouraging to hear how they had been using the apparatus they had been given, and about the impact that this had had on their students."

In addition, the IOP had also agreed to fund a workshop in which the apparatus required could be assembled locally. Two technicians – former students at Apred Ndera – were trained to make the equipment. "Over 12 months, they produced 65 complete sets of apparatus ready to be distributed to schools in Rwanda," says David. "They displayed what they produced at an education exhibition for Rwanda and Uganda, and many people commented on the quality, hardly believing that it was produced locally." It was at this point that the science journal *Nature*[w3] heard about the project. They are paying the salaries of the two technicians, initially for three years, and provide the money to buy enough components to build 100 sets of apparatus each year.

The final stage was to introduce a local project manager, so the project could be run from Rwanda. Since then, David has met with representatives from the Rwandan government to discuss the importance of practical demonstrations in secondary-school education. The IOP and *Nature* are working with the Kigali Institute of Education[w4] to ensure that the project is sustainable. A similar IOP project is being rolled out in Ethiopia, and there are plans to extend the initiative to other African countries including Ghana, Tanzania, Uganda and Malawi[w5].

"I hope and believe that this project provides a good model of how to start to introduce practical work into secondary science education," says David. "I'm looking forward to seeing how the government responds to this challenge and trust that, ultimately, it will be the students who see the benefit: improved physics teaching."

Image courtesy of RollingEarth / iStockphoto

Web references

w1 – Find out more about Clifton College, Bristol, on their website: www.cliftoncollegeuk.com

w2 – The UK-based Institute of Physics is a scientific charity devoted to increasing the practice, understanding and application of physics. See: www.iop.org

w3 – To find out more about the science journal *Nature* and associated activities, see: www.nature.com

w4 – Learn more about the Kigali Institute of Education, a young public institution of higher learning in Rwanda, here: www.kie.ac.rw

w5 –To help support physics education in some of the poorest countries in the world, you can donate online to the IOP's Physics for Development programme. See: www.iop.org/about/international/development/africa

Resources

If you enjoyed reading this article, why not take a look at our other teacher profiles published in *Science in School*? See: www.scienceinschool.org/teachers

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Vienna Leigh studied linguistics at the University of York, UK, and has a master's degree in contemporary literature. As well as spending several years as a journalist in London, she has worked in travel and reference publishing as a writer, editor and designer. She then widened her scientific horizons at the European Molecular Biology Laboratory in Heidelberg, Germany, before moving to the Institute for Bioengineering of Catalonia, Spain, as the head of communications.

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

Image courtesy of domi-san; image source: Flickr

Braille

Image courtesy of YinYang / iStockphoto

To sea with a blind scientist

Scientific research is not a career that most people believe to be suitable for the blind, but such beliefs are changing. Biologist **Geerat Vermeij** explains that, whether you are blind or not, science is competitive, tedious and hard – and he loves it.

REVIEW

- **Biology**
- **General science**
- **Ages 12-15**

This article could be used to introduce any scientific subject, whether biology, geology, general sciences or something else. It could be used to discuss what working in science actually involves. Being a (blind or sighted) scientist involves so much exciting collaborative work: fieldwork, conferences in many different countries, writing articles, reviewing the work of other scientists, supervising PhD students and, of course, teaching. This article is perfect for a classroom discussion to 'unmake' the myth that working in science means being closed up all day alone in a laboratory.

This discussion could also be used to emphasise that scientists are normal people (whether blind or not) who build their careers on hard work and continuous study (see also the review of Leigh, 2010).

Questions relating to the article that could be asked in the classroom include:

1. The author refers to biology as "that most visual of all the sciences". Do you agree with this statement?
2. Do you agree that science is that most powerful of all ways of knowing?
3. After reading the article, describe in your own words what 'being a scientist' means.

   Alternatively, the question could be asked to the students before reading the article. After the students have read the article, compare and discuss if / how their views of being a scientist have changed.
4. Geerat Vermeij is a successful (blind) biologist. After reading the article, what more would you like to know about him and his work? Write three or four questions and briefly justify each question.

Betina da Silva Lopes, Portugal

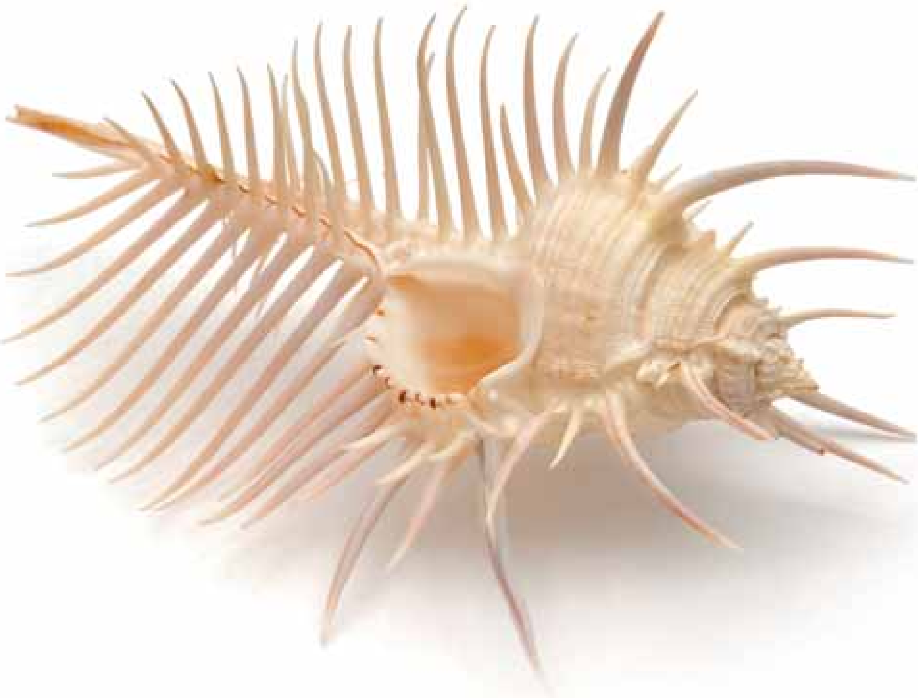
How, a sceptic might ask, could a blind person ever hope to be a scientist? After all, science is difficult even for many sighted people. How would I carry out experiments or read the huge scientific literature? Perhaps a blind person could be a theoretical physicist, but surely not a biologist. Why would the blind willingly choose biology, that most visual of all the sciences?

The answer is very simple: biology fascinates me. Someone is actually paying me to study shells – some of the most beautiful works of architecture in all of nature. What is more, I get to travel to exotic places, read the scientific literature in all its fantastic diversity, see my own papers and books published, and teach others about science, that most powerful of all ways of knowing. What more could one ask of a profession?

Like many of my colleagues, I came to science early in life. Even as a small boy growing up in the Netherlands, I picked up shells, pine cones and pretty stones. My parents, both of whom are avid natural historians, encouraged me; the fact that I was totally blind made no difference at all. At the age of ten, shortly after moving to the USA, I became seriously interested in shells and started my own collection. My parents and brother were enthusiastic; they read aloud, transcribed or dictated every book on natural history they could find.

The reactions of my teachers at school ranged from polite acceptance to genuine enthusiasm when I told them of my intentions to become a biologist. If they thought blindness and biology were incompatible, they kept it to themselves.

I moved on to study biology and geology at Princeton University, where I received strong support from nearly all of my professors, and then applied to do doctoral work at Yale University. The interviewer was apprehensive; he took me down to the university's shell collection and asked me if I knew two of the specimens. Fortunately, the shells were familiar to me and his misgivings evaporated. After my PhD at Yale, I moved to the University of Maryland at College Park, becoming a professor there in 1980. In 1988, I moved to the University of California, Davis, as a professor of geology. Along the way, I married a fellow biologist and we had a daughter, Hermine, who is now 29.



As a PhD student, Geerat Vermeij wondered whether some molluscs had evolved elaborate shells such as this to ward off predators

Image courtesy of busypix / iStockphoto

What do I actually do in my job that seemed so improbable to the sceptics? Again the answer is simple. I do what my sighted colleagues do: research, teaching and administration.

My research centres on how animals and plants have evolved to cope with their biological enemies – predators, competitors and parasites – over the course of the last six hundred million years of Earth's history. When I was still a PhD student, I noticed that many of the shells I found were broken, despite their considerable thickness and strength. It soon became clear that shell-breaking predators, especially crabs and fishes, were responsible for this damage. I began to suspect that many of the elegant features of tropical shells – their knobby and spiny surfaces, their tight coiling, and the narrow shell opening often partially occluded by knob-like thickenings – could be adaptations to protect the snails inside from their predators.

How do I do my research? I combine field, laboratory, museum and library work, visiting coral reefs, mangrove swamps, deserts, rain forests, research vessels, marine biological stations, secret military installations, great libraries and big-city museums all over the world. I collect specimens in the field, work with living animals in laboratory aquaria, measure shells in museums and in my own very large research collection, and read voraciously.

Wherever I go I am in the company of a sighted assistant or colleague. There is nothing unusual about this; every scientist I know has assistants.

Image courtesy of malmesjo; image source: Flickr

Image courtesy of cobalt123; image source: Flickr

At the library, as my reader reads to me, I transcribe extensive notes on the Perkins Brailler. My Braille scientific library now comprises more than 17 000 publications compiled in more than 300 thick Braille volumes.

Like many of my colleagues, I spend a great deal of time writing. First, I prepare drafts on the Perkins Brailler, then type the manuscript on an ink typewriter. An assistant proofreads and corrects the manuscript, which is then submitted to a journal. So far, I have published 205 peer-reviewed papers and books in this way.

Teaching has always been inextricably intertwined with research for me. Over the years I have taught a great variety of courses – animal diversity, evolutionary biology, ecology, marine ecology, malacology, the mathematics and physics of organic form, and a seminar on extinction. In the large introductory courses, teaching assistants take charge of the laboratory sections and help in grading papers. Again, there is nothing unusual in this: science professors at most universities depend heavily on teaching assistants (as a PhD student, I myself was lucky enough to receive full funding, which meant I did not need to be a teaching assistant).

Like other research-oriented professors, I also train graduate students. Thus far, 15 students have received their PhDs under my direction.

Of course, science isn't all fun and games: it is competitive and hard work, full of tedious calculations, disappointment when a cherished paper is rejected, or quibbling about grades with a frustratingly inept student. Nobody in science is exempt from this, but in the end the work is immensely rewarding.

In short, there is nothing about my job that makes it unsuitable for a blind person. Of course, there are inherent risks in the fieldwork; I have been stung by rays, struck down by stomach cramps and detained by police who mistook me for an operative trying to overthrow the government of their African country. All field scientists have similar experiences. The blind, no more than the sighted, must act sensibly and with appropriate caution. Along with independence comes the responsibility of assuming risks.

What would I say to a blind person who is contemplating a career in science? Very simple. I would tell that person exactly what I would tell a sighted one: love your subject, be prepared to work hard, don't be discouraged, be willing to take risks, get as much basic science and mathematics education as you can take, and perhaps above all, display a reasoned self-confidence without carrying a chip on your shoulder. You will need stamina, good grades, the support of influential scientists, and a willingness and ability to discover new facts and new ideas. It is not enough to do well in courses; you must make new observations, design and test hypotheses, and interpret and present the results in such a way that the work is both believable and interesting to others. Science is not for everyone, but I can think of no field that is more satisfying.

Acknowledgement

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Reference

Leigh V (2010) Sowing the seeds of science: Helke Hillebrand. *Science in School* **15**. www.scienceinschool.org/2010/issue15/helke

Resources

Not all blind children attend a mainstream school like Geerat Vermeij did; there are also schools especially for blind and partially sighted students. To learn more about one such school, and how science is taught there, see:

Rau M (2010) Blind date in the science classroom. *Science in School* **17**. www.scienceinschool.org/2010/issue17/wernerliese

To learn more about Geerat Vermeij's research, see his latest book:

Vermeij GJ (2011) *The Evolutionary World: How Adaptation Explains Everything from Seashells to Civilization*. New York, NY, USA: Thomas Dunne Books. ISBN: 9780312591083

If you enjoyed this article, you may like to browse the other scientist profiles in *Science in School*: www.scienceinschool.org/scientists

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

Image courtesy of YinYang / iStockphoto

Bad science

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

By Ben Goldacre

Reviewed by Eleanor Hayes, Editor-in-Chief of *Science in School*

Ben Goldacre, writer, broadcaster and doctor, is on a crusade: a scientific crusade – against pseudoscience.

Why should British teachers stop using the Brain Gym, which refers to itself as an 'educational movement-based model' and is used in thousands of British schools? In *Bad Science*, Ben Goldacre describes the Brain Gym as "a vast empire of pseudoscience" that tells children "that if they wiggle their head up and down it will increase the blood flow to the frontal lobes, thus improving concentration; … that there is no water in processed food; and that holding water on their tongue will hydrate the brain directly through the roof of the mouth". In a sense, he acknowledges, the Brain Gym works: it encourages regular breaks in lessons, light exercise and drinking plenty of water. All good – and effective – activities.

So what's the problem? According to Goldacre, this "transparent, shameful and embarrassing nonsense" poses two problems, which apply to all pseudoscience. First, you can blind people with scientific-sounding language and get them to do something intrinsically sensible, but is it ethical to lie to them to achieve this? Second, by hiding common sense in scientific-sounding hocus pocus, you create a veil of mystery around science, preventing people from thinking for themselves about seemingly scientific claims or using the scientific knowledge they have.

Over the course of his book, Goldacre examines:

- The misleading but accurate claims of the cosmetics industry (read the claims carefully: do they simply – and truthfully – state that one of the ingredients can make your skin look younger, or do they actually claim that the cream contains enough of the ingredient to do this?).
- How we test whether a treatment works (why is the 'evidence' for homeopathy flawed? How can you design a fair test of a treatment?).
- Some fascinating research on the placebo effect, how the results can explain some of the claims of pseudoscience, and how the placebo effect could be used in conventional medicine.

My only criticisms are minor. The book would benefit from a more careful editor, to correct some grammatical errors, improve some clumsy sentences and – more importantly – remove some leaps in logic or missing information. Also, I suspect that many readers will find statements like "you may disagree, and you now have the tools to do so meaningfully" rather patronising.

Notwithstanding, *Bad Science* is a wonderful book and appropriate for a wide audience. Read it – please! Enjoy it, share it with your friends and colleagues and above all, with your students. It's simply written, funny and utterly compelling; I nearly missed a train connection because I was so absorbed in it. This book reminds us what is wonderful about science – science is powerful, it's great fun, and needn't even be difficult.

I'm not a teacher, but I do have some suggestions for how you could use *Bad Science* in school. Give an individual chapter, or part of a chapter, to your students to read: they'll enjoy it (particularly the bit about why teachers shouldn't use the Brain Gym in lessons) and it will encourage them to question the world around them.

Get your students to practice what Ben Goldacre preaches: exposing pseudoscience for what it really is. Why not ask the class to collect pseudoscientific claims (e.g. from newspapers, the Internet, adverts) and discuss them in class? Perhaps you could have regular 'pseudoscience busting' lessons: why is a particular claim misleading? Could there be any truth in it? If so, what could the real explanation be, and how could you set up an experiment to test it? Perhaps your students could even carry out the experiment.

Finally, to read Ben Goldacre's weekly newspaper column, visit the Bad Science website[w1].

Details

Publisher: Fourth Estate
Publication year: 2008
ISBN: 9780007240197

Web reference

w1 – Bad science: www.badscience.net

Instructables website

Reviewed by Sue Howarth, UK and Marlene Rau, Germany

Www.instructables.com is a website that shows you how to make all sorts of weird and wonderful things, from apple coasters to a z-bend hyper-hornet.

With this exciting website, you can access most of the information without registration. For this review, we registered for free membership (you don't have to) and were sent a welcome message, followed by a personalised email from the 'Instructables Robot', which tells you that there are "tons of awesome things to see on Instructables", and offers a choice of browsing or a "guided tour".

The guided tour really helped; we did not really understand what the site was about until we worked through it. The 'home' page does not tell you enough, but the tour certainly does. Through this, we learned that Instructables is a web-based "documentation platform" where "passionate people share what they do and how they do it, as well as learn from, and collaborate with, others". This was still a little vague, and had we not been prompted by pictures of all sorts of gadgets, we might have wondered what we had wandered into. A link to the "awesome people" who make Instructables happen, reassuringly shows some fairly normal people, and, in the terminology of the site, the "seeds of Instructables germinated" at the Massachusetts Institute of Technology Media Lab in Boston, USA, with the site developing as a place for sharing projects and helping others.

Instructables are step-by-step descriptions of things that people have made, along with information about how they made them. As the site says, they are "educational, inspirational, and often replicable", and so they could be useful for enhancing and enriching science, technology, engineering and maths subjects, in and out of the classroom. The contents are divided into a number of sections, such as 'Health', 'Outside', 'Solar' and 'Technology'. The keyword-guided navigation leading to specific collections of instructables and information is not always intuitive, but it can be helpful.

Some of the instructables are clearly rather specialised, such as the dachshund wheelchair[w1], made to help an injured dog exercise during recovery, or fun-based, such as making a mermaid tail for swimming[w2]. Many other ideas, however, are very educational, and certainly many look both exciting and feasible for students to try themselves, with suitable help as appropriate. This could be as a project or perhaps as extension and / or extracurricular activities, or even in cross-curricular groups. The longer you browse the site, the more you find. It seems to be a very active site, with new material being constantly added.

For the physics classroom, there is a large variety of gadgets to be built as teaching activities, such as a simple steam engine[w3] or a Stirling engine built from a crisp package[w4], a Savonius wind turbine built from cardboard[w5], a fifteen-minute self-propelled hovercraft[w6] or a solar-powered LED-lighted sun jar[w7]. More complicated projects include the breath-powered USB charger[w8], building a macro particle accelerator[w9] that propels a conductive ping pong ball, or creating a lighted star map[w10]. Or you may trick your students with the fake portable gravitation shield[w11] – very useful for teaching magnetics.

Whereas many of the instructables from the 'Technology' and 'Solar' sections are most appropriate for use in the physics classroom, there are many interesting ideas for the other sciences, too: you could make luminescent silicone paint[w12], grow silver crystals[w13] or build a ballistic soap bubble machine[w14] in the chemistry classroom. In Earth sciences, building a tsunami model[w15] with gutter segments could be fun; and in biology, you could grow oyster mushrooms in a coffee cup[w16], have the students build muscular anatomy models with Halloween skeletons[w17], bake or sew a cell model[w18, w19], or, if you want to get seriously involved, build your own thermocycler for PCR[w20].

The numbered steps for all the instructables, or projects, ought to make following the instructions easier, and the accompanying pictures look as though they should help a great deal. Some of the materials, e.g. "ultra-concentrated Dawn dish detergent (blue)", might be hard to come by outside the USA, but the great thing about this site is that you can ask about alternatives and are likely to get a response from either the project maker or others who contribute to feedback and discussions on the site. Suggestions for modifying projects are common, giving a strong sense of user involvement.

Obviously, teachers thinking of using any of the ideas need to try them first and make sure that all the necessary materials are to hand. It is useful that approximate costs are given. Importantly to note is that the extent of the safety advice provided for each project is variable, so a thorough risk assessment would be necessary before letting students start.

If all goes well, and students want a further challenge, there is scope to design their own instructable, and a guide[w21] is provided to help with this and to show how to upload it onto the site.

In addition to step-by-step instructions, the website offers photos and videos of the gadgets, informative articles on miscellaneous topics, contests amongst the users for uploading the best instructable on a given topic – such as the 'Belt re-use challenge' or the 'Homemade soup contest', and a very active discussion forum, including a question-and-answer section.

Note: There is an option of signing up and paying for 'pro' membership, for USD 1.95 / month, billed annually or USD 39.95 for two years as a one-time payment. A membership comparison list points out that signing up as a paid member would let you download PDFs, see instructions on a single page, view less advertising, and generally help to support the site. Members also receive the newsletter and gain access to past newsletter archives.

Web references

Below are the links to the individual instructables mentioned in the article. The URLs are fairly self-explanatory:

w1 – www.instructables.com / id / Dachshund-wheelchair

w2 – www.instructables.com / id / How-to-Make-A-Mermaid-Tail-for-Swimming

w3 – www.instructables.com / id / A-Simple-Steam-Engine-Anyone-Can-Build

w4 – www.instructables.com / id / The-amazing-pringles-tube-Stirling-engine

w5 – www.instructables.com / id / Cardboard-Savonius-turbine

w6 – www.instructables.com / id / Fifteen-Minute%2c-Self-propelled-hovercraft

w7 – www.instructables.com / id / Home-made-Sun-Jar

w8 – www.instructables.com / id / Breath-powered-USB-charger

w9 – www.instructables.com / id / How-to-make-a-macro-particle-accelerator

w10 – www.instructables.com / id / Star-Map

w11 – www.instructables.com / id / A-small-portable-gravitation-shield

w12 – www.instructables.com / id / Making-Ooglo-Luminescent-Silicone-Paint

w13 – www.instructables.com / id / Grow-Silver-Crystals-by-Electrochemistry

w14 – www.instructables.com / id / Make-a-Ballistic-Bubbles-Machine

w15 –www.instructables.com / id / Tsunami-Model

w16 – www.instructables.com / id / Gourmet-mushrooms-in-an-old-coffee-cup

w17 – www.instructables.com / id / Muscle-anatomy-with-Sugru-and-a-Halloween-skeleton

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Relativity: A Very Short Introduction

By Russell Stannard

Reviewed by Michalis Hadjimarcou, Cyprus

Relativity is, admittedly, a difficult subject to understand, even to science-oriented people. In *Relativity: A Very Short Introduction*, Russell Stannard has made an effort to explain relativity and its implications for the laws that govern the Universe in a way that can be understood by those with at least some basic knowledge of physics. The book is rich in scientific terminology, so a good knowledge of English is essential to understand it. Stannard has also included a wealth of diagrams and mathematical equations. These can make the book more difficult to understand if the reader is not adequately trained in dealing with such information. But, there is an alternative solution: ignore most of the diagrams and formulas and concentrate only on the basic ideas presented. Such casual reading will allow the reader to filter out all the explanatory details and keep the basic description of what relativity is all about. Of course, if one is determined to capture the full extent of relativity, this book provides an excellent opportunity for achieving this.

Regardless of the background and scope of the reader, he / she will be rewarded in the last chapters of the book with information on exciting subjects, the type favoured by science fiction. The Big Bang, black holes, worm holes, supernovas, the expanding Universe, dark energy and dark matter are but a few of such issues Stannard has elaborated on and enables the reader to distinguish between science and imagination.

In school, there are a number of ways in which this book can be useful, especially in an advanced physics or astronomy class. Considering that the theory of relativity is taught in secondary schools across the world, teachers can use the book to draw basic information on the theory itself, but more importantly, to inform themselves and their students on the latest theories regarding the nature and the peculiarities of the Universe. Students might find it very difficult to read and understand the entire book, but if they concentrate on specific sections of the book, with a little help from their physics teacher, they will be able to benefit greatly from it. Along those lines, the teacher could assign projects to his students that would require more careful study of specific sections of the book.

The book is also available in a German translation.

Details

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