Spring 2015 Issue 31

Science in School

The European journal for science teachers

In this issue:

The challenging logistics of lunar exploration

Also:

Taking teaching home

Published and funded by EIROforum

Editorial

Welcome to the 31st issue of *Science in School*

Now the delighted mother of healthy twin boys, I'm also happy to be back at *Science in School*, working with Laura and Isabelle to continue their good work on the new design of our journal.

What is the purpose of *Science in School*? For the past nine years, we have aimed to inform, inspire and support science teachers in Europe and beyond – and our new website reflects just that. As you'll see, we've reorganised the articles into three main categories: understand (science topics or research), inspire (scientist or teacher profiles, event reports, reviews of resources, and much more) and teach (activities and projects for your lessons).

Using the drop-down menus, you can browse all the articles in these categories or refine your search further, for example by age group or using search terms. Do you need some recent research for your biology students? Two mouse clicks give you a wealth of articles to choose from. Are you looking for a teaching idea for your physics lesson? Again, you are just two clicks away. Do you think a particular article looks interesting but you'd prefer to read it in Spanish? (or Polish, or Greek, or German, or French, or….) Just choose the appropriate flag on the article page.

We're still working on the website, so you should notice it getting better and better over the next few months. In particular, we've initially concentrated on the English articles; the formatting of the translated articles will be improved as soon as possible. If you notice any problems with the website or have any comments or suggestions, do let us know.

You may notice that this print issue looks a little different to previous ones. This is just the beginning: we're also working on a completely new design of the print journal. So if you have any suggestions for improvement, now is the time to tell us!

And as if that weren't enough, *Science in School* now tweets regularly about science, teaching and everything in between. Why not follow us on Twitter? www.twitter.com/sciinschool

For now, we hope you enjoy the articles in this issue.

Eleanor Hayes
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www.scienceinschool.org

About *Science in School*

The European journal for science teachers

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

Brought to you by Europe's top scientific research institutes

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

Inspiring science teachers worldwide

The *Science in School* website offers articles in 30+ languages and is read worldwide. The free quarterly journal is printed in English and distributed across Europe.

Subscribing

Register free online to:

- Subscribe to the e-newsletter
- Request a free print subscription (limited availability)
- Post your comments.

How can I get involved?

Science in School relies on the involvement of teachers, scientists and other experts in science education.

- Submit articles or reviews
- Join the reviewer panel
- Translate articles for publication online
- Tell your colleagues about *Science in School*
- Make a donation to support the journal.

See www.scienceinschool.org or contact us.

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Contents

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Image courtesy of NASA/Dennis M. Davidson

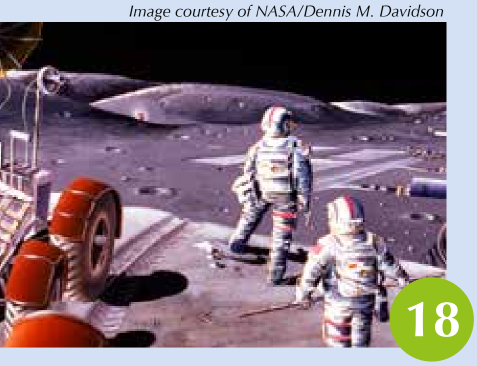


Image courtesy of Janine/Wikimedia Commons

Image courtesy of the National Institutes of Health (NIH)

Image courtesy of EMBL/Laura Castaldi

Making new connections and learning in new ways

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

CERN

Opening up the Higgs Hunt

The hunt for the Higgs boson occupied many many physicists at CERN, but now anyone can help analyse real data and perhaps find a new molecule. Higgs Hunters is a new website that shows you images from the ATLAS experiment in the hope you might spot something new that the scientists and their computers missed.

The images on Higgs Hunters are snapshots of newborn particles flying at close to the speed of light through the huge underground ATLAS detector. Higgs particles rapidly decay and it's hoped that the decay products might include new, unknown particles.

"Discovering what happens when a Higgs boson 'dies' could be even more exciting than the original discovery that the Higgs boson exists made at CERN back in 2012," says Alan Barr, lead scientist of the Higgs Hunters project.

For further information or to get hunting, visit: www.higgshunters.org

Don't forget that the CERN education website hosts many more activities that you can use with your students. See: http://education.web.cern.ch/education/

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

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

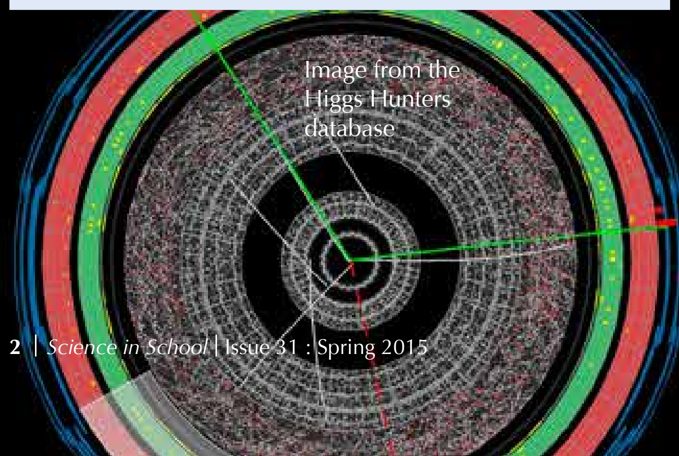


Image from the Higgs Hunters database

Image courtesy of Higgs Hunters

EMBL

Delighting in detail

This riot of colour is a visualisation of touch, or rather the skin nerves that relay that information. Neurons that detect gentle touch are shown in green, while red and blue represent two types of nerve cell involved in sensing pain. The image was obtained by Paul Heppenstall's lab at EMBL Monterotondo, Italy, using a technique not previously used in live animals. "Already we've been able to see things that we couldn't see before," says Paul.

Skin seems designed to thwart fluorescence microscopy – not only is it a barrier, often preventing dyes from penetrating, but it also glows green under blue light. That means it's hard to distinguish between the skin and fluorescent proteins, which are commonly used to label tissue.

To get around the problem, Paul's lab genetically engineered mice so their cells would produce a protein that binds to a specific chemical structure. The team then injected the mice with fluorescent probes that contained that structure. The protein binds to it and glues the probes in place, allowing the scientists to pinpoint the cells under the microscope.

Read more about this story on the EMBL news portal: http://news.embl.de/science/1412_snaptag

Read the original research article in *Nature Methods*:

Yang G et al. (2014) Genetic targeting of chemical indicators *in vivo*. *Nature Methods* [published online 8 December]. doi: 10.1038/nmeth.3207

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

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

ESA

Teach with Rosetta

On 12 November 2014, the Rosetta spacecraft's Philae lander touched down on the surface of comet 67P/Churyumov–Gerasimenko: the most spectacular landing in the history of space exploration. Build on the extraordinary source of inspiration represented by the Rosetta mission to attract your students to science and technology.

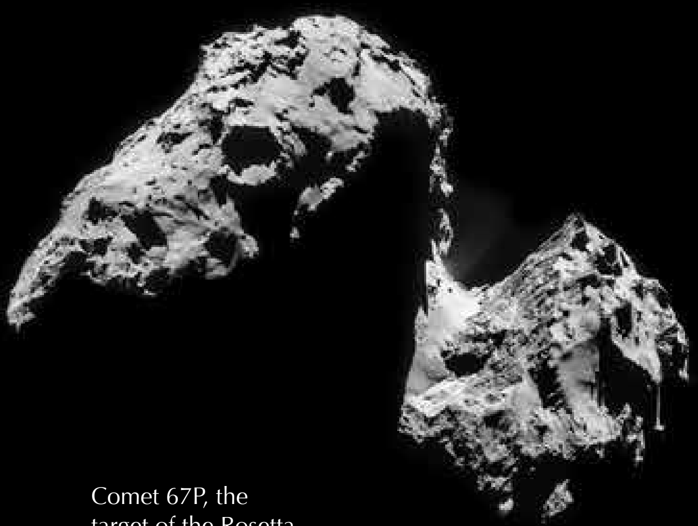
The Teach with Rosetta website contains teaching materials for both primary- and secondary-school levels. The lessons use space, Rosetta and comets as a context for teaching curricular subjects from physics, chemistry, maths, biology and astronomy to comprehension, art and design.

The site will grow with time, hosting new ESA education resources and links to Rosetta news as they become available during the course of the Rosetta mission, until its end in 2015.

Don't miss the chance to teach with ESA and Rosetta at the Teach with Rosetta website. See: www.esa.int/Education/Teach_with_Rosetta

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

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



Comet 67P, the target of the Rosetta mission.

Image courtesy of ESA/Rosetta/NAVCAM

EUROfusion

The European Commission launches EUROfusion

After almost two years of preparation, the European Commission officially launched the European Consortium for the Development of Fusion Energy (EUROfusion) in autumn last year. EUROfusion manages the European fusion research activities on behalf of Euratom, which awards the appropriate grant to the consortium. The new consortium agreement substitutes the fourteen year-old European Fusion Development Agreement (EFDA), as well as 29 bilateral Association agreements between the Commission and 28 European member states plus Switzerland. The formation of EUROfusion marks a big step forward for Europe's quest to develop fusion power as a climate-friendly energy source that will contribute to meet a growing global energy demand. The EUROfusion Consortium enables Europe's national laboratories to pool their resources even more efficiently – a measure which became necessary to meet the challenge of increasingly complex and large-scale projects such as ITER and DEMO. The preparation for such a joint fusion programme started in 2012.

The European Consortium for the Development of Fusion Energy (EUROfusion) comprises representations of 28 European member states as well as Switzerland and manages fusion research activities on behalf of Euratom. More than 40 European fusion laboratories collectively use the Joint European Torus (JET), which has remained the world's largest magnetic fusion device since it was built in 1983. Smaller national experiments in Germany, Switzerland, and the United Kingdom complement the experimental programme. The aim is to realise fusion electricity by 2050.

To learn more see: www.euro-fusion.org

For a list of EUROfusion articles in *Science in School*, see: www.scienceinschool.org/EUROfusion

A computer-generated visualisation of EUROfusion's flagship experiment JET

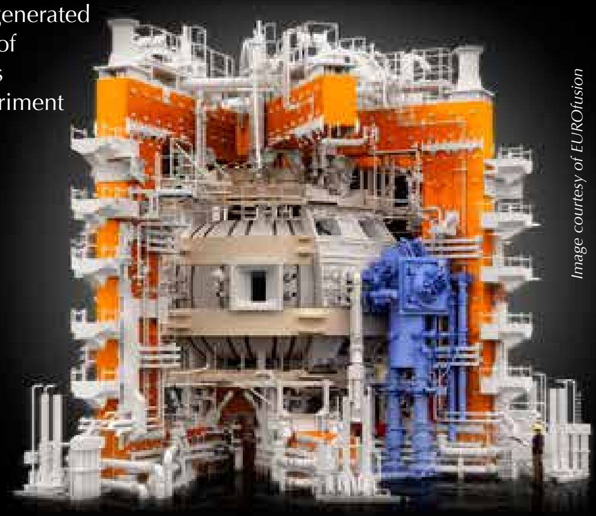


Image courtesy of EUROfusion

ESO

Connect with ESO in your language

Friends of ESO can now connect with the organisation on social media platforms available in their native language. Together with volunteers, ESO has started making ESO's latest news available in several languages on Facebook and Twitter.

The news items from ESO are already translated into more than 18 languages thanks to the ESO science outreach network. The network has also translated important parts of ESO's website, as well as the *ESO News* weekly newsletter. Now, with the help of volunteers, the aim is to offer as many people as possible the chance to read ESO's astronomical news on social media across language barriers.

View a list of ESO's social media accounts at www.eso.org/public/outreach/social

Those who wish to contribute translations for ESO local social media accounts which are still missing translations are invited to submit the form at: www.eso.org/public/outreach/partnerships/translators

ESO is the world's most productive ground-based astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. ESO is a major partner in the revolutionary astronomical telescope ALMA and is building the 39-metre European Extremely Large Telescope, the E-ELT. For more information, see: www.eso.org

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

Image: Image courtesy of ESO

Workers walk past the first section of the European XFEL linear accelerator, which has been nearly completely assembled in the tunnel.

Image courtesy of DESY

European XFEL

Accelerator installation underway

To generate the world's most intense X-ray flashes, European XFEL needs very high-energy electrons travelling at nearly the speed of light. To obtain flashes with laser-like quality, a linear particle accelerator is needed – in European XFEL's case, a superconducting one that is nearly two kilometres in length.

This past summer, the German research centre DESY, which is European XFEL's largest shareholder, began installing the first of 100 accelerator modules in the European XFEL accelerator tunnel beneath western Hamburg. Each module is twelve metres long and weighs ten tonnes.

The accelerator feeds large electromagnetic pulses into specially designed metal tubes called cavities. The electromagnetic pulses, combined with the shape of the cavities, create conditions that cause the electrons to move faster and faster. There will be 800 of these cavities in the European XFEL linear accelerator, eight in every module. Each cavity will be immersed in liquid helium to keep it at the necessary temperatures.

The European X-ray Free Electron Laser (European XFEL) is a research facility currently under construction in the Hamburg area in Germany. Its extremely intense X-ray flashes will be used by researchers from all over the world. To learn more, see: www.xfel.eu

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

EIROforum

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

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

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

ILL and ESRF

Exploring new ways to reach younger generations

In our digital world, science, education and communication are evolving at great speed. Connected devices, collaborative and free-content websites, social networks, gamification, fab labs and living labs become new ways for scientists to engage with the (young) public.

During the International Year of Crystallography in 2014, ESRF and ILL participated in various projects, from individual events to the development of innovative tools for educational purposes.

- **Krystallopolis website**
  The website is an invitation to explore the world around us, which is full of (mostly invisible) crystals. The hunt for nanoscopic crystals is open! And, to prove that crystallography can be fun, Crystal Maze, Crystal Crush and quizzes help you play with crystals. The website has been developed in French and will be translated into English soon. It is a very useful resource to discover crystals and crystallography, for students, teachers and the general public.
  www.krystallopolis.fr

- **vDiffraction**
  This 'serious game' about diffraction, which targets science students and teachers, is a fun way to enter the world of crystals. In crystals, atoms are arranged in a highly ordered structure with specific symmetries that are clearly visible in the diffraction patterns produced when crystals are hit by X-rays, neutrons or electrons. In vDiffraction, you become the scientist who has to identify the characteristic symmetries of a crystal. This is the first, crucial step towards understanding the atomic and molecular structure of a crystalline material.
  http://www.ill.eu/vdiffraction/

- **Crystal game jam**
  In order to facilitate the development of new games about crystallography, we organised two simultaneous sessions, one in Grenoble, France, and one in Paris, France, with a team comprised a game designer, an illustrator, a programmer and a scientist.
  Most of the participants were university students but some of them were secondary school children.
  They had from Saturday morning to Sunday afternoon to develop their idea of a game and present a first draft.
  Among the ten games presented at the end of the game jam, four were selected by a jury and their creators have been invited to participate in iGam4er (igam4er.org), an international competition of video games for education and research, organised in Paris.
  http://lacasemate.fr/programmation/hackathon-game-jam-cristallo

- **Geolocalised Crystal Z app**
  This smartphone app was a one-off initiative developed for the public during the three weeks of the *Fête de la Science* from late September to mid-October in Grenoble, where many events and activities focused on crystallography. It targeted mainly the young public, from 15 to 25 years old. The scenario included following a story (how a strange epidemic struck the population), going to various places and gaining crystals, answering scientific puzzles and playing 'mini games'. Relying strongly on geolocalisation in the Grenoble area, it could also be played in other cities but with less interactivity.
  www.crystalz.fr

- **More educational tools: card games, LED cubicle, Fourier transform demonstrator**
  These tools have been conceived and developed for the International Year of Crystallography, mainly by students. From the simplest (card games for primary-school children) to the most advanced (Fourier transform demonstrator), they are adapted to be used in schools or events such as the *Fête de la Science*.

- **Crystalline growth competition**
  In a more traditional way, a competition was run in more than 100 schools in Grenoble and its surrounding region. The objective was to grow the largest and most beautiful crystals:
  http://concourscroissancecristaux2014.blogspot.fr/
  www.knowtex.com/nav/rires-et-cristaux-dans-l-amphi-du-cnrs_41649

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

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

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

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

Greening chemistry

Chemistry is not always completely environmentally friendly; green chemistry is working to change that.

By Dudley Shallcross and Tim Harrison

Chemistry has a mixed reputation. We all benefit from the consumer goods and medicines that the chemical industry produces, but there is also a dark side – such as the industry's huge power needs and its creation of toxic solvents, reactants and waste products. For more than 20 years, chemists have been trying to clean up chemistry through the growing field of green chemistry.

Also known as sustainable chemistry or environmentally benign chemistry, green chemistry is a concept that is slowly being introduced at school level. Two of its earliest champions, Paul Anastas and John Warner, define green chemistry as 'the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances'.

The removal of, or reduction in, chemical waste; the lowering of total energy requirements for chemical processes; and an increase in safety awareness are in the interests of humanity and the environment. Industry too is interested; a report in 2011 suggested that green chemistry could

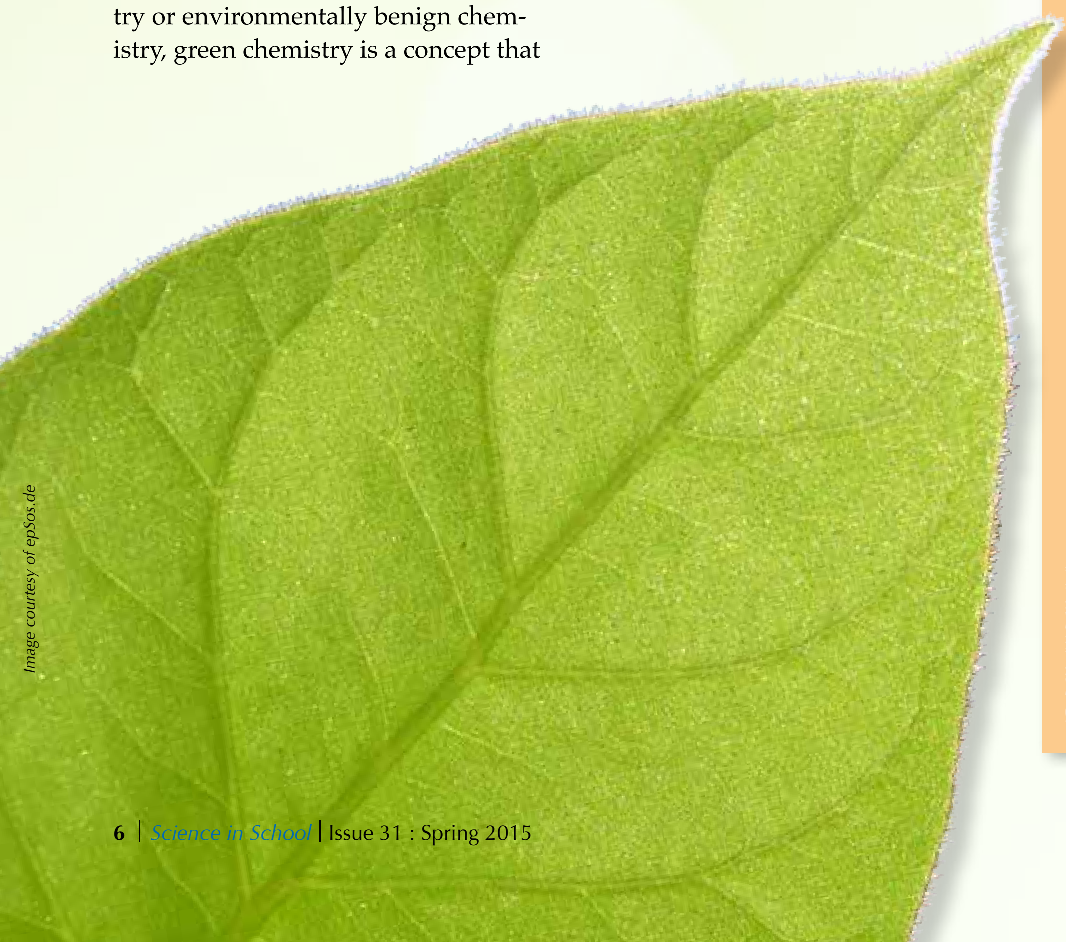


Image courtesy of epSos.de

REVIEW

- Chemistry
- Environmental science
- Ages 12–19

As the authors point out, chemistry is surrounded by a negative halo among students and general public, but the chemistry behind objects and materials is indispensable in our life. This is the reason why I recommend this article for use before addressing a chemistry course in secondary school.

The ideas behind green chemistry are clearly outlined in a simple style with examples taken from everyday life, from drug synthesis to biofuels. The topic, of course, would be worth further deepening and, if possible, direct experience through practical activities.

Both these objectives are at hand by means of the quoted references (ACS website and Royal Society of Chemistry educational pages).

Moreover, the history of chemical accidents, such as the Bhopal disaster, can provide teachers with elements for discussing chemical safety, environmental sustainability and the role of green chemistry.

Gulia Realdon, Italy

save the industry US$65.5 billion by 2020.

The main ideas underlying green chemistry can be summed up briefly in a few simple points that could form interesting topics for general class discussion or an in-depth consideration of the chemical processes traditionally taught in schools. Here we will look at this from a climate chemistry perspective. A full list of the 12 principles of green chemistry can be found online[w1], but we will limit ourselves to those aspects that are more applicable to school-level chemistry: atom economy, the source of the reactants, using environmentally benign substances and reducing energy use.

Reducing waste

One theme of green chemistry is how much of the reagents and solvents end up in the desired products, rather than as waste or by-products. Reducing the waste reduces the associated environmental problems. The idea of 'atom economy' and the simple exercises that students can perform (see box) will underpin such ideas. The sources of starting materials should also be considered. Reactants should be renewable wherever appropriate or obtained from sources that are readily and easily available.

Pharmaceuticals, in particular, are often produced in a multi-step synthesis rather than simply by reacting reagent A in a test tube with reagent B to create the drug. In a multi-step synthesis, the product made in one step is used in the next but the yield of each step is much less than 100% so materials, solvents and energy are lost along the way.

Synthetic routes with fewer and more productive steps, bearing in mind the other green principles, make less waste. For example, the painkiller ibuprofen was originally made in a six-step synthesis from the starting material isobutylbenzene, but a new, more efficient, synthesis only uses three steps (figure 1).

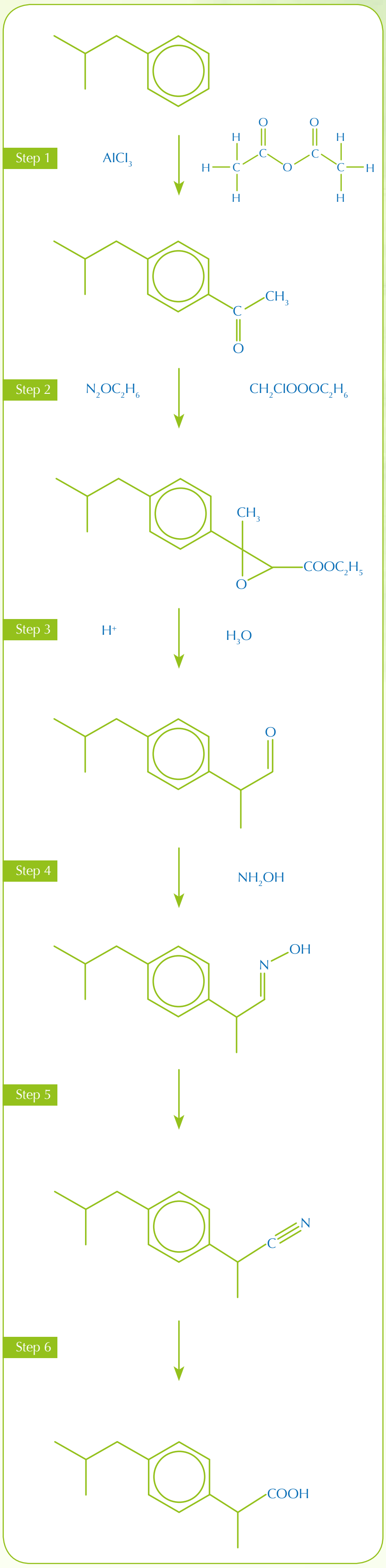


Image courtesy of Nicola Graf

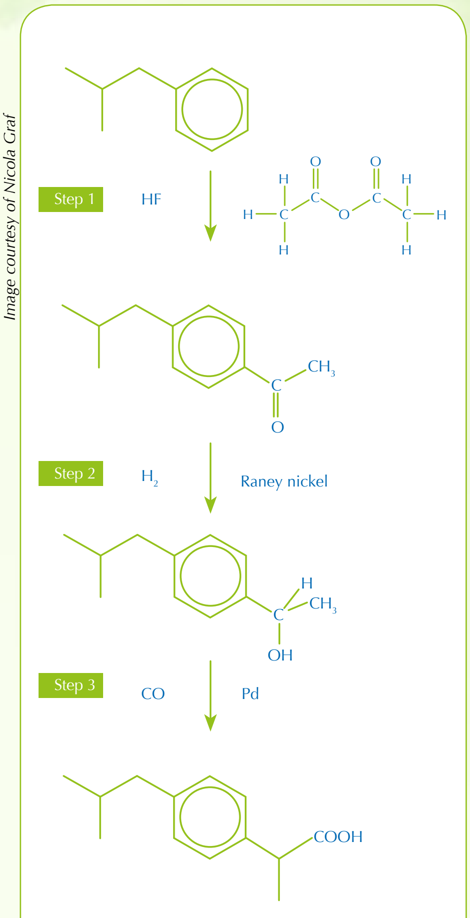


Figure 1: The original six-step synthesis of ibuprofen has now been replaced with a more efficient three-step synthesis

BACKGROUND

Atom economy

Traditionally, chemists have calculated the efficiency of a chemical reaction through a percentage yield calculation.

Percentage yield = (moles of product achieved / moles of product expected) x 100

Barry Trost of Stanford University, USA, introduced the concept of atom economy as an alternative way to view the efficiency of a reaction. Atom economy relates the total mass of starting materials to the mass of desired product. Therefore, the calculation highlights the wasted resources: if little of the starting materials are in the product, they must be in the waste.

Percentage atom economy = (mass of desired product / total mass of all reagents) x 100

It is easy to demonstrate by calculation that a chemist using atom economy would use simple starting materials to build up a product rather than break a large molecule down, thereby producing a lot of waste products.

Consider the reactions in which magnesium oxide is the desired product:

a) $2Mg + O_2 \rightarrow 2MgO$

$2 \times 24 = 48$ g   32 g $2 \times 40 = 80$ g

Atom economy = (80 / (48 + 32)) x 100 = 100%

b) $MgCO_3 \rightarrow MgO + CO_2$

84 g   40 g   44 g

Atom economy = (40 / 84) x 100 = 48%

More advanced students may like to look at how changes to the production of ibuprofen would improve atom efficiency[w2].

Reducing toxicity

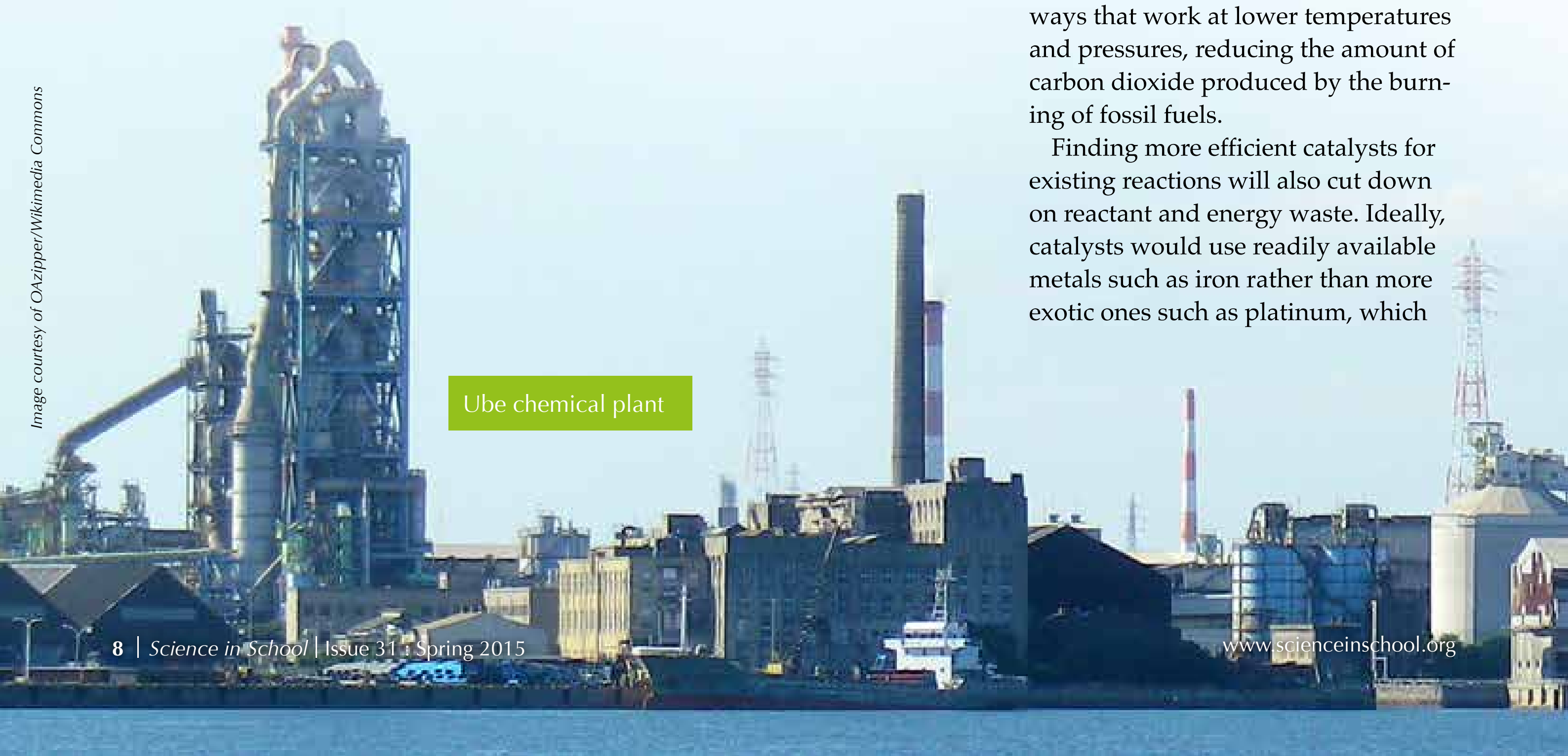
Green chemists also try to use only substances that do not harm the environment. In one of the world's worst industrial disasters, methyl isocyanate gas (CH_3NCO) used in pesticide production leaked from the Union Carbide India Limited plant in Bhopal, India, in 1984. Thousands of people were exposed. The immediate death toll was reported as several thousand, and around half a million people were injured, suffering temporary or permanent disability.

As well as choosing less toxic reagents, green chemists also try to switch to non-organic solvents like water and super-critical carbon dioxide. The previously used hydrocarbon solvents are toxic and emit vapours that are greenhouse gases, while halogenated solvents are often carcinogens as well as greenhouse gases and sources of free radicals – which destroy ozone.

Reducing emissions

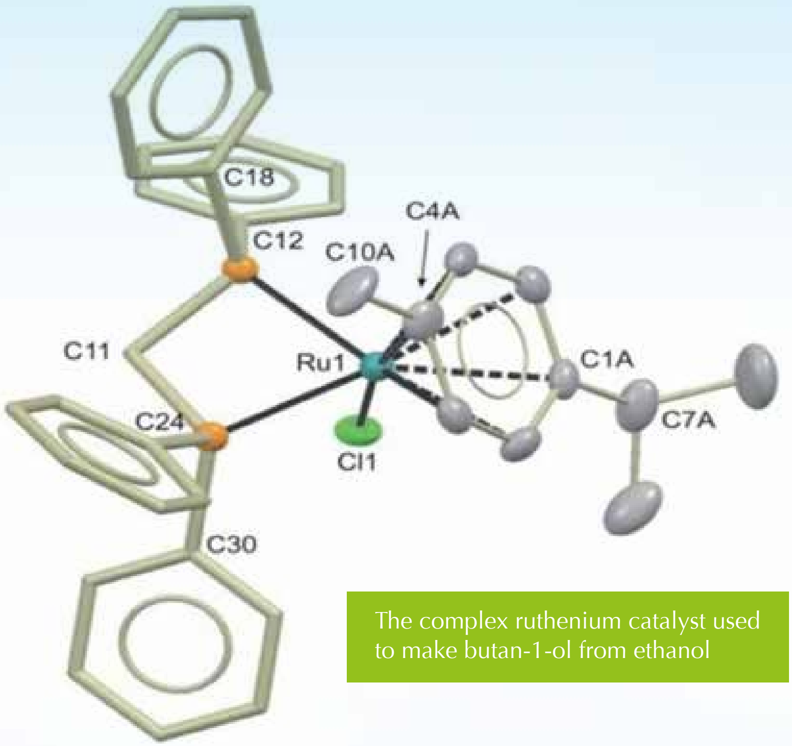
The chemical industry needs a huge amount of electricity; reducing that requirement is important both economically and environmentally. Researchers use energy to heat and increase the pressure of reactions as well as to transport materials. Scientists are looking for alternative reaction pathways that work at lower temperatures and pressures, reducing the amount of carbon dioxide produced by the burning of fossil fuels.

Finding more efficient catalysts for existing reactions will also cut down on reactant and energy waste. Ideally, catalysts would use readily available metals such as iron rather than more exotic ones such as platinum, which



Ube chemical plant

Image courtesy of OAzipper/Wikimedia Commons



The complex ruthenium catalyst used to make butan-1-ol from ethanol

Image courtesy of Duncan Wass/University of Bristol

are scarce and require considerable energy to obtain. Some catalysts also become 'poisoned' during the reaction, meaning that chemicals bond to the active sites of the catalyst and form products on the surfaces that may be toxic and difficult to dispose of safely.

Applying green chemistry to green fuels

When energy is needed, biofuels are desirable substitutes for fossil fuels. Ethanol is a well-known biofuel produced by many fermentation processes. Ethanol can be produced from vegetable matter including some grasses and corn husks. Adapted vehicles can use 100% ethanol (E100) or ethanol–petrol mixtures, known as gasohol, ranging from E5 to E25. However, ethanol is not a particularly good fuel as it:

- Does not vaporise as easily as gasoline
- Has only around 70% the energy density of gasoline
- Has a tendency to attract water
- Is acidic at the temperatures within the engine and can cause corrosion
- Requires engines to be adapted to run with larger proportions of it.

Butan-1-ol (which has an energy density of 29.2 MJ/l) would be a much better fuel additive than ethanol (19.6 MJ/l) as it has properties more similar to petrol (32.0 MJ/l). Butan-1-ol can be produced from biomass (biobutanol) and from fossil fuels (petrobutanol). However, these processes either need large amounts of energy or rely on biological catalysts (enzymes) and produce low yields. The separation of butan-1-ol from a mixture of products is also energy demanding.

It has long been the target of the chemical industry to make butan-1-ol by condensing two ethanol molecules together:

$$CH_3CH_2OH + HOCH_2CH_3 \rightarrow CH_3CH_2CH_2CH_2OH + H_2O$$

In 2013, however, a breakthrough enabled butan-1-ol to be produced from ethanol in yields of more than 95% using a ruthenium catalyst. The challenge now is scaling the process up for industry.

Environmental problems are not going away, so green chemistry will become even more important. Bright young people will be needed to apply green chemical principles throughout chemical sciences and engineering.

References

Anastas PT, Warner C (1998) *Green Chemistry Theory and Practice*. New York, NY, USA: Oxford University Press. ISBN: 0198502346

Trost BM (1991) The atom economy – a search for synthetic efficiency. *Science* **254**: 1471–1477

Chemistry

Web references

w1 – The 12 principles of green chemistry can be found on the website of the American Chemistry Society (www.acs.org) or by following the direct link: http://tinyurl.com/ocjc5q8

The ACS website also offers a range of educational resources on green chemistry, including books, online resources and experimental protocols for all age groups (from secondary school to undergraduate). See the ACS website (www.acs.org) or use the direct link: tinyurl.com/pq8cd6c

w2 – The Royal Society of Chemistry's Learn Chemistry website has a lesson on the synthesis of ibroprofen, which also considers the drug's structure and bonding. Visit: www.rsc.org/learn-chemistry/resource/res00000012/nurofen

Resources

For practical activities associated with climate change, please see:

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

Shallcross D, Harrison T, Henshaw S, Sellou L (2009) Fuelling interest: climate change experiments. *Science in School* **11**: 38–43. www.scienceinschool.org/2009/issue11/climate

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

Dudley Shallcross is the professor in atmospheric chemistry at the University of Bristol, UK.

Tim Harrison also works at the University of Bristol, as the school teacher fellow at the School of Chemistry. This is a position for a secondary-school teacher that was created to bridge the gap between secondary schools and universities, and to use the resources of the School of Chemistry to promote chemistry regionally, nationally and internationally.

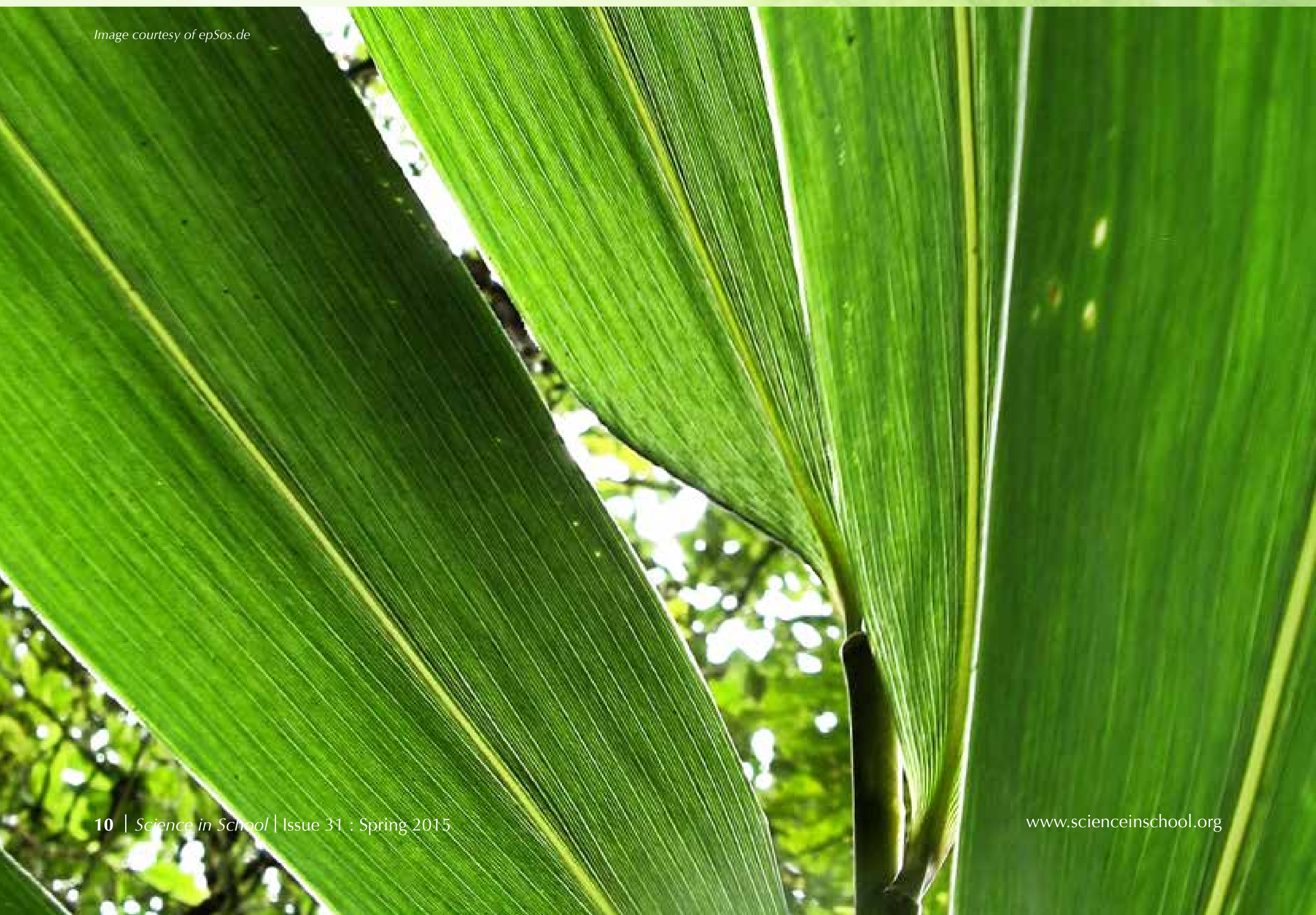


Image courtesy of epSos.de

Fighting HIV with neutrons

When thinking about diffraction studies, X-rays most often come to mind, but neutrons can also provide important structural information – and could help in the fight against HIV.

By Matthew Blakeley

When you think about crystallography, the technique that most often comes to mind is X-ray diffraction. It's no wonder: in biology, more than 88 000 structures of proteins, nucleic acids, viruses and macromolecular assemblies have been determined using X-rays. But as neutron crystallography has improved, it is becoming increasingly useful in helping to design drugs. Researchers at the Institut Laue-Langevin (ILL) in Grenoble, France, have recently used the facility to understand how an anti-retroviral drug targets HIV.

Since the early days of protein X-ray crystallography around one hundred years ago, the technique has undergone dramatic developments and become widespread. High-intensity X-ray beams provided by synchrotron radiation sources allow data to be routinely collected from tiny crystals just micrometres across and in a matter of seconds (see Cornuejols, 2009).

In contrast, the development of neutron crystallography of large biological molecules has been far less pronounced and its application much less widespread. The main reason for this is that the number of particles per square centimetre per second (known as fluxes) from even the most intense neutron sources are many orders of magnitude less than the corresponding fluxes at X-ray sources.

That meant that until recently, neutron crystallographers needed large crystals and long exposure times of months to collect sufficient data. Recent improvements, however, allow enough data to be collected from much smaller crystals in just a few days. That's still longer than many X-ray-based experiments though, so why would we use neutrons? One of the reasons is the smallest atom in the Universe: hydrogen.

REVIEW

- **Physics**
- **Biology**
- **Ages 15–18**

This is an interesting article which demonstrates how advances in different branches of science, in this case neutron diffraction, may be used in the development of new drugs for the benefit of mankind.

The article should serve as useful background reading for teachers and may be used to complement the teaching of science with real-life applications. It can also be used in comprehension or discussion activities especially with older students. The type of questions asked depend on what the teachers would like to teach or focus on. For example, what is the advantage of using neutrons instead of X-rays?

Paul Xuereb, Malta

The Institut Laue-Langevin (left) in Grenoble, France, is one of the most intense sources of research neutrons in the world

Image courtesy of ILL

Image courtesy of Andrey Kovalevsky

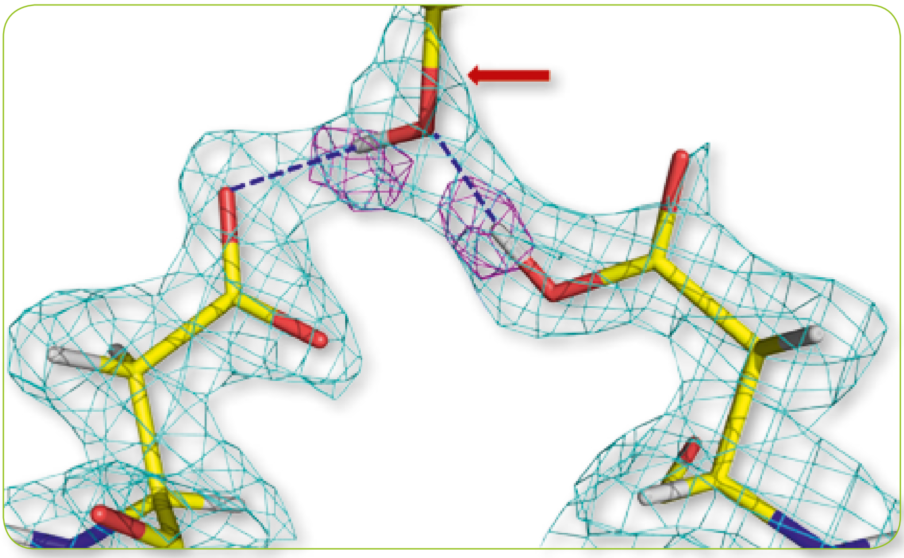


Figure 1: The aspartic acid residues of two HIV-1 protease molecules (left and right) hydrogen-bonded to the hydroxyl group of the drug aprenavir (centre)

The importance of hydrogen

Most drugs work by binding to a specific enzyme involved in a disease, so that its function is inhibited. A lot of modern drug design therefore focuses on analysing and optimising the interactions between the drug and its target. X-ray crystallography has been the favoured method to unravel these structural details, but X-rays do not generally reveal the position of hydrogen atoms in a molecule. These often play a crucial role in binding through weak yet important interactions known as hydrogen bonds.

By contrast, neutrons can locate the positions of all atoms including hydrogen, and so they provide a powerful analytical tool for analysing drug-binding interactions. Recently, this was demonstrated in a study of the binding between an anti-retroviral HIV drug (amprenavir) and its target enzyme, HIV-1 protease. This enzyme is a key part of the HIV life cycle – it breaks down viral polypeptides to create the proteins needed for the maturation and the production of new infectious virus particles.

Scientists fired neutrons at a tiny crystal of HIV-1 protease bound to amprenavir (only 0.2 mm^3 in size) to collect data at a resolution of just 0.2 nanometres. These data allowed researchers to locate the hydrogen atoms in the enzyme–drug complex and, critically, to identify those atoms participating in hydrogen bonding between the drug and the enzyme.

Better resolution

Using previous X-ray studies, scientists had speculated that several hydrogen-bond interactions were important in the binding of HIV-1 protease and amprenavir. However, the neutron study revealed that, in fact, only two strong, direct hydrogen bonds exist between the drug and the enzyme (figure 1). This finding shows drug designers new ways to strengthen this binding by subtly modifying the drug's molecular structure. Hopefully these changes will increase the effectiveness of the drug and reduce the necessary dosage.

For example, drug designers could make the two hydrogen bonds even stronger by adding a reactive atom such as fluorine to the drug. Alternatively, they could add more direct hydrogen bonds, for example by incorporating larger groups of atoms into the structure that would expel water molecules currently found in the binding site.

The unique sensitivity of neutron analysis to hydrogen atoms provides the pharmaceutical industry with a new and powerful tool for structure-guided drug design. Although the value of X-ray macromolecular crystallography will certainly continue for many years because of its higher resolution, using both X-rays and neutrons reveals more clearly how drugs interact with their protein targets and will no doubt improve the efficacy of other pharmaceuticals in the future.

Reference

Cornuejols D (2009) Biological crystals: at the interface between physics, chemistry and biology.

More about ILL

The Institut Laue-Langevin (ILL)[w1] is an international research centre based in Grenoble, France. It has led the world in neutron-scattering science and technology for over 40 years, since experiments began in 1972. ILL operates one of the most intense neutron sources in the world, feeding beams of neutrons to a suite of 40 high-performance instruments that are constantly upgraded. Each year 1200 researchers from over 40 countries visit ILL to conduct research into condensed matter physics, chemistry, biology, nuclear physics and materials science.

ILL is a member of EIROforum[w2], the publisher of *Science in School*. See the list of all ILL-related articles in *Science in School*: www.scienceinschool.org/ill

BACKGROUND

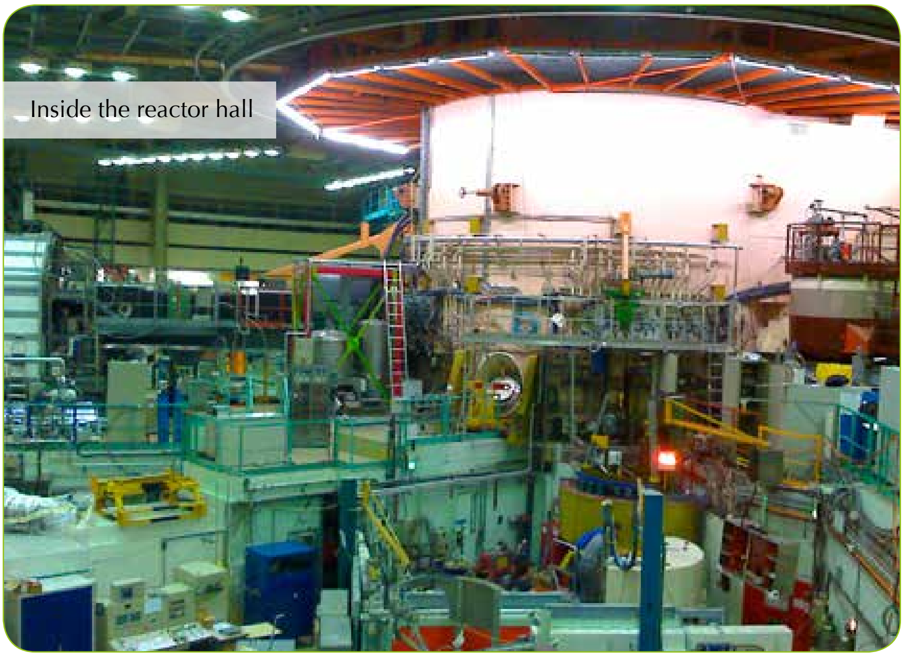
Neutron diffraction

When a crystal is placed in an X-ray beam, the X-rays interact with the electron clouds of the atoms in the crystal, causing them to diffract in specific directions. By measuring the angles and intensities of these diffraction spots – or 'reflections' – we can produce a three-dimensional picture of the electron density within the crystal, from which the mean positions of the atoms can be determined.

Neutron diffraction is conceptually very similar, except that the neutrons are diffracted by the atomic nuclei of the crystal lattice rather than the electron clouds around them. The scattering strengths for different atom types therefore don't correlate with electron configuration but with the nuclear forces, which can even vary between different isotopes of the same element.

Because of their small electron clouds, hydrogen and deuterium don't have much effect on X-rays but they have similar neutron scattering strengths to the other elements common in biological macromolecules: carbon, nitrogen, oxygen and sulfur. Consequently, hydrogen and deuterium, are not visible using X-ray scattering but are visible with neutron scattering.

This visibility of hydrogen and deuterium allows their positions to be determined at resolutions of around 1.5 and 2.5 Å (1.5×10^{-10} m and 2.5×10^{-10} m), respectively. A hydrogen atom is about 1 Å across. This makes neutron macromolecular crystallography particularly useful for studies in which a knowledge of hydrogen atom positions is important, such as studies of enzyme mechanisms or drug-binding studies where details of the hydrogen-bonding interactions can help guide drug design.



Inside the reactor hall

Image courtesy of Nerd bzh/Wikimedia Commons

Science in School **11**: 70–76. www.scienceinschool.org/2009/issue11/crystallography

Resource

Neutron diffraction has also helped researchers investigate how antifreeze in Arctic fish blood keeps them alive in sub-zero conditions. Read more at:

Blakely M, Hayes E (2011) Neutrons and antifreeze: research into Arctic fish. *Science in School* **20**: 18–22. www.scienceinschool.org/2011/issue20/arctic

Web references

w1 - Get more information about ILL: www.ill.eu

w2 - EIRO forum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, fascilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum published Science in School. See: www.eiroforum.org

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

Biology

Chemistry

Physics

Charles Spence

Image courtesy of Charles Spence

The perfect meal

Psychology is teaching us how to make food sweeter without changing its ingredients.

By Adam Gristwood

Normally it might be considered rude to take your mobile phone out at the dinner table, but at London-based restaurant House of Wolf, diners used their phones as part of an experiment into 'sonic seasoning'. Inspired by research led by Charles Spence, a psychologist from the University of Oxford, UK, the restaurant invited diners who had been served a dessert of 'cinder toffee lollies' to use their mobile phones to ring one of two numbers. On one phone line was music chosen to enhance the sense of sweetness; on the other, a tune to bring to mind a feeling of bitterness. This helped each diner to alter their perception of the dessert and enjoy it more. "It seems we associate higher notes, such as a tinkling piano, with sweetness, and deeper, more resonant tones with bitterness," says Charles.

The simple experiment encourages diners to flick between high- and low-pitched sounds as they enjoy a delicious bittersweet snack[w1]. Try it with your class, perhaps with a toffee, and if you happen to experience sweetness flooding over your taste buds as you

listen to the high notes, or bitterness as the pitch gets lower, you are not imagining things. The music has changed your perception of flavour, or at least prompted your brain to alter how it perceives the snack.

This tasty exercise illustrates one of many approaches that Charles's team, in collaboration with neuroscientists, marketers, musicologists, designers and chefs, are using to better understand our experience of food and drink. "Flavour is shaped not only by taste and smell, but also by the environment, the context of the meal and visual cues," he explains. "Food is the one place where all the senses come together. The room, the music played, even the shape and colour of your plate – they all matter."

Sensory science

Charles's publication list reads like an experimental tasting menu. In one study, designed with top Spanish chef Ferran Adria, diners rated an identical strawberry mousse as 10% less sweet if it was served on a black plate rather than a white one. Another illustrated how perceptions of whisky taste can be influenced to be grassier, woodier or sweeter, by changes in lighting, background noise or surrounding scents. Woody notes, for example, are enhanced by low mellow lighting, whereas red lighting and a rounded glass can make your drink taste sweeter.

Charles has also investigated why tomato juice is a drink of choice on an aeroplane but not on the ground (Spence et al, 2014), and found that potato chips that sound crunchier taste better. It seems that what we enjoy depends not only on our taste buds but also on our minds. "Even before we put food into our mouths, our brains have made a judgement about it," explains Charles. "People buy a wine that tasted great when they were on holiday in the sun, open it on a cold winter's night and it tastes horrible – everyone has had a version of this experience."

REVIEW

- **Biology**
- **Psychology**
- **Philosophy**
- **Neurobiology**
- **Ages 16–18**

This novel article is useful to understand the interaction between vision, odour and taste perception. It is of general interest to read scientific reports of works on vision and chemical senses but the article also allows teachers to perform a simple experiment with groups of students to explore how their different senses affect the tastes of specific foods.

This activity could be used to study the biology and evolution of the olfactory system, including studying Nobel Prize winner Linda Buck.

Teachers could also use this article to link neuroscience with humanistic subjects as philosophy or psychology, including a discussion with students about these activities and about environmental conditions. You might also discuss the applications of the work to consumer psychology.

Marina Minoli, didactics expert, Agora' Science University Centre, Italy

Image courtesy of Dennis Wong/Wikimedia Commons

Image in the public domain / Wikimedia Commons

The taste of whisky can change with the lighting.

The work has attracted the attention of academia and industry alike. Coffee giant Starbucks has developed playlists for customers to listen to, to get that 'coffee-shop experience' at home. Meanwhile, chocolate company Cadbury learned a harsh lesson when it gave its Dairy Milk bar a more rounded shape, only to receive complaints from consumers who believed the recipe had been modified (it hadn't). The reason? Round tastes sweeter. "Surprisingly, these perceptions are common across groups of people," Charles explains. "By taking our understanding of how the brain works, we can learn which shapes, instruments and notes go with particular tastes, and present them together to make food healthier and taste better."

New ideas on the menu

Amongst many other projects, Charles is currently working with a philosopher and a chef to identify ways of making insects more attractive as a substitute for meat – and they could be used to nudge people to make healthier food choices. "Before, the focus has been on technology in the kitchen – you do not see it, but you taste the results," he says. "I think we will increasingly see more things like directional soundscapes and harnessing mobile technologies at the table. Restaurants are a fantastic test bed of innovation – and if you can convince chefs that the colour of their plate matters, then it could be on the menu the following day, just like that."

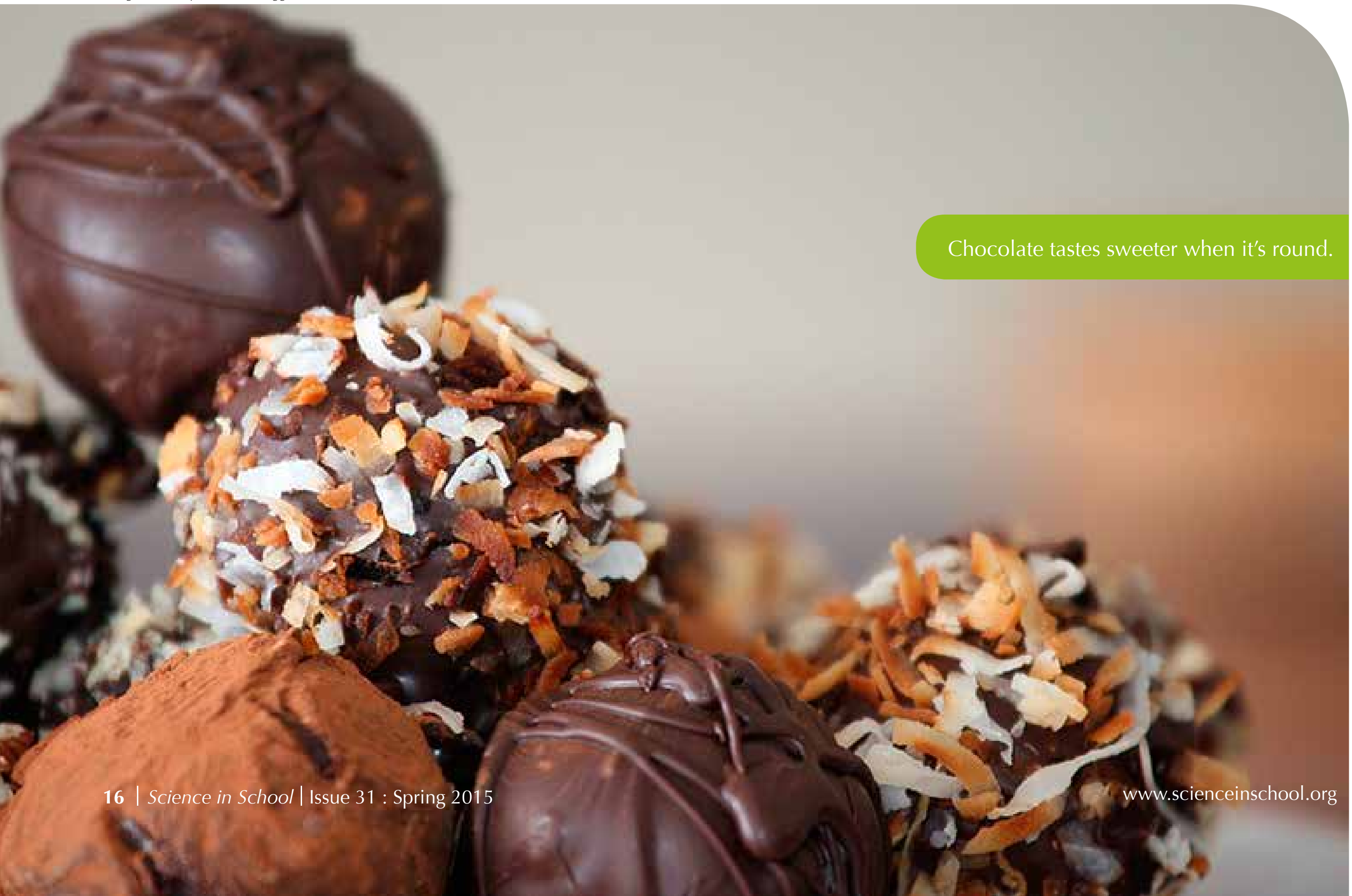
Reference

Spence C, Michel C, Smith B (2014) Airplane noise and the taste of umami. *Flavour* **3**: 2. doi: 10.1186/2044-7248-3-2

Web references

w1 – You can try the experiment with your class using the two audio

Image courtesy of David Leggett/Wikimedia Commons



Chocolate tastes sweeter when it's round.

Image courtesy of Gobierno de la Ciudad de Buenos Aires/Wikimedis Commons

If chefs want to create the perfect meal they don't just need to work in the kitchen.

tracks available from Charles's blog at http://condimentjunkie.co.uk/blog/2014/6/20/bittersweet-symphony or extend the experiment using the new EP with five tracks, one for each flavour: http://condimentjunkie.co.uk/blog/2014/11/17/sonic-taste-ep

w2 - The original article can be read on the EMBL news portal, see http://news.embl.de/events/1410_spence

w3 – Get more information about EMBL: www.embl.org

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

Resources

Charles Spence spoke at the 2014 EMBL/EMBO Science and Society Conference, 'Foods are us! On eating and becoming', about 'The perfect meal'. You can watch the recorded talk here: http://tinyurl.com/qfprovz

Don't forget when teaching your students about taste that the well-known 'tongue map' is an oversimplification, as this useful paper explores:

Marshall PA (2013) The tongue map, real or not? *The American Biology Teacher* **75**: 583–586. doi: 10.1525/abt.2013.75.8.11

For other articles on taste, why not read these *Science in School* articles:

Schollar J (2006) The chocolate challenge. *Science in School* **2**: 29–33. www.scienceinschool.org/2006/issue2/chocchallenge

Davis E (2014) From methional to fried chicken. *Science in School* **30**: 44–48. www.scienceinschool.org/2014/issue30/HThis

For another article on perception, see:

Paterlini M (2010) Exploring out-of-body experiences: interview with Henrik Ehrsson. *Science in School* **15**: 4–7. www.scienceinschool.org/2010/issue15/ehrsson

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Adam Gristwood is a journalist and editor of *EMBLetc* magazine. Reporting mainly on life sciences, he's also covered stories from the Atacama Desert, the Large Hadron Collider and a helicopter.

More about EMBL

This is a modified version of a story that first appeared on EMBL's news portal[w2].

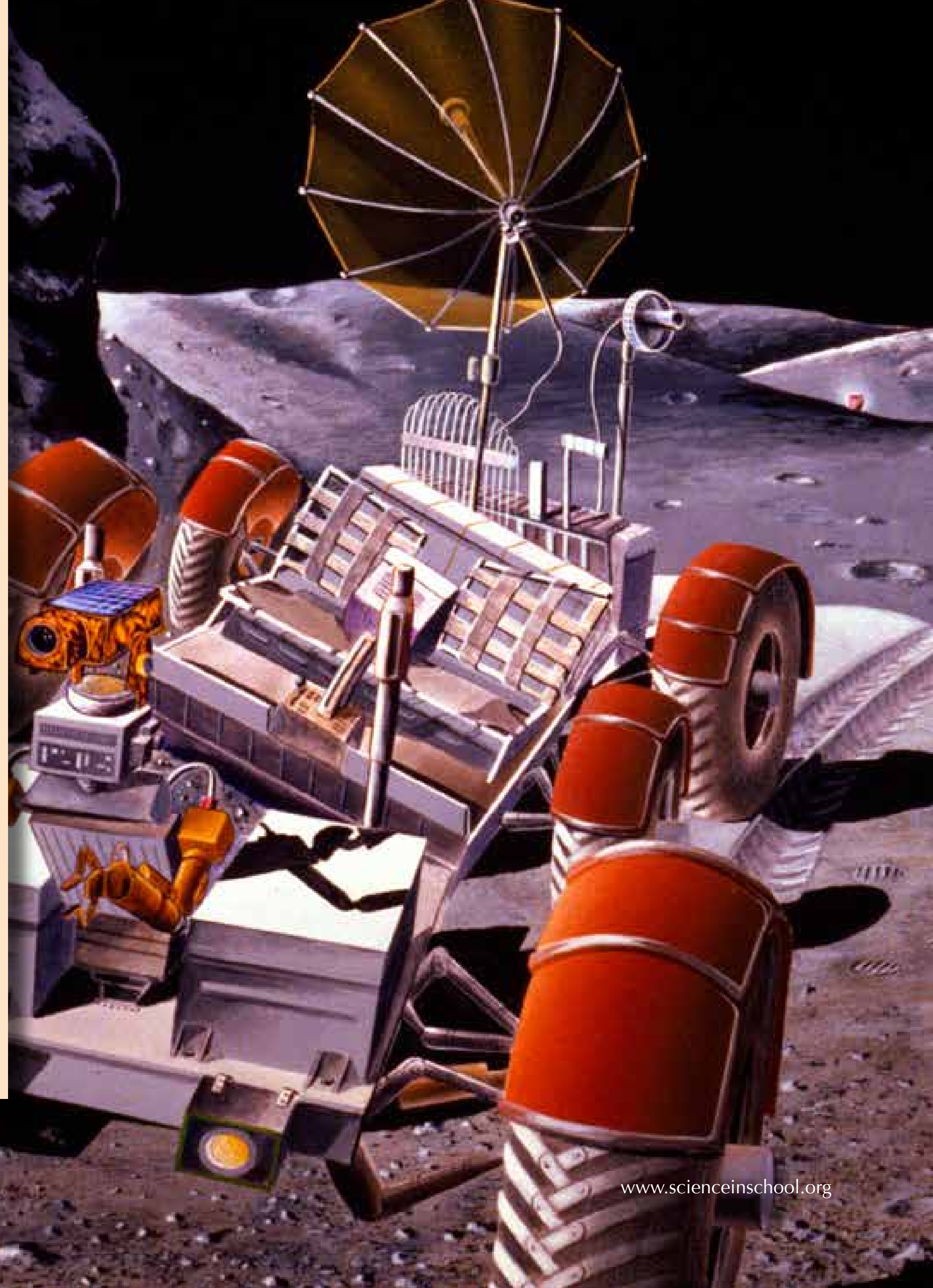
The European Molecular Biology Laboratory (EMBL)[w3] is one of the world's top research institutions, dedicated to basic research in the life sciences. EMBL is international, innovative and interdisciplinary. Its employees from 60 nations have backgrounds including biology, physics, chemistry and computer science, and collaborate on research that covers the full spectrum of molecular biology.

EMBL is a member of EIROforum[w4], the publisher of *Science in School*.

See the list of all EMBL-related articles in *Science in School*: www.scienceinschool.org/embl

The challenging logistics of lunar exploration

The path to the Moon is paved with many challenges. What questions do the next generation of space explorers need to answer?



REVIEW

- Physics
- Geography
- Biology
- Astrophysics
- Astrobiology
- Languages
- History
- Economics
- Ages 10–19

This article (part two of two) summarises challenges facing future journeys to our Moon.

The article stimulates questions around how or if scientific missions to the Moon provide sufficient benefit to mankind and around how these missions are carried out.

The students can consider questions like:

- Where should we land on the Moon, and should robots or humans be used?
- Should experiments be conducted on the Moon or Earth, and how should problems of transport be solved?
- How many missions should be planned, and who should pay?

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

By Erin Tranfield

In the first of this two-part series, I explained why scientists wish to return to the Moon, what scientific questions remain and why it is important to find the answers (Tranfield, 2014). In this follow-up article, I describe some practical but non-trivial challenges to fulfilling a successful mission to the Moon, together with potential leads for solutions. Your students, the next generation of space explorers, can put their minds to work to generate ideas and solutions to these problems.

Where should we go on the Moon and why?

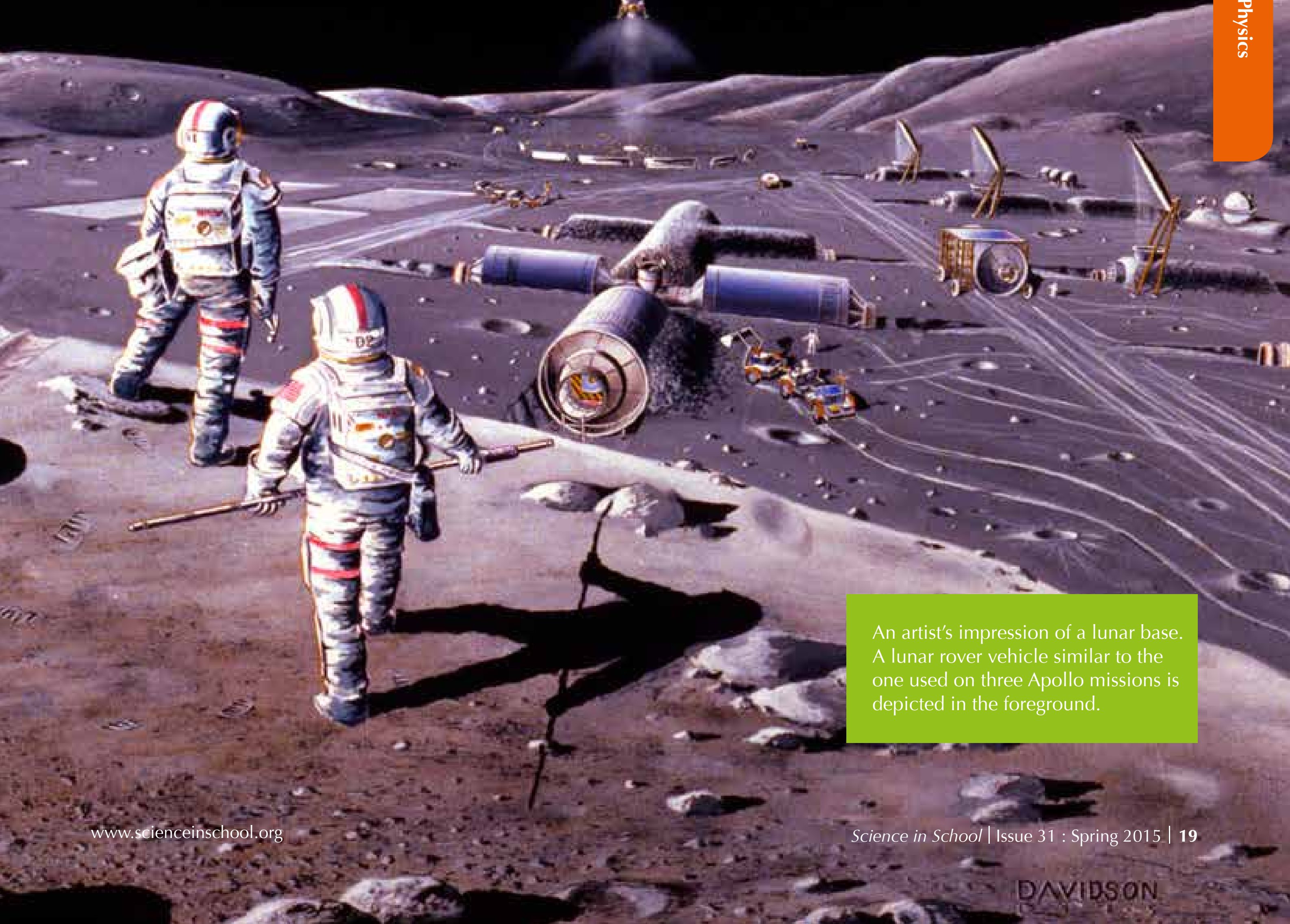
To the poles? The equator? The near side of the Moon? Its far side? The answer to this depends on which scientific questions are being studied. The Apollo missions all landed on the near side of the Moon, near the equator[w1]. Scientists think new destinations should be explored to expand our understanding of the Moon. Destinations of interest include the poles, particularly the South Pole–Aitken Basin, which is the largest, oldest and deepest known crater on the lunar surface[w2], making it an interesting study location for lunar geologists.

Furthermore, NASA's LCROSS mission in 2009 determined that there is ice at the poles in regions that never receive direct sunlight[w3]. Any experiments that study lunar ice will need to target the lunar poles. The far side of the Moon would also be an interesting new destination for exploration but it is technically more challenging because there is never a direct line of sight between the far side of the Moon and Earth, which would make mission control and communication more difficult.

Should humans go? Should robots go?

Or should both go? Humans can do more science than a robot in the same amount of time. Humans can learn quickly from their environment and apply their knowledge to assess a situation. However, a human mission costs a lot more money and endangers more lives than a robotic mission. Commonly, robotic missions are planned first to perform preliminary scientific studies: they use cameras and scientific instruments to study the area prior to human arrival, and deliver supplies in anticipation of later human missions. After a series of successful robotic missions, human missions are planned to perform more complex tasks, including advanced scientific experiments, habitat construction and exploration.

Image courtesy of NASA/Dennis M. Davidson



An artist's impression of a lunar base. A lunar rover vehicle similar to the one used on three Apollo missions is depicted in the foreground.

Should the experiments be done on the Moon or on Earth?

BACKGROUND

The unique benefits of human exploration are illustrated by the work of Apollo astronaut Jack Schmidt, the only geologist to have stood on the Moon. Jack Schmidt noticed a uniquely coloured orange rock on the lunar surface and he collected samples. These unplanned samples have proved to be extremely important to our understanding of the history of the Moon[w4] and would have been missed completely if it were not for the training and experience of Jack Schmidt.

Lunar samples exist in an environment of minimal air and water and away from contamination sources such as humans, spacecraft and Earth's atmosphere. Studying samples on the Moon therefore reduces the risk of sample change and contamination during transportation. However, the cost and technological challenge of developing and launching scientific instruments that are small enough and that function in lunar gravity limits what analysis can be performed on the lunar surface.

Therefore, samples that require multiple forms of analysis, or complicated instrumentation, should be tested on Earth. This implies that they must be carefully collected and transported to Earth to minimise changes and contamination. The rock boxes designed for the Apollo missions are a good example of how challenging this task can be. They were designed to keep oxygen and water away from the samples during the journey back to Earth; however, in some cases the abrasive nature of the lunar dust degraded the seals and the samples were exposed to air and humidity. Another consideration will be ice core sampling. Ice cores collected by drilling may be damaged by heat generated during the collection process, and collected ice cores will presumably need to be transported back to Earth in specially designed containers to protect the samples from heat, light, radiation, oxygen and biological contaminates.

Image courtesy of Wknight94/Wikimedia

This sample of lunar olivine basalt was collected from the Moon by the Apollo 15 mission. It was formed around 3.3 billion years ago and is now on display in the National Museum of Natural History in Washington, DC, USA.

A case used for the transport of lunar samples between the Moon and Earth during the Apollo programme. Inside the case are several sample collection and containment bags, used on the surface for initial sample collection and sorting. These items are on display at the National Museum of Natural History in Washington, DC, USA.

Image courtesy of Tyrol5/Wikimedia

Image courtesy of Rick Kline, Cornell University

The Orientale Basin is an impact site approximately the size of the American state of Texas.

Image courtesy of Gregory H Revera

Full Moon photograph showing the northern hemisphere

Who should pay? Who should go?

In the political and economic landscape today, very few countries have all the necessary resources and skills to launch their own lunar missions. International co-operation, where countries contribute skills and resources, allows all countries to contribute to a shared mission of long-term space exploration, to the Moon and beyond. It will be a challenge to agree which countries can send astronauts and equipment, and this could be an interesting topic to discuss with your students.

The benefits of returning to the Moon from a scientific and exploratory standpoint are enormous.

How can samples be stored on Earth without compromising their quality?

The NASA curation facility in Houston, Texas, USA, has established successful procedures for handling soil samples under inert nitrogen gas, which ensures that they are well protected from humidity, biological and gas contamination. Dedicated facilities exist for the investigation of samples, and detailed records document what has been done with each sample. New samples, such as ice cores, will require additional method development to make sure that they are handled in a way that protects their scientific value.

How many missions to the Moon should be made?

Every mission should be built with the goal of furthering our knowledge and our exploration abilities. However, every mission requires a considerable investment in technology, human time and money. As an example, at its peak, 400 000 people worked on the Apollo programme, which cost US$20 billion in 1970[w5] (equivalent to about US$120 billion in 2013 when adjusted for inflation). In contrast, the LCROSS / Lunar Reconnaissance Orbiter (LRO) mission cost US$583 million in 2009 (US$633 million in 2013 dollars)[w6]. The LCROSS / LRO mission was much cheaper than the Apollo programme, but its scientific value was much smaller and did not involve human exploration. When planning large exploration programmes, a balance must be achieved between robotic and human missions to maximise scientific return at a reasonable cost.

Astronauts in simulated weightless flight (in C-131 aircraft flying 'zero-g' trajectory at Wright Air Development Center). Weightless flights were a new form of training for the Mercury astronauts, and parabolic flights that briefly go beyond Earth's tug of gravity continue to be used for spaceflight training purposes. These flights are nicknamed the 'vomit comet' because of the nausea that is often induced. Such forms of training are part of the huge costs associated with human missions in space.

Image courtesy of NASA

Physics

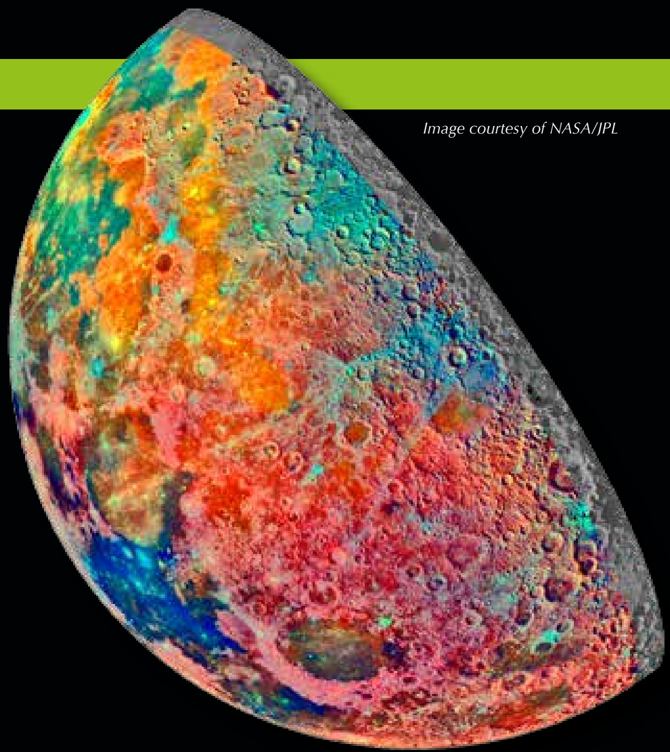


Image courtesy of NASA/JPL

False-colour mosaic constructed from a series of images taken through three spectral filters by Galileo's imaging system as the spacecraft flew over the northern regions of the Moon in 1992. The part of the Moon visible from Earth is on the left side in this view.
Bright pink: highland materials, such as those surrounding the oval lava-filled Crisium impact basin towards the bottom of the picture.
Blue to orange: volcanic lava flows. To the left of Crisium, the dark blue Mare Tranquillitatis is richer in titanium than the green and orange maria above it. Thin mineral-rich soils associated with relatively recent impacts are represented by light blue colors. The youngest craters have prominent blue rays extending from them.
The monochrome band on the right edge shows the unretouched surface of the Moon.

However, many challenges must be overcome to accomplish those goals. This was achieved during the Apollo era, and there is a growing momentum within the scientific community today to do this again.

Reference

Tranfield E (2014) Lunar diary: a chronicle of Earth's journey through space and time, as seen from the Moon. *Science in School* 30: 36–43. www.scienceinschool.org/2014/issue30/Moon

Web references

w1 – NASA's website on Lunar and Planetary Science has a map of the landing locations of the Apollo missions. See: http://tinyurl.com/2rtfo9

w2 – To learn more about the Moon's South Pole–Aitken Basin, see NASA's website of the Solar System Exploration Research Virtual Institute (http://servi.nasa.gov) or use the direct link: http://tinyurl.com/nddcqzt

w3 – NASA's LCROSS mission was designed to search for water on the Moon. For more information, see: http://lcross.arc.nasa.gov/mission.htm

w4 – To learn more about Troctolite 76535, the sample collected by Jack Schmidt during the Apollo 17 mission, see NASA's Lunar Sample Compendium: http://curator.jsc.nasa.gov/lunar/lsc/76535.pdf

w5 – The NASA History Program Office provides a detailed history of the Apollo programme. See: http://history.nasa.gov/Apollomon/Apollo.html

w6 – NASA's extensive 2009 press kit for the LRO and LCROSS missions provides detailed information, including cost estimates. See: www.nasa.gov/pdf/360020main_LRO_LCROSS_presskit2.pdf

Resources

The website of the Lunar and Planetary Institute, which provides support services to NASA and the science community, includes information and resources for students and teachers.

To learn more about the tools used during the Apollo programme, see: www.lpi.usra.edu/lunar/samples/apollo/tools/

To access a lecture series from 2008 about the Moon, see: www.lpi.usra.edu/lunar/moon101/

NASA's Human Spaceflight website provides details about Apollo program, including its cost. See: http://spaceflight.nasa.gov/history/apollo

Many different technologies have arisen from space exploration. To read stories on these technologies and products, read NASA's *Spinoff* publication: http://spinoff.nasa.gov

To learn more about how extraterrestrial materials are documented, preserved, prepared and distributed, visit the website of NASA's Astromaterials Acquisition and Curation Office: http://curator.jsc.nasa.gov

To find out more about past and future lunar exploration, see:

Baker A (2010) Space exploration: the return to the Moon. *Science in School* **16**: 10–13. www.scienceinschool.org/2010/issue16/lunar

To watch a video giving an overview of past, present and future Moon expeditions, see: http://youtu.be/Xe_nuRMH30c

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Erin Tranfield worked at NASA's Ames Research Center in Moffett Field, CA, USA, where she studied the toxicity of lunar dust. Erin is now based at the Instituto Gulbenkian de Ciência in Oeiras, Portugal, and she works with the European Space Agency on the effort to resume lunar exploration.

Chemistry

The Aspirin screen experiment

An online resource published by the Royal Society of Chemistry

By Tim Harrison, Bristol ChemLabS, University of Bristol, UK

The synthesis of one of the world's most common pharmaceuticals, aspirin, or acetylsalicylic acid, is found in many advanced chemistry courses. The typical student carrying out the experiment may view the the lab script as a set of cookery instructions to be followed without thinking about the underlying science. This free web-based resource should put an end to that[w1].

The aspirin screen experiment comprises a series of exercises designed to help the student through commonly asked questions, such as 'Why is the experiment conducted that way?', 'Why is that reagent used?', 'Why is it heated for that long?', and 'Why was that particular catalyst used?'. The resource comprises four sections – two pre-lab and two post-lab exercises – which take around 40 minutes each to work through and so make ideal homework. The use of pre-lab support resources has been shown to aid students' confidence in the laboratory setting.

Students are taken through each stage in the synthetic preparation and must make decisions based on the information presented. Exercises aid the students' practical skills and understanding of the particular chemistry involved. Their answers are automatically stored in an online laboratory note book, which can be printed or accessed with login details. Individuals can obtain their own ten-digit user number for the website, or a teacher can register the whole class at one time.

The website provides additional notes and resources to aid teachers in making the best of their students' time. The original 'aspirin' booklet, which is the basis of this online resource, is also available and can be used independently in its own right.

This is the first of a proposed series of exercises aimed at supporting students around the world who are studying the UK's A-level and international baccalaureate chemistry courses (for ages 16–18). However, the resources should find a much wider audience with all those wishing to understand their practical sessions.

Web references

w1 – The online resource is published by the UK's Royal Society of Chemistry: www.rsc.org/learn-chemistry/resource/res00001644/aspirin-screen-experiment

Resource

Download the related booklet on which this resource is based:

Osborne C, Pack M (eds) (2003) *Aspirin* 2nd edition. London, UK: Royal Society of Chemistry. ISBN: 0854043888. Available for download at: www.rsc.org/learn-chemistry/content/filerepository/CMP/00/000/045/Aspirin.pdf

Image courtesy of the Royal Institution

Taking teaching home

Image courtesy of Alom Shaha

Alom Shaha

At the Royal Institution, science teacher and communicator Alom Shaha has helped develop the Experimental project to boost science at home.

By Laura Howes

Last summer, the UK-based Royal Institution (RI) started publishing a series of short films about science activities for children on YouTube[w1]. Instead of just showing how to perform the experiment, each video shows a parent and their children setting up the experiment, asking questions and working out what's going on. The Experimental series was developed by science teacher Alom Shaha, who splits his time between teaching physics at Camden School for Girls in London, UK, and making films for the RI.

Parents are often children's first teachers, Alom explains: "I learnt to read on my father's knee." But many parents don't have the confidence to teach science in the same way, Alom adds, and that's the goal of these videos – to give parents confidence.

"What we found in our research was that a lot of existing videos and books are about how to physically do the experiments," he explains. "And

Image courtesy of the Royal Institution

Image courtesy of the Royal Institution

they might even give you an explanation of the science…but what we felt was missing was the pedagogical technique to actually get your children thinking critically."

"As a teacher, I know the importance of using questions to lead students into thinking about problems and experiments," Alom says. "I feel strongly that science is about asking questions." So the videos show the same pedagogical techniques that Alom uses in the classroom. Each video also has accompanying information, outlining how to do the experiment and what sorts of questions to consider. "Some of the most positive feedback we've had has been along the lines of 'I didn't realise that's how I should have been talking to my child.'"

Positive feedback

The RI has a long history of making science accessible to the public. It is most famous for its Christmas lectures and could be thought of as the home of the science demo. Outside the RI's London home is a sign saying 'Science Lives Here' and Experimental's motto is a play on this, stating the series is about 'Bringing science home'.

In particular, the project is aimed at families that might not traditionally do science activities at home, or visit the RI, says Alom. The goal is to help boost what some people term science capital. "If you've got people in the family who are scientists or engineers," he explains, "you are more likely to be exposed to science as a cultural activity and that can have a positive benefit."

The first videos were produced in time for the summer holidays, but while parents and their children are the primary audience, Alom also hopes that the videos will help teachers of younger children, many of whom might not be confident about science themselves.

"These videos have been produced to help people engage young children in science. They could be 30 children in a class with a primary-school teacher or one child with a parent

REVIEW

- **Physics**
- **Chemistry**
- **General science**
- **Ages 11 and under**

Science should be fun both in and out of school, both when done with teachers and with parents. The ExpeRimental videos provide parents with a way to co-construct knowledge with their children in a non-typical educational setting and Alom describes how we (as parents) can explore several phenomena and perform experiments with our children to explain how nature works.

As a teacher I would love to see my students working with their parents at home and I would also like to support them and even invite them into my class to demonstrate their experiments and explain what they learned. I will definitely recommend the Experimental project to the parents of my students.

Christiana Th Nicolaou, Saint Demetrios Elementary School, Nicosia, Cyprus

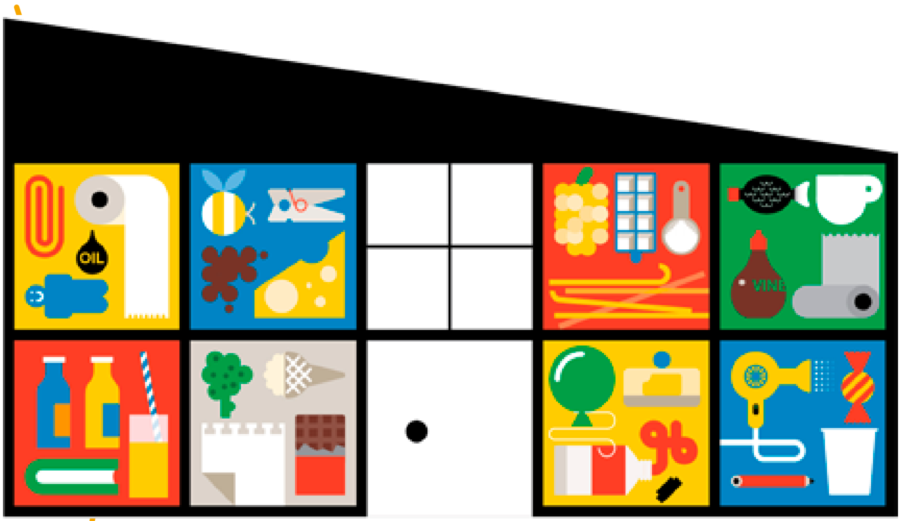

Image courtesy of the Royal Institution

ExpeRimental — Bringing Science Home

Rubber band cannons help Serafino and Alessandro explore projectile motion and conservation of energy

Images courtesy of the Royal Institution

at home," he adds. "We know that primary schools suffer from a shortage of qualified science teachers." The Experimental team has already had feedback from many primary teachers who say that the project is an incredible resource.

The website started with 10 different experiments, most of which focus on physics. However, another 10 with a focus on chemistry are now starting to appear, and Alom can also be found adding other videos on the RI channel. In a year's time, Alom and his colleagues hope that they might have 30 or 40 activities, with both videos and text-based resources.

The importance of communication

As well as training as a teacher, Alom is qualified with a master's degree in science communication, and for the past few years has divided his time between teaching and science communication projects, of which Experimental is the most recent.

For Alom, the two areas of teaching and science communication are complementary, but he says he is glad that he gained his teaching qualification first. Having taken a break to work in television, he then returned to teaching. "I feel that being a science communicator made me a better science teacher," he says. "But at the same time I think being a science teacher makes me a better science communicator." The perspectives of both roles enhance each other in a positive feedback loop.

"Often the two jobs are the same," he says. "For both, you're a cheerleader for science and teaching it, and there the pedagogical background helps – there's an obvious connection.". For Alom, it's a pity that more teachers don't do science communication and vice versa. Of course, managing to combine both activities depends on teachers having the time to take on other roles.

BACKGROUND

A history of education

The Royal Institution in London, UK, was founded more than 200 years ago, in 1799. Its building in London has housed famous scientists such as Humphrey Davy and Michael Faraday. One of the Institution's most famous activities is its annual series of Christmas lectures for children, but this is just one part of the organisation's broader educational work, including videos like Alom's and interactive games.

Image courtesy of the Royal Institution

Chemistry

Physics

Filming in progress as Oly and Viola explore the science of floating and sinking

Alom describes working at the RI as an amazing experience, but that is only half of his job. He is extremely grateful to his school for allowing him to work part-time, something he knows is quite rare. "Working with young people and seeing how they relate to science has inspired me to do some of my best work as a science communicator," he concludes.

Web reference

w1 – The Experimental project website collects all its videos and resources together at: http://rigb.org/experimental

Resources

Some of Alom's other work has focused on helping teachers improve their demonstration skills with Demo: The Movie (www.youtube.com/watch?v=ei57i78leUo and developing the resource 'Why science' to answer that perennial question from students: "What's the point of this?" (www.whyscience.co.uk).

Laura Howes is co-editor of *Science in School*. She studied chemistry at the University of Oxford, UK, and then joined a learned society in the UK to begin working in science publishing and journalism. In 2013, Laura moved to Germany and the European Molecular Biology Laboratory to join *Science in School*.

Climbing up the PISA ladder

Image courtesy of the German Federal Archive/Wikimedia Commons


Teaching has changed over the years

Since the first PISA study in 2000, changes in the system and innovations in the classroom have improved performance in Germany.

By Berit Viuf

Since it was first introduced, the triennial OECD Programme for International Student Assessment (PISA) has been the subject of concern or celebration for teachers and policy makers. However, in more than a decade since its launch, it has also led to innovations and changes in teaching practice. The PISA reports reveal how practices have changed and what can be learned.

A focus on Germany

It was a shock to the population of Germany when, in December 2001, the results from the first 2000 PISA study were published. The results showed much lower maths and

Image courtesy of Metropolitan School /Wikimedia Commons

Image courtesy of Metropolitan School /Wikimedia Commons

REVIEW

General science

By discussing the evolution of PISA results, the author emphasises the image of school as the pivotal means to counter the impact of socio-economic differences on youth job opportunities and life horizons.

The article raises the importance of studying the entire organisation of education as the major determinant of learning success in mathematics and sciences. Of course, evaluation of teachers or the investment in material and technological resources are also important. But the innovation and creativity delivered to the class planning process – to achieve a more goal- and context-oriented learning – play a role whose importance is difficult to surpass.

I hope this text stimulates a larger debate around the following questions among school decision-makers and teachers:

1. What themes and classroom methodologies have the potential to improve students' attitudes towards maths and science learning?
2. How should schools be organised to support all kinds of students and thus promote social mobility?
3. Are good practices shared and reproduced? How can this be achieved?

And, perhaps, more relevant:

4. What is the best approach to treating PISA results? Is the assessment itself an end or simply an additional criterion with which to work out the prevailing trends?

Luis M. Aires, Antonia Gedeao Secondary School, Portugal

Image courtesy of DALIBRI/Wikimedia Commons

science performance than the average for OECD countries. Children of poor socio-economic families were primarily at risk, and so a very unequal school system was revealed.

The debate rising from the PISA results kickstarted different reforms in the educational system, by placing emphasis on individual support, extending the school day and introducing federal educational standards.

By 2012, Germany had improved reading, maths and science scores to above the OECD average – mainly because of improvements in low-achieving students – and was the only European country to show improvement in both mathematics ability and equality.

Wolfgang Pöschl, a science teacher in a Gymnasium in the state of Bavaria, explains that he has noticed how the reform has put much more emphasis on social mobility. In his area, a lot of parents do not send their children to the Gymnasium even if they have good grades, because they think that Realschule is sufficient to get a good job or to study at a university of applied science (see box for an explanation of the German school system).

At Wolfgang's school, the staff encourages families to let their children stay in the Gymnasium if they have the talent. To help with this, the way that children are assessed has changed to make it easier to identify talented students and to argue that they should continue their education.

"We used to test a lot of pure knowledge," Wolfgang explains. "The problem is that students from wealthier families usually have better general knowledge and therefore get better grades. Now we try to teach and test skills in science. So you can get good grades even if your parents don't teach you a lot of general knowledge at home."

Individual support

One of the newest initiatives in Bavaria is the so-called individual learning class, where the teacher's role is to coach individual students to deepen their understanding of a topic or to provide extra support in those areas in which the student has difficulties.

"This kind of mentoring is quite new, so there is yet no data to prove if the project is a success or not," Wolfgang says.

What is a success though, according to the experienced science teacher, is another initiative: intensification classes. In these extra classes on basic subjects, no new material is introduced but the students practise existing skills.

"It's helpful because I can give different exercises to different students

BACKGROUND

The German three-pillar school system

After four or six years of primary school, depending on which state they live in, German school students are divided into three different pathways:

- The Gymnasium offers a demanding academic programme for those who will be allowed to apply for university.
- The Realschule, with a less demanding academic programme, leads to a lower secondary diploma.
- The Hauptschule offers a programme for those of limited academic ability or interests and culminates in a school-leaving certificate.

The system has come under criticism from PISA for essentially dividing students according to social background.

and help them solve them. A lot of people think that these classes are really successful in helping low-achievers," Wolfgang explains.

He thinks that this initiative is a success and that it helps the slow-learning students to understand faster and better.

The benefits of innovation

The introduction of 'remedial education' is a trend that was picked up by the OECD in its July report *Measuring Innovation in Education: A New Perspective* (OECD, 2014), which looked at the association between school innovation and educational outcomes. The report concluded that high maths performance, more equal learning and more satisfied teachers correlate with the amount of educational innovation in each country.

The report also noted the move towards context-based learning and the importance of skills over pure factual recall in Europe, including introducing more student-directed experiments. In addition, it recognised the benefit of 'enrichment' activities, for example in the UK and Slovenia.

Wolfgang Pöschl's Gymnasium offers extra courses, usually in the afternoon, in which students can specialise in alternative skills such as music, programming and foreign languages. However, these 'Leistungskurse' or extension courses have been stopped in the past two years to make time for the individual and intensification classes.

Longer school days

Many German states have chosen to extend school hours to move closer to the OECD averages of 842 hours for primary schools and 936 hours for secondary schools.

Longer days give teachers more time to focus on inclusion. But even though more time has the advantage of more hours to spend with individual students, it also has its limitations, Wolfgang explains, as students have less time at home to complete their homework.

As a consequence, teachers usually don't give written homework for the next day if the student has afternoon classes. Depending on the grade, students have afternoon classes up to four times a week.

Those who have many afternoon classes do get tired by the end of the day, so complicated topics must be taught earlier in the day. The planning of curricula becomes a challenge for many teachers.

Between 2003 and 2009, Germany spent €4 billion on the establishment of full-day schools. It is still voluntary if a school wants to make afternoon classes obligatory.

Happy but noisier

It is clear that by innovating in the classroom, Germany has improved its overall academic performance. Not only have testing scores improved, but also the motivation and enjoyment of attending school has been enhanced. According to the 2012 PISA, German children have the highest self-belief in maths, showing motivation and believing in their own ability to learn.

The only little fly in the ointment is that the same children that report enjoyment of learning also report more noise and disorder in the classroom.

Reference

OECD (2014) *Measuring Innovation in Education: A New Perspective*. Paris, France: OECD Publishing. ISBN: 9789264215696

Web reference

w1 – You can read the full 2012 PISA results and various overview documents here: www.oecd.org/pisa/keyfindings/pisa-2012-results.htm

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Berit Viuf is a freelance journalist based in Copenhagen, Denmark.

An artistic introduction to anthocyanin inks

Making pH-sensitive inks from fruits and vegetables is a creative variation of the cabbage-indicator experiment.

By Gustavo Giraldi Shimamoto and Adriana Vitorino Rossi

Long before synthetic dyes and pigments were available, natural products were used to create simple but efficient inks (such as that described by Farusi, 2012) – which we can still see in the paintings of prehistoric and extinct civilisations. These natural colours could be mineral in origin or from plant extracts; in this activity we focus on a particular group of plants that contain anthocyanins (ACY, figure 1).

Natural colours are often less stable than many synthetic dyes, changing colour or disintegrating with temperature, light, pH variation and oxidising agents. This can lead to interesting lessons, and in our work with primary school students we have used anthocyanins as colourants for pH-reactive ink production.

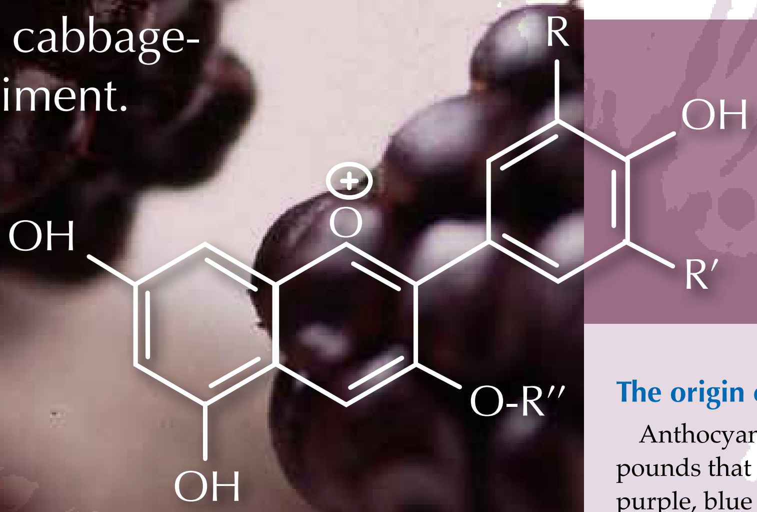


Figure 1: General structure of anthocyanin, in which R and R′ are H, OH, or OCH_3 and R″ is a sugar unit

The origin of colour

Anthocyanins are organic compounds that produce the orange, red, purple, blue and nearly black colours in the flowers, fruit, leaves and roots of several fruit and vegetable species. Anthocyanin molecules contain ring structures that absorb light, and so act like a sunscreen, protecting the cells of the plant. The wavelengths of light that are not absorbed by the anthocyanin are instead reflected, and so the flower or fruit is seen as coloured. These colours also attract pollinators and seed dispersers and so are also important for the plant's reproduction.

Chemistry

REVIEW

- Biology
- Physics
- Chemistry
- General science
- History
- Art
- Ages 8–14

This is a novel way of teaching old science, either in class or through a science club.

The introduction to the article could be used in a comprehension exercise and the article could be used to stimulate discussion around acids, alkalis and indicators; chemical extraction; plant science; and science and art.

Tim Harrison, Bristol ChemLabS, University of Bristol, UK

Image courtesy of Janine/Wikimedia Commons

Strawberries, blueberries and blackberries all contain anthocyanins

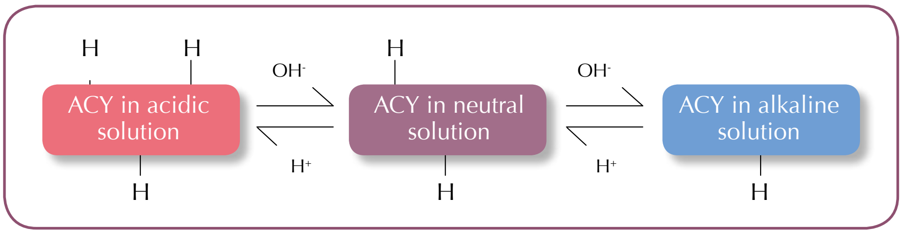


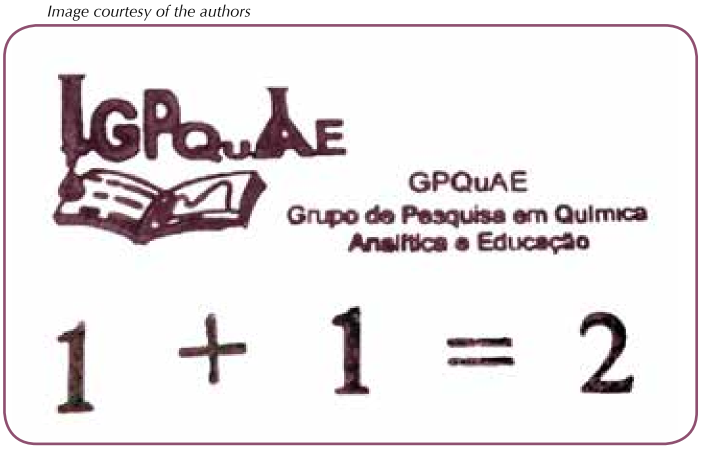
Figure 2: Simplified representation of the chemical equilibrium responsible for the change in colour of anthocyanin inks

Anthocyanin solutions change colour with the pH of the medium, acting as a natural pH indicator (figure 2). Generally, anthocyanins exhibit a red colour in acid solutions and a blue colour in alkaline media; however, other colours can be observed, depending on the pH and the particular anthocyanin and its source. This is because adding and removing hydrogen ions (H^+) from the pigment's molecular structure changes its electronic properties and so alters the wavelengths of light that the pigment absorbs. This property allows us to use plant extracts to determine the pH of household materials and to indicate the endpoint of acid/base titrations, as in the famous cabbage-indicator experiment (Terci & Rossi, 2002; Rossi & Shimamoto, 2010). The colour variability of anthocyanins can also be explored by producing ink for brushes, stamp painting or screen printing.

What is an ink?

Inks are mixtures of dyes or pigments and a binder compound which helps the ink stick to the surface to be painted. This trivial formulation has been used for thousands of years, but advances in chemistry and new technological alternatives have made inks much more sophisticated, with infinite colour options and diverse properties, such as the ability to adhere to glossy paper or egg shells.

Image courtesy of the authors



Reproduction of a stamp print made using ACY ink

An essential component of an ink is the substance that imparts the colour: the pigment or dye. A pigment is a finely divided solid that is insoluble in the dispersion medium of the ink and provides – in addition to colour – opacity and strength, among other effects, whereas dyes are generally compounds that are soluble in the ink medium. In our ink, the anthocyanin extract is a pigment.

Anthocyanin ink for painting, stamping, or screen printing

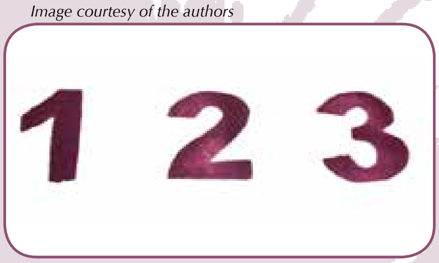
Materials

- Fruits or vegetables containing anthocyanins, such as blackberries, grapes, strawberries, blueberries, raspberries, or red cabbage.
- 94% ethanol (volume / volume)
- filter paper (a coffee filter can also be used)
- Petri dishes
- water
- bond paper (a high-quality durable writing paper with a density greater than 50 g/m^{-2})
- stamps, paint roller or brushes
- vinegar
- multi-purpose cleaning products with alkaline properties

Procedure

1. Crush the fruit or vegetable and mix in ethanol at an approximate ratio of 1 : 3 (weight : volume) for 30 minutes.
2. Filter using filter paper and pour the filtrate into Petri dishes.

Image courtesy of the authors



Reproduction of stamp prints made using ACY ink

Image courtesy of the authors

Children using the anthocyanin ink

3. Dry the anthocyanin extract by leaving the extract in opened Petri dishes protected from light until the solvent evaporates (2 days). For more rapid evaporation, the dishes can be subjected to cold airflow or stored in a chemical hood or under a range hood.
4. After it is dry, mix the dried anthocyanin extract (which has a pasty appearance) with water in a ratio of approximately 1 : 10 (weight : volume).

You can then use the prepared ink with brushes or stamps, or for screen printing. As this ink is a pH indicator, its colour can be changed by the addition of acid or alkaline solutions. A brush could be used to apply an acid solution (vinegar) and an alkaline solution (diluted multi-purpose cleaner) on paper dyed with the ink, or paintings could be sprinkled with acid and alkaline solutions to change their colours. Another option is to write or draw with acid and alkaline solutions, which are colourless, and reveal the message by spraying with anthocyanin ink, simulating an invisible ink. Approximately 1 minute after applying the anthocyanin ink to bond paper, the paintings will be partially dried.

Safety note: Check your local regulations when using acid or alkaline solutions, as safety glasses may be required.

About what happens

Anthocyanin extracts are natural pH indicators in solution as well as on paper. The change in colour can be explained by the interaction between the anthocyanin-impregnated water molecules on the paper, and the acetic acid from vinegar or the alkali from the multi-purpose cleaner.

The ink's colour change is linked to a chemical equilibrium (shown in simplified form in figure 2). Anthocyanins are organic compounds that have several substituents on which H^+ ions are added or removed at various pH values to produce different coloured solutions. In figure 2, there are three main colours because three media were used with the anthocyanin paints: acid, neutral and alkaline. By using solutions of different pHs, the different dyes can be compared.

Image courtesy of the authors

Changing the colour of the paintings with vinegar solution

The anthocyanin ink can be used by younger children (under 11) for drawing and painting activities. Older children (11+) or supervising adults can use vinegar (acid) and diluted cleaner (alkaline) to change the designs and engage in interactions with the group. You can easily modify the preparation and application of this ink, which does not require toxic reagents and does not generate residues that need to be treated before disposal.

The main purpose of this recreational activity is to arouse curiosity, but because you can use any fruit or vegetable that contains anthocyanins to produce these pH-sensitive inks, an interdisciplinary approach that incorporates environmental education and local values is possible. While making the inks, you can discuss nature, the environment, biodiversity and their rational exploitation to obtain useful products.

Acknowledgement

The authors acknowledge the São Paulo Research Foundation (FAPESP) for financial support.

References

Farusi G (2012) Indigo: recreating Pharaoh's dye. *Science in School* **24**: 40–46. www.scienceinschool.org/2012/issue24/indigo

Rossi AV, Shimamoto GG (2010) Antocianinas e gelo seco para visualizar equilíbrios ácido/base numa abordagem contextualizada. *Educació Química EduQ* **7**: 31–36. http://bit.ly/1voRl uf (in Portuguese)

Terci DBL, Rossi AV (2002) Indicadores naturais de pH: usar papel ou solução? *Química Nova* **25**: 684–688 [in Portuguese]

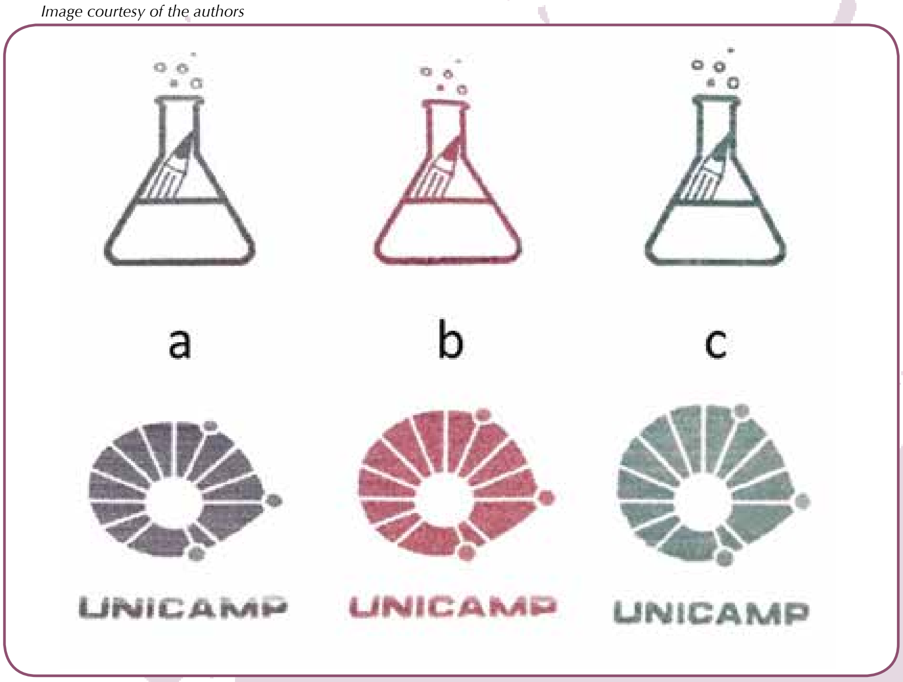
Web reference

w1 – For more information about the Group for Research in Analytical Chemistry and Education at the University of Campinas (UNICAMP) in São Paolo, Brazil, see: http://gpquae.iqm.unicamp.br (in Portuguese)

Resources

Beautiful Chemistry, a website based in China, has videos and pictures of plants changing colour with pH. Visit: http://beautifulchemistry.net/reactions.html

Image courtesy of the authors



Changing colours with different pH solutions. (a) Initial colour print, (b) after acid treatment, and (c) after alkali treatment

Anthocyanins can also be used to make dye-sensitised solar cells, as described in this teaching activity:

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

If you enjoyed reading this article, you may find the following book chapter interesting:

Salamão AA, et al. (2010) Jogo pedagógico que explora a propriedade indicadora de pH de extratos de antocianinas de espécies brasileiras. In de Rezende CM, Braibante HTS (eds) *A Química Perto de Você – Experimentos de baixo custo para a sala de aula do Ensino Fundamental e Médio* pp35–43. Cidade Universitária, São Paulo, Brazil: Sociedade Brasileira de Química. ISBN: 9788564099005 [in Portuguese]. This e-book is freely available to download: http://bit.ly/1CpCNML

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Adriana Vitorino Rossi has a PhD from UNICAMP and is now a professor in the Institute of Chemistry. She works in analytical chemistry and chemical education and co-ordinates the Group for Research in Analytical Chemistry and Education[w1] at UNICAMP.

Image courtesy of Amada44/Wikimedia Commons

Figure 1: The constellation of Orion

Image courtesy of H. Raab

Starlight inside a light bulb

Different stars shine with different colours, and you can use a light bulb to help explain why.

By Carla Ribeiro

After sunset, we can see thousands of stars as white dots across the night sky. They appear white because our eyes cannot usually detect the colour of such dim objects. However, if we look carefully at the brightest stars we can see that not all of them are white; they have different hues. And based on their colour alone, we can tell which stars are hotter and which ones are colder.

The brightest star seen from Earth – the Sun – is yellow, but stars have a range of colours. Near the Orion constellation, in the winter sky, some of the stars are bright enough to discern their hue (figure 1): white / blue (Sirius, above the tree on the left), blue (Rigel, above the tree on the right), and red / orange (Betelgeuse and Aldebaran at the top centre and right, respectively).

Orion

To understand the relationship between a star's colour and its temperature, we need to observe an object close to us that, like the stars, shines because it's hot: the filament of

REVIEW

- Physics
- Astronomy
- Astrophysics
- Ages 11–19

The article proposes an experimental method for highlighting the colour dependence of the star's temperature and is a welcome support for astrophysics lessons.

The students learn more easily with experiments and generally they have a misconception about the stars' colour which can be removed with a simple bulb.

The experiment can be extended by getting the students to make a class Hertzsprung–Russell (H–R) diagram. Give each student the name of a star, and they have to find on internet the main characteristics of this star: temperature, age, brightness, luminosity. Then they fill these features on a dot with the same colour as the star and put the dot on a big H–R poster.

The article can be useful for young students: 11–13 years old without the theoretical part from the beginning, only with the experiment and with H–R diagram with coloured dots. The older students can use the formulas from the article to calculate different parameters.

Corina Toma, Computer Science High School "Tiberiu Popoviciu" Cluj Napoca, Romania

Physics

Image courtesy of Mpfiz/Wikimedia

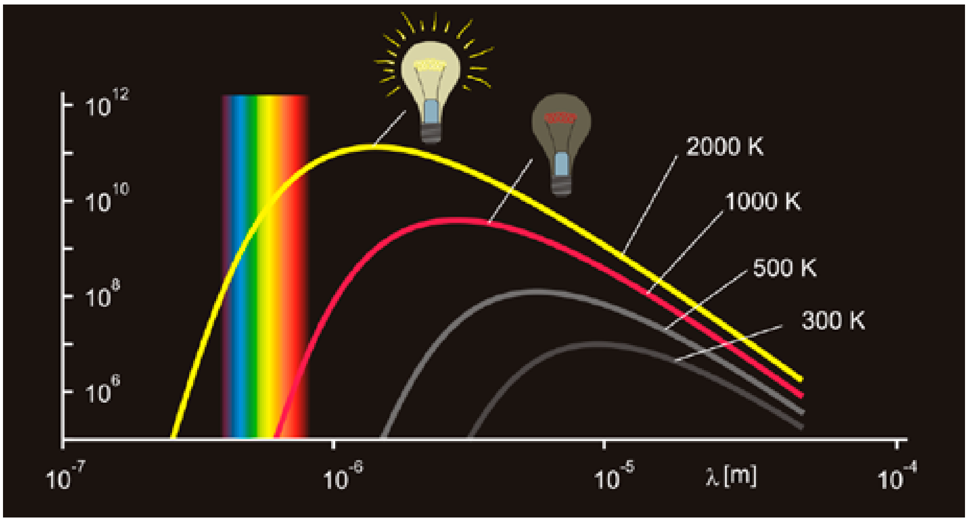


Figure 2: Spectra of a black body at different temperatures

an incandescent lamp. The filament behaves like a black body, a subject studied by physicists that represents a milestone in the history of modern physics.

Black body radiation

By the late 19th century, scientists knew that bodies would glow when heated and that their colour would depend not on their material but on their temperature. But physicists could not find a model that described the radiation emitted by a black body, a perfect physical entity that reflects all the electromagnetic radiation that strikes it, regardless of its incoming direction or frequency.

The intensity and colour of the light emitted by a body could be explained by the Stefan–Boltzmann and Wien's displacement laws, but a model that describes the spectrum emitted by a black body only appeared at the beginning of the 20th century. Published by the physicist Max Planck, it laid the foundations of quantum physics.

A black body emits a continuum spectrum of light, like those represented in figure 2. According to the Stefan–Boltzmann law (equation 1), the black body radiates energy at a rate that is proportional to the fourth power of its absolute temperature. In other words, the hotter the black body, the brighter it will shine:

$P = A\sigma T^4$ (1)

where P is the total power radiated by the black body, A its surface area, σ the Stefan–Boltzmann constant and T the absolute temperature.

Wien's displacement law (equation 2) states that the peak wavelength of the spectrum of emitted light is inversely proportional to the absolute temperature. In other words, when a black body is heated, the radiation emitted with higher intensity is displaced to shorter wavelengths (red, orange, yellow, and so on):

$\lambda_{max} = b / T$ (2)

where λ_{max} is the wavelength of maximum intensity, T the absolute temperature and b the Wien's displacement constant.

Incandescent lamp and its tungsten filament

Image courtesy of Dickbauch/Wikimedia

A lamp's filament at 2000 K, so not very hot, will shine a reddish light because the visible light it emits is mainly longer wavelengths. At 3000 K, the filament will not only shine brighter but also emit a yellow light, because the light now has shorter wavelengths (figure 2).

The Stefan–Boltzmann and Wien's displacement laws that explain the filament's behaviour, and their mathematical equations, are studied by secondary school students (15 years and older), but they can be demonstrated to the general public and even to young children with something as simple as a light bulb. The lamp's filament is a cheap, safe and accessible black body, whose temperature – and, therefore, emitted light – can be controlled.

The incandescent lamp

For many years, incandescent light bulbs were the most common lamps used in our homes. The tungsten filament, which is heated to incandesce

Image courtesy of Carla Isabel Ribeiro

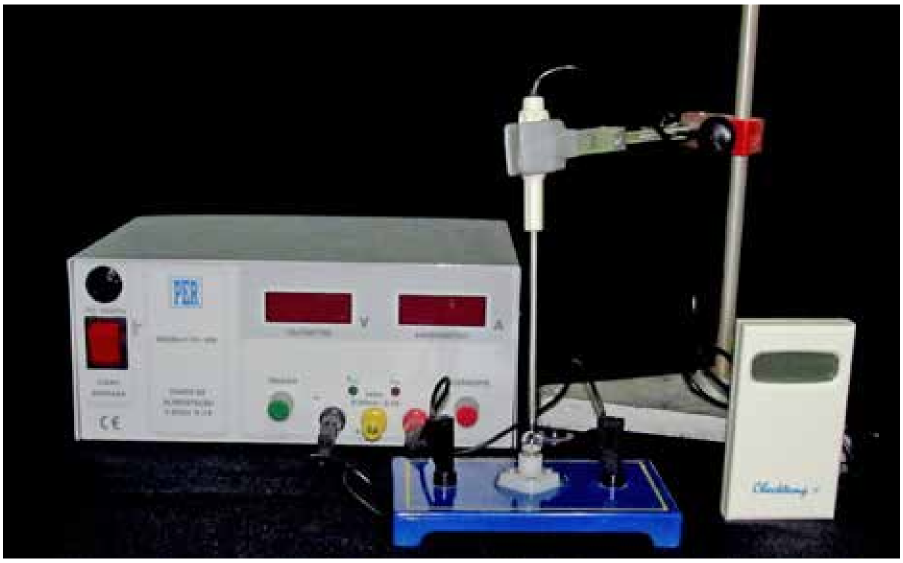


Figure 3: Set-up of the experiment

Image courtesy of Carla Isabel Ribeiro

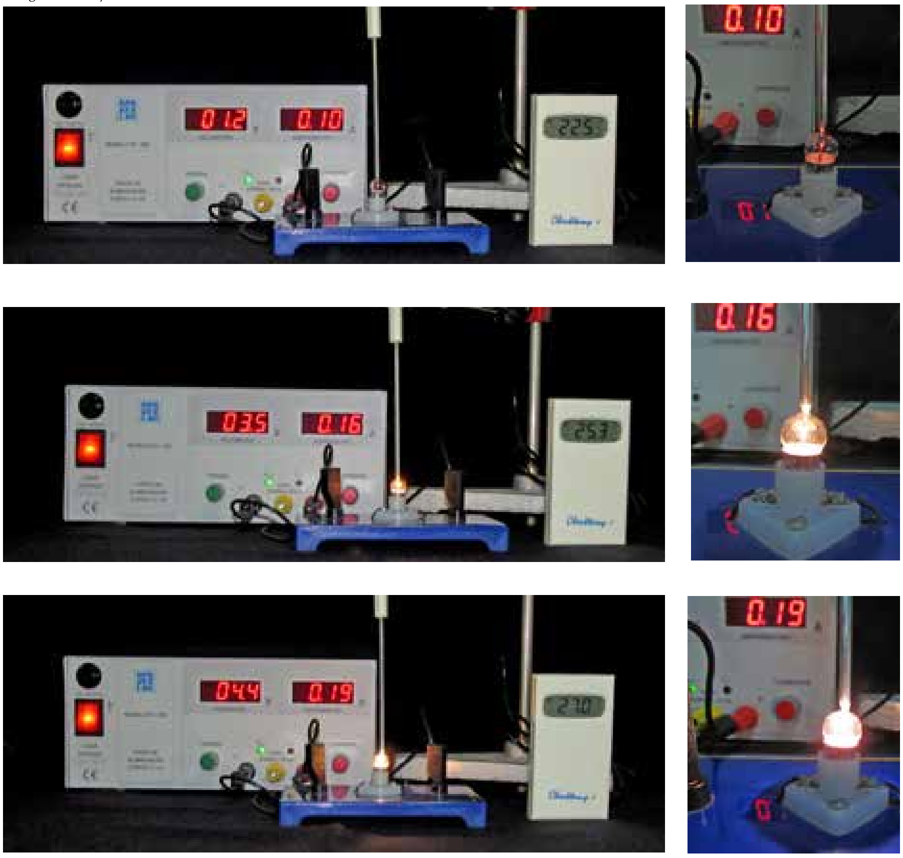


Figure 4: The experiment showing how the temperature (measured by the thermometer on the right) increases as the voltage increases.

by an electric current, is responsible for the light emitted. Tungsten is used because it has a high melting point of 3695 K (3422 °C).

The electric power (P_e) input to the lamp depends on the voltage (V) and the electric current (I) according to Ohm's law:

$P_e = IV$ (3)

If we assume that all the electric power (equation 3) is radiated by the filament (equation 1) and that the filament behaves like a perfect black body, then we can vary the filament's temperature, and the light it emits, by controlling its voltage and electric current :

$IV = A\sigma T^4$ (4)

Image courtesy of Carla Isabel Ribeiro

Light bulbs with the glass bulbs at 22.5 °C, 24.0 °C, 25.3 °C, 26.7 °C and 27.0 °C

Measuring the temperature of a black body

Materials

The experiment requires only a 3.5 V light bulb and a variable direct current energy supply (or a battery and a rheostat), and a digital thermometer.

Procedure

The increase in the filament's temperature can be inferred by the glass bulb's temperature, measured by a thermometer. The experimental set-up is simple : the lamp is connected to the variable DC energy supply and a digital thermometer is placed so it touches the lamp's bulb (figure 3).

Gradually increase the voltage, observe the colour and intensity of the light emitted by the lamp, and measure the bulb's temperature (figure 4). Try to avoid a completely dark room so that staring at the lamp is not uncomfortable.

About what happens

As the voltage increases, so does the temperature of the filament and bulb. The colour and intensity of the light also changes.

Starting at a low voltage, the lamp shines a dim red light. As the voltage and the filament's temperature increase, the light becomes more intense and changes colour: from red to orange, yellow and then white.

Although the filament can reach temperatures of up to ~3000 °C, it is too small to release much heat so the bulb itself has a low temperature. Nonetheless, it's possible to infer that red light is related to a lower filament temperature and that orange, yellow and white light is linked to increasingly higher temperatures. The filament cannot reach the temperature required to emit blue light; the metal would simply melt.

Based only on this experiment, it's possible to deduce that the surface of the stars Betelgeuse and Aldebaran (red / orange) are colder than the Sun (yellow) and that Sirius (white / blue) is hotter than all of them. And, although it could not be shown using the incandescent lamp, Rigel (blue) is the hottest of all the stars described here.

The stars' surfaces can reach higher temperatures than the tungsten filament, so their colour range is greater. This is represented by the Hertzsprung-Russell (H-R) diagram (figure 5), which plots the stars' temperature against their luminosity. Our experimental results are consistent with the temperature information

The heated metal of a blacksmith also acts like a black body.

Image courtesy of Jeff Kubina /Wikimedia

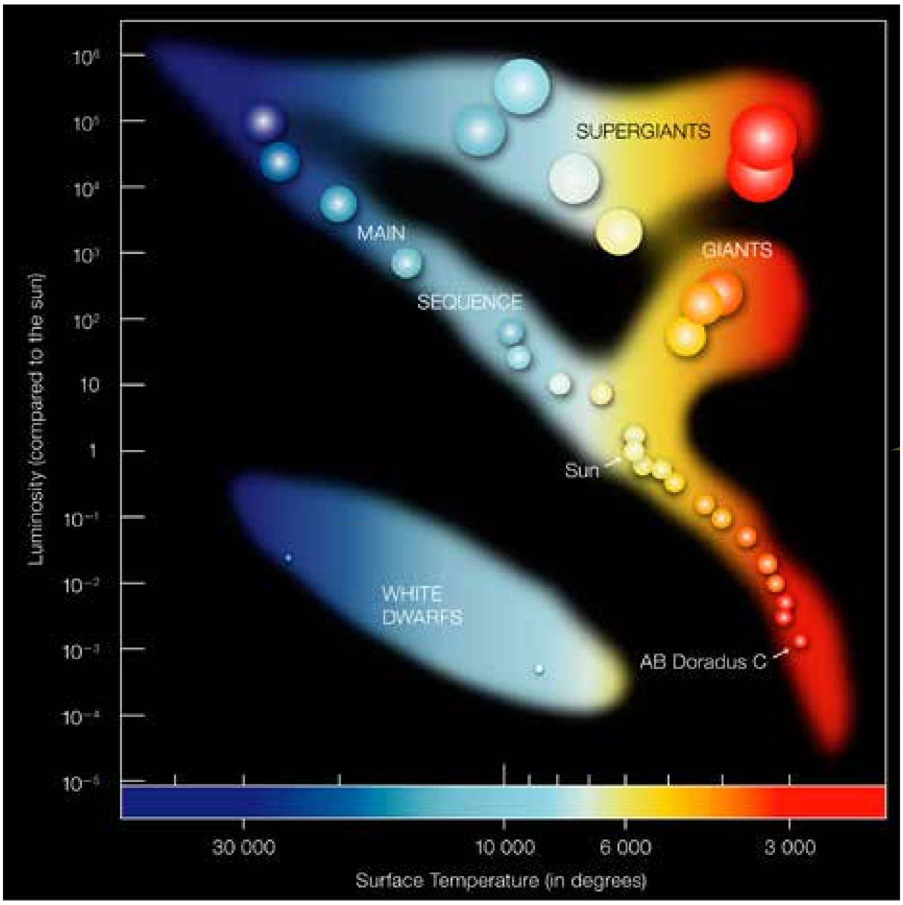


Image courtesy of ESO/Wikimedia

Figure 5: The Hertzsprung–Russell diagram plots the temperaure of the stars against their luminosity.

in this diagram: unlike the convention for water taps, which marks hot water with red and cold water with blue, a red star is much colder than a blue star. Although it seems to contradict the Stefan–Boltzmann law, the brightest stars are not always the hottest due to their size (a white dwarf is hotter than the Sun, but because it is much smaller, it does not shine as brightly).

We do not see any green stars because of how we interpret light[w1]. A star that emits mainly green light also emits red and blue light, and the sum of all the visible radiation emitted is perceived by our brains as white light.

Other incandescent bodies

Stars and incandescent lamps are not the only examples of objects that shine because they are hot. Lava and heated metal worked by a blacksmith are other, albeit less common, examples of incandescent bodies. Like the lamp's filament, they glow because they are hot; they emit red light when their temperature is lower and yellow/orange light when it is higher.

Light sources and colour temperature

Remember, the light emitted by a light source does not always indicate its temperature. A simple example is the fluorescent lamps in our homes.

Whereas the filament of the incandescent light bulb is about 2700 K (figure 6), fluorescent lamps are much colder (and energy efficient). The mechanism that produces the light in fluorescent bulbs is different, so the colour and temperature of these light sources are not linked in the same way.

It's possible to differentiate incandescent and fluorescent lamps by their light spectrum by using an object as simple as a DVD to act as a diffraction grating. The light from an incandescent object has a continuous spectrum whereas the other sources of light do not. So, if the spectrum is discontinuous, then the rule that links temperature and light colour does not apply.

Web reference

w1 – Understand why there are no green or purple stars by watching a short video on the How Stuff Works website: http://videos.howstuffworks.com/nasa/5329-why-arent-there-green-or-purple-stars-video.htm

Resources

Learn more about the night sky and how astronomers investigate the life cycle of stars:

Mignone C, Barnes R (2014) More than meets the eye: how space telescopes see beyond the rainbow.

Images courtesy of Carla Isabel Ribeiro and Reguiieee/Wikimedia

Continuous spectrum of a fluorescent lamp split by a CD

Science in School **29**: 49–54. www.scienceinschool.org/2014/issue29/EM_Astronomy

Learn how to build your own spectrometer:

Westra, MT (2007) A fresh look at light: build your own spectrometer **4**, 30 – 34. www.scienceinschool.org/2007/issue4/spectrometer

For a step-by-step lesson plan on how to calculate the temperature of stars based on their emission spectra, read: Olivetto C. et al. (2014) Camping under the stars – the ESO Astronomy Camp 2013 *Science in School* **30** 8–15 www.scienceinschool.org/2014/issue30/ESOcamp

Read more about how living creatures produce their own light of different colours in this *Science in School* article on chemiluminescence:

Welsh, E (2011) What is chemiluminescence?, *Science in School*, **19**, 62–68 www.scienceinschool.org/2011/issue19/chemiluminescence

Max Planck was a German theoretical physicist best known for devising Planck's constant, as part of his work on black body radiation. Learn more about Planck's constant, including a method to determine it yourself:
de Amorim e Sá Ferreira André MR, de Brito André PS (2014) Classroom fundamentals: measuring the Planck constant. *Science in School* **28**: 28–33. www.scienceinschool.org/2014/issue28/planck

Carla Isabel Ribeiro teaches chemistry and physics at a public Portuguese school, to students ranging in age from 13 to 18, and is particularly interested in astronomy.

Coding without computers

Programmes don't need a computer – turn your students into coders and robots with just pens, paper and a stack of cups.

By Thinkersmith

Coding and computer science are becoming important parts of the curriculum and the scientific world, but many of their principles can be explored without the need for computers. Using a predefined 'robot vocabulary', your students will figure out how to guide one another to accomplish specific tasks without discussing them first.

This activity teaches students the connection between symbols and actions, as well as the valuable skill of debugging. If time allows, there is an option to introduce functions at the end of the lesson.

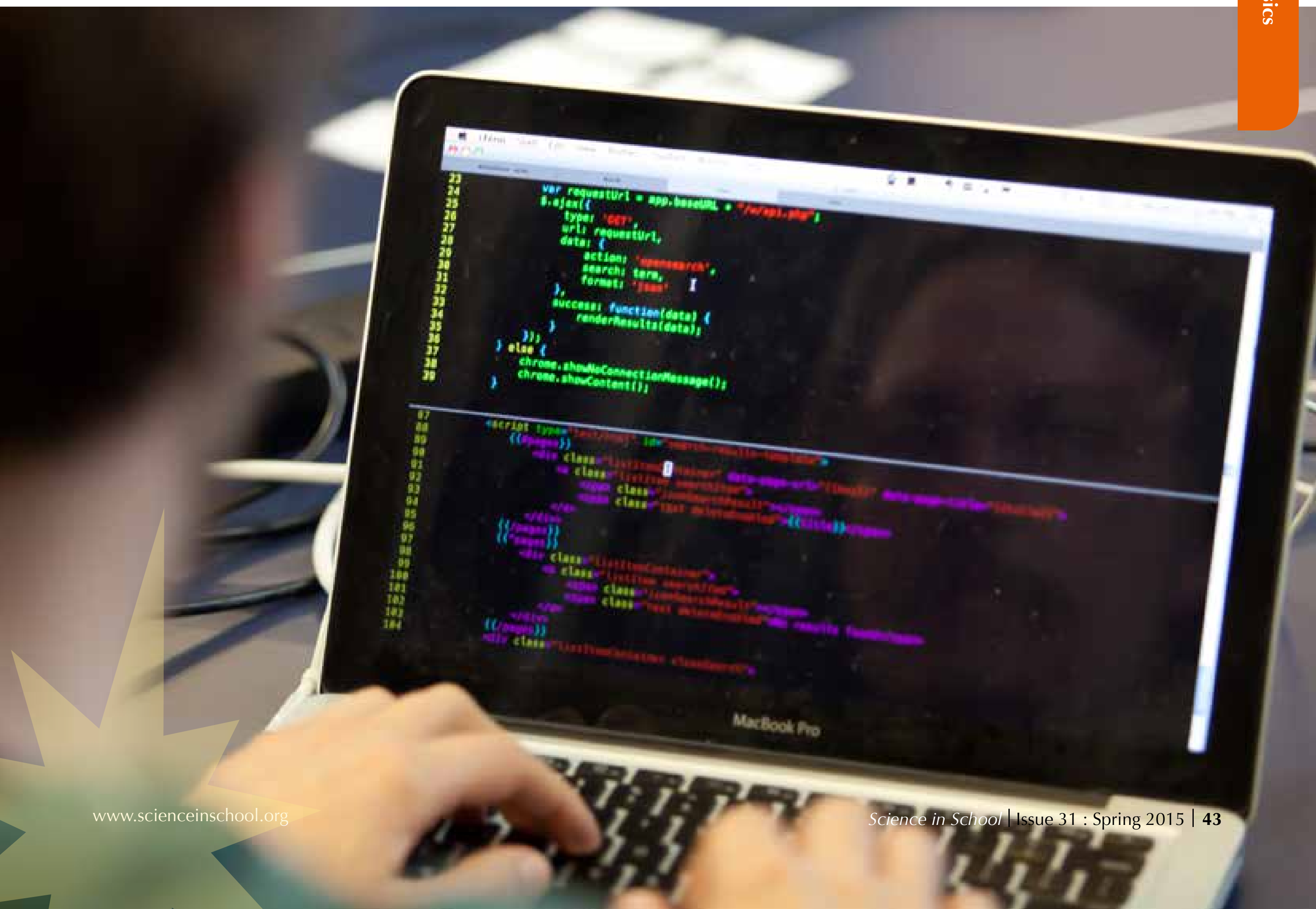
Programming a robot

Start by asking the class if anyone has heard of robotics. Has anyone seen a robot or touched one? Does a robot really 'hear' you speak? Does it really 'understand' what you say? The answer to the latter question is: "Not in the same way as a person does."

Robots operate using instructions:

Learning code doesn't have to look like this

Image courtesy of Almonroth/Wikimedia Commons



specific sets of things that they have been pre-programmed to do. To accomplish a task, a robot needs to have a series of instructions (sometimes called an algorithm) that it can follow. This activity teaches the students what it takes to make that happen.

Materials

- symbol key (1 per team)[w1]
- cup stack cards (1 set per team)[w1]
- disposable cups (6 or more per team)
- blank paper (1 per person)
- a pen or pencil (1 per person)

Procedure

Pull out a copy of the symbol key or write the symbols on the board (figure 1). These are the only six symbols that the students will use for this activity. For this task, they will instruct their robot to build a specific cup stack using only these arrows.

First work through an example with the class. Show them the stack of cups illustrated in figure 2. Place your cups on the table where everyone can see them. Ask the class to give you the first instruction to create this stack. The correct answer is "pick up a cup". When you pick up each cup, note that you should lift the cup above the highest cup already in the stack.

Image courtesy of Thinkersmith

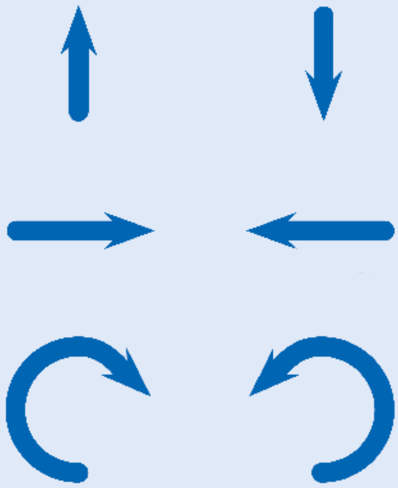


Figure 1: Symbol key

Figure 2: The three-cup stack

With your hand still in the air, ask for the next move. You may have to remind the class that one step forward is only half the width of a cup (see figure 3).

Once you've placed a single cup ask the class to help you write the symbols on the board so that you can 'run the program' later.

1. Split class into teams (see Adjustments box for ideal sizes).
2. Each team should choose one 'robot'. Send the robots to the 'robot library' in another part of the classroom while the 'programmers' start coding. Robots can use their time in the library to practice cup stacking and make sure they understand the rules.
3. Choose the cup stack cards for each team.
4. Each team should create an algorithm for the robot to build the selected stack.
5. The teams should then translate their algorithm into arrows, as described in the symbol key. The programmers should review their code to see if it makes sense.
6. When the programmers have finished coding the creation of their cup stack, they can retrieve their robot.

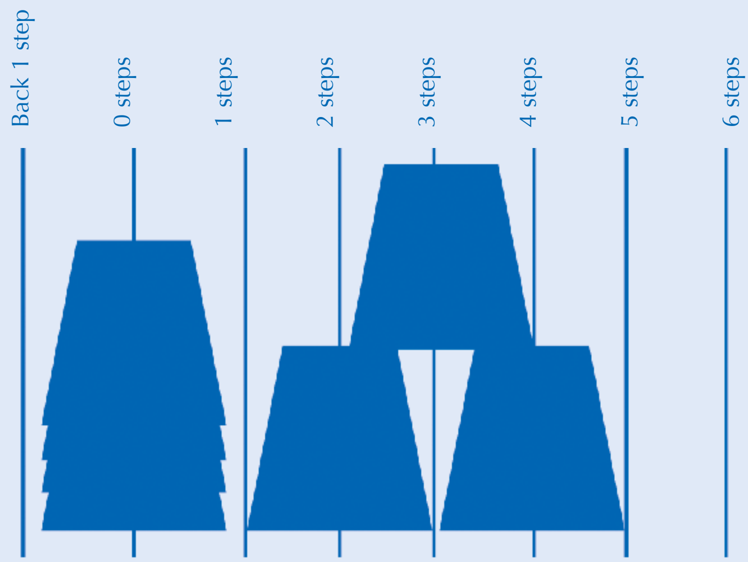


Figure 3: How to build the three-cup stack

Image courtesy of Thinkersmith

Adjustments:

For primary school classes

- Try this lesson together as one class. Let the students call out directions for the teacher to write down.
- If you have a classroom assistant, he or she can leave the room during programming, then return to perform the finished code.
- If there is time, swap roles so that the class assistant writes the instructions from the class and the teacher performs them.

For students aged 11–14 years old

- Keep team sizes between three and five students, depending on the personality of the students.
- Expect each student to want a turn, which will likely use the entire hour.

For students aged 14+ years old

- Limit teams to a maximum of four students, although groups of three are ideal.
- Once each student has been the robot there is usually still time for the activity on functions.

BACKGROUND

Image courtesy of Mastalroh/Wikimedia Commons

7. Once the robot returns, everyone in the team should remain silent. The robot reads the symbols from the cards and translates them back into movements.
8. If there is a mistake in their code, the team can halt the programme and send the robot away before debugging their programme and asking the robot to re-run it.

Each time a team solves a challenge, the team members should choose a new robot to send to the library, and the team should be given a new (preferably more difficult) cup stack card.

Optional: Functions

Often, during this activity, students begin to write a shortened version of the instructions using numbers. For example →x5 instead of →→→→→.

Discourage this practice, and remind students to stick only to the six symbols they are allowed. In the following activity, however, you can recognise the brilliance and foresight of students who tried that trick, and acknowledge that they independently discovered the need for functions.

An arrow with numbers is a clever way of indicating that we want to repeat a movement a specific number of times. By allowing repetition, we are essentially creating a new symbol to avoid re-using code unnecessarily. This is exactly the idea behind functions. Your students may come up with other shortcuts and functions.

Now that the class has these new functions, let them tackle one of the more challenging cup stack cards. Teams may work together if they need more cups to work with.

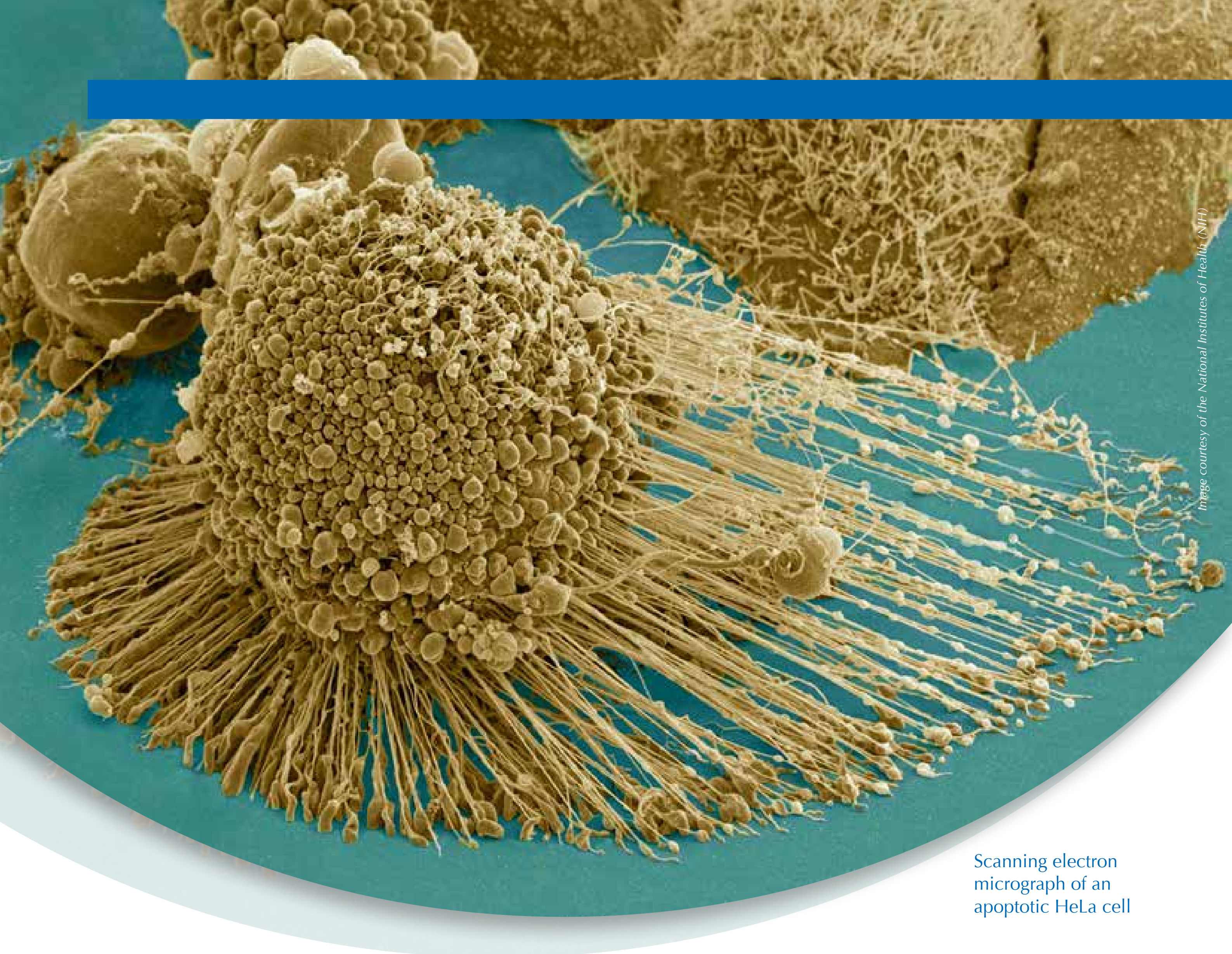
Physics

Web references

w1 – The symbol key and cup stack cards are available to download from the article page on the *Science in School* website: www.scienceinschool.org/2015/issue31/coding

w2 – More classroom activities are available from the Thinkersmith website: www.Thinkersmith.org

w3 – The lesson plan and accompanying video can be found at the Computer Science Education Week website at: http://csedweek.org/unplugged/thinkersmith



Scanning electron micrograph of an apoptotic HeLa cell

Cell spotting – let's fight cancer together!

"Tell me and I forget, teach me and I may remember, involve me and I learn," Benjamin Franklin once said. Make that quote yours and involve your students in a real cancer-research project that will teach them more than just genetics and cell death.

By António J Monteiro, Cândida G Silva and José C Villar

Efficient cancer drugs need to selectively destroy tumour cells without harming healthy cells. Existing chemotherapy treatments have failed to reach that ideal level of selectivity, but many research teams continue to look for compounds that

BACKGROUND

HeLa cells

HeLa cells are a special human cell line. They originate from a woman called Henrietta Lacks, who died from cervical cancer in 1951. Her doctor took some cells from her tumour and managed to grow them in a culture medium, developing the first human cell line. HeLa cells are the most widely used human cells in biology labs across the world.

could become the effective and side-effect-free drugs of tomorrow.

The search for suitable compounds is performed primarily by robotic systems that quickly test and identify millions of candidate chemical compounds: they put cancer cells together with potential drugs and observe whether the cells die or survive. Such experiments generate thousands or even millions of cell images that then need to be analysed according to several parameters – such as the cell's status, the release of cellular content, the distribution of the mitochondria, or the shape of the nucleus – and classified to determine the cell's response to each potential drug. The ideal solution to treat this huge amount of data would be to use computers. However, they are not good enough to recognise patterns: nothing beats the human eye for that task (Lostal et al, 2013a; 2013b)!

That is where you and your class step in. Researchers need help from as many volunteers as possible to support them with image analysis and to identify potential new drugs against cancer as rapidly as possible. Your students will learn about cell death by helping scientists to characterise the response of HeLa cells to different chemical compounds.

The Cell Spotting project

The Cell Spotting team is testing more than 14 000 chemical compounds in HeLa cells and observing their reaction using advanced optical microscopy techniques. HeLa cell cultures are being photographed every half hour in three different channels: normal light, blue and green fluorescence (Lostal et al, 2013a; 2013b). The normal light reveals the global shape of the cell membranes; the blue fluorescent channel is specifically for the observation of the cell nuclei (they are dyed with the fluorochrome Hoechst 33342, which emits blue light when bound to DNA); and the green light is for the observation of the cells' mitochondria (which are dyed with the fluorochrome Mitotracker). By combining data acquired from the three channels, the scientists can generate images that contain detailed information about these three elements of the cells' structure and also videos that show cell movements, division and death over time. More than 4000 images are taken per day and about 14 112 images are produced in a single experiment.

REVIEW

- Biology
- Technology
- Ages 14–18

This article describes a student-centred activity that introduces the concept of efficient cancer drugs and how different compounds are tested to see if they are effective in killing cancer cells. Students are then led through an exercise in which they learn about HeLa cells and how these are cultured with isolated compounds to test the effect of that compound on cancer cells. They also learn about cell apoptosis and cell necrosis through visual examples.

Students are then introduced to the Cell Spotting research project, which allows participants to analyse cells and contribute to the project by uploading their analyses.

Each step of the project is supported by clear instructions and explanatory notes to help students use their knowledge and contribute to the project.

Dr Shaista Shirazi, UK

Biology

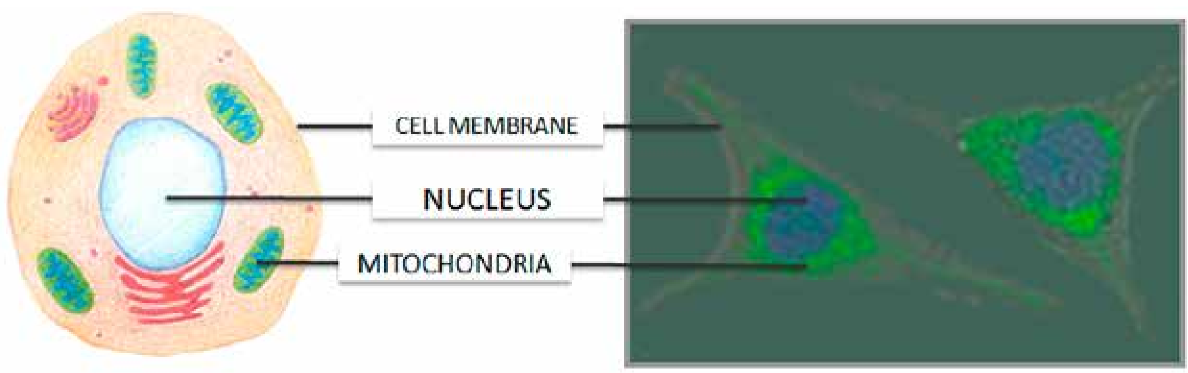


Image courtesy of SCIENTIZE

Figure 1. Comparison of an animal cell representation with a HeLa cell image

Spot cells and help fight cancer from your classroom

This activity is designed to be implemented in biology courses for students aged between 14 and 18 years old, however you can also adapt it for other groups. It explores themes such as cell division, cell death, genetic regulation, cancer and biotechnology.

The activity is divided into two parts:

A) Explore the Cell Spotting research project and understand its context, and

B) Play with the Cell Spotting application.

Materials

The resources available for this activity are:

- a video[w1] that puts the Cell Spotting research project into context
- a didactic unit[w2] that provides a potential lesson plan and activities to do with students
- a teacher's package[w3] that contains a detailed document about the research, a PowerPoint presentation and three short clips about HeLa cells.

Procedure

A) Explore the Cell Spotting research project and understand its context.

In the first part of the activity, students should use enquiry-based thinking to learn about the research project and its methodology.

1) Watch the video[w1] 'Socientize: Cell Images Experiment' to place the activity into the right context.
2) Go through the didactic unit[w2] and find the answers to the following questions:
   a) What is José Villar doing in his research?
   b) What type of cells is he using?
   c) What methodology is he using to observe the cells?
   d) What results can he expect from different chemical compounds?
   e) What type of cell death does José Villar want to induce in cells? Why?

At this stage, it may be useful to build a simple diagram like the one shown in figure 2:

3) Show your students how to differentiate between apoptosis and necrosis and to identify healthy HeLa cells from dying cells:
   a) Ask your students to analyse figure 5 from the didactic unit and to build a table similar to table 1 to summarise the main morphological differences between the two types of death: cell volume differences, nucleus condensation and final reaction.
   b) Watch the three short clips showing HeLa cells in different states (healthy, in apoptosis, in necrosis) from the teacher's package. Ask students to identify which cell state is represented in each short clip based on the morphological differences.

Now your students are ready to help José identify HeLa cell images!

B) Play with the Cell Spotting application.

The Cell Spotting application[w4] allows you and your students to analyse HeLa cell images and send your analysis to the research team. The application interface is very intuitive, user-friendly and self-contained, so everybody can easily access and

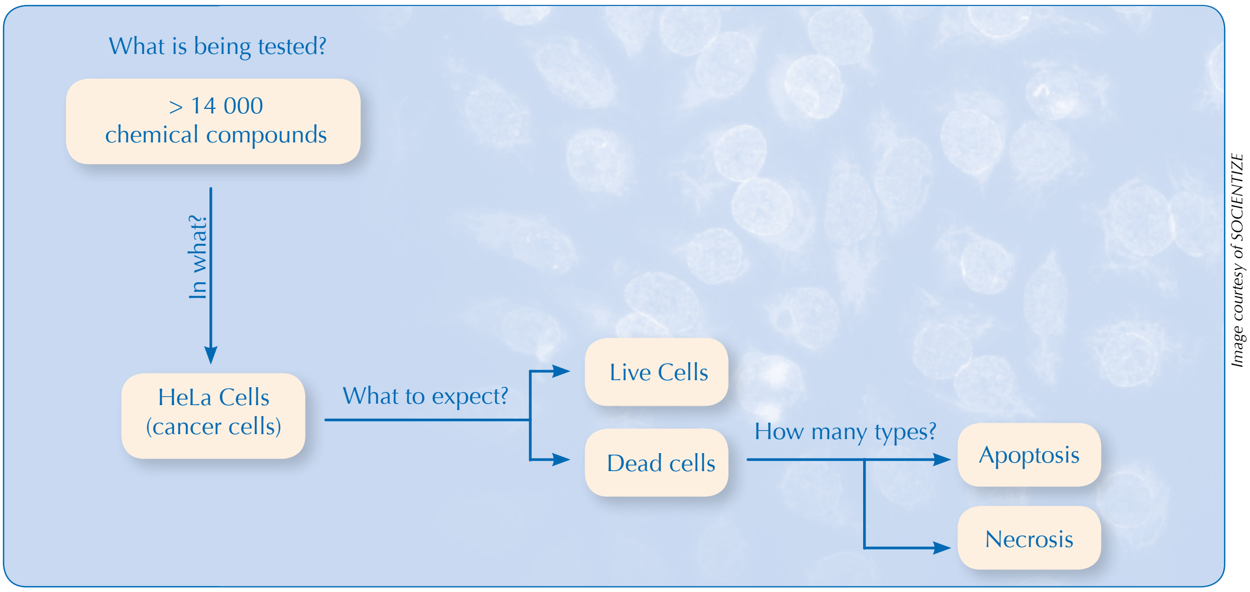


Figure 2. Example of a diagram to explore the Cell Spotting experiment

Image courtesy of SOCIENTIZE

	Apoptosis	Necrosis
Cell volume	Decrease	Increase
Cell nucleus	Fragmentation after condensation	Volume increase
Content release	No (formation of apoptotic bodies)	Yes
Inflammatory response	No	Yes

Table 1. Example of a table summarising the main morphological differences between apoptosis and necrosis

contribute. When you access the application for the first time, we recommend that you follow the tutorial that explains its structure, objectives and resources. This will ensure that you have all the necessary details before you log in and start spotting and tagging cells with specific stamps.

To complete each task, you need to analyse the same image according to four parameters:

- Current cell status (dead or alive)
- Cell content release (whether the cell releases material or not)
- Mitochondria distribution (whether the mitochondria are clustered or scattered inside the cell)
- Other remarks (e.g. multinucleated cell, abnormal sized cells and nuclei)

1) Ask your students to log in the application and register so their contributions do not remain anonymous.
2) Explore the application with your students and define exactly what they should do. If you have a projector, this can easily be achieved by doing a cell image analysis together while projecting it on a wall.

   In a nutshell, the application includes:

   - the blue bar (see A on the image) on the top, which summarises what you need to do and the resources to achieve that task, including:

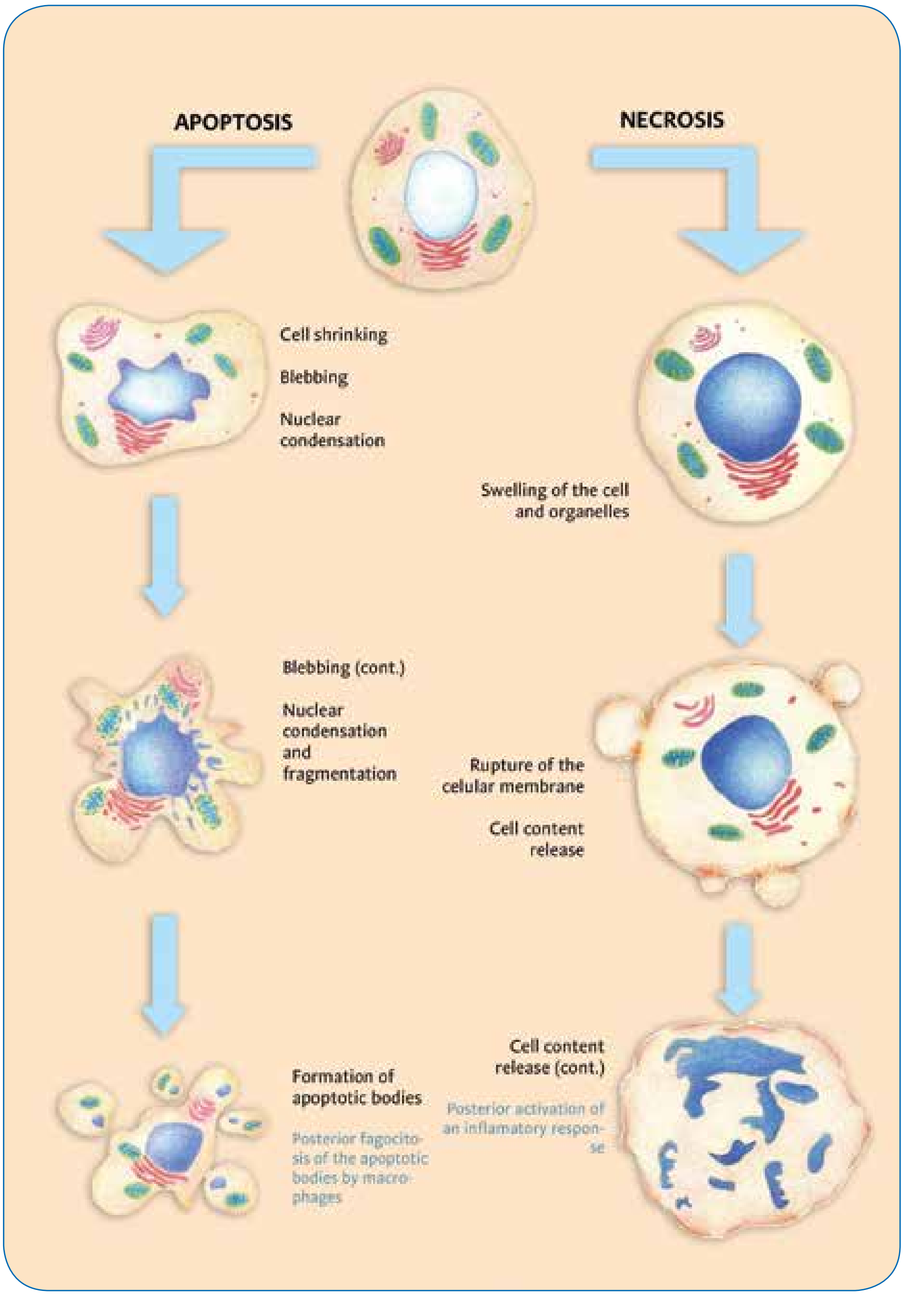
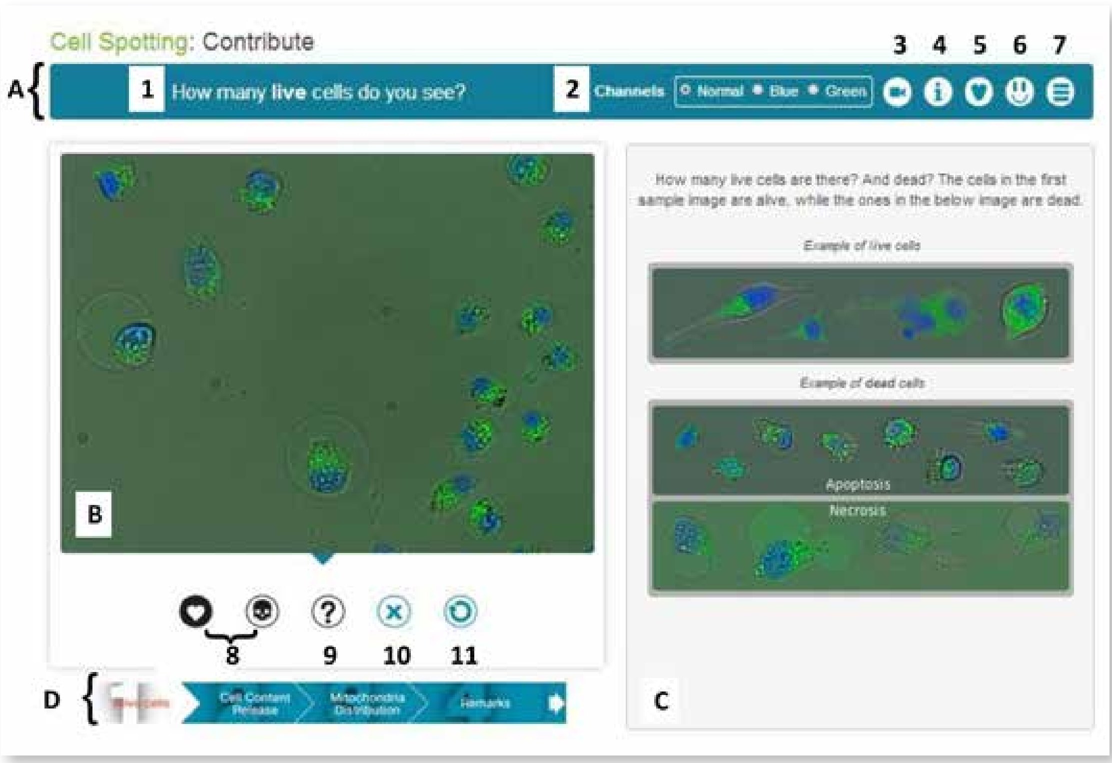


Image courtesy of Juliana Bortoletto

Figure 3. Representation of cell death: apoptosis and necrosis

Image courtesy of SOCIENTIZE



Representation of cell death: apoptosis and necrosis

Figure 4. Cell Spotting application

- the specific question that you need to answer
- the three different light channels that you can use to visualise specific details on the image: blue to visualise the nucleus; green to view mitochondria; and normal, which is a result of the blue, green and bright white field images merged
- the video from which each image was extracted
- additional information on each step
- access to Vish, the Virtual Science Hub, an educational platform where you can virtually visit the lab where Cell Spotting takes place
- a feedback survey
- a direct link to the didactic unit

The image awaiting analysis is in box B (in figure 4). Below it you can find the various stamps to tag the cells and identify their state (see point 8 on Fig. 4). You can also remove the tags individually (see point 10 on Fig. 4) or start over (see point 11 on Fig. 4). If you are not sure how to classify the cells, you can use a specific tag with a question mark (see point 9 on Fig. 4).

Box C provides you with a set of examples of the patterns that need to be identified.

Finally, below the image for analysis, you will find a progress bar with the four parameters that you need to complete for each task (see box D in figure 4). Every time you finish analysing a parameter, you must click on the arrow to the right of the progress bar so you can move to the next parameter. When the four parameters have been analysed, an icon will appear so you can finish the task. After that, a new image will automatically appear and you can start the analysis all over.

NOTE: A guide to get started with Cell Spotting is available in the teacher's package. The analysis is very simple and your students will probably do it easily.

3) Let your students play with the programme and contribute freely. Let them know that they can also log in from home.

References

Lostal E, Serrano F, Carrodeguas JA, Martínez P, Sanz F, Val C (2013a) Cell Images Analysis as a Case of Citizen Science for Advanced Education: Laboratory and School, Back and Forth. In *Proceedings of the 7th International Technology, Education and Development Conference (INTED 2013)* pp 2489–2496. Valencia, Spain: IATED

Lostal E, Serrano F, Carrodeguas JA, Martínez P, Sanz F, Val C (2013b) A case of Citizen Science for Cell Biology Images Analysis. In *Proceedings of the XXXIII Congresso da Sociedade Brasileira de Computação (CSBC 2013)* pp 1855–1862. Maceió, Brazil: CSBC

Web references

w1 – Watch the 'Socientize: Cell Images Experiment' video on Ibercivis Ciencia's YouTube channel:

- in English: http://youtu.be/XXegth8CmM4
- in Portuguese: http://youtu.be/OGTITEp-ybI

w2 – Download the didactic unit for the Cell Spotting activity:

- in English: www.ibercivis.net/?p=6985
- in Spanish: www.ibercivis.net/?p=6987
- in Portuguese: www.ibercivis.net/?p=6989

w3 – The teachers' package for the Cell Spotting activity contains a detailed document about the research, the Cell Spotting guide, a version of the didactic unit with solutions, and three short videos of different health states of Hela cells. You can download it here:

- in English: http://bit.do/ibercivis_teacherspackage
- in Portuguese: www.ibercivis.net/?p=6993

w4 – To access the Cell Spotting application and start playing, visit the Socientize website: https://pybossa.socientize.eu/pybossa/app/cellspotting/

Resources

Find out more about the EU-funded project Socientize from its official website: www.socientize.eu. You will also find other citizen science projects that you can get involved in.

To keep track of citizen science projects promoted by Socientize, consult the official website of the Ibercivis project: www.ibercivis.com

For another cancer-related teaching activity, see:

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

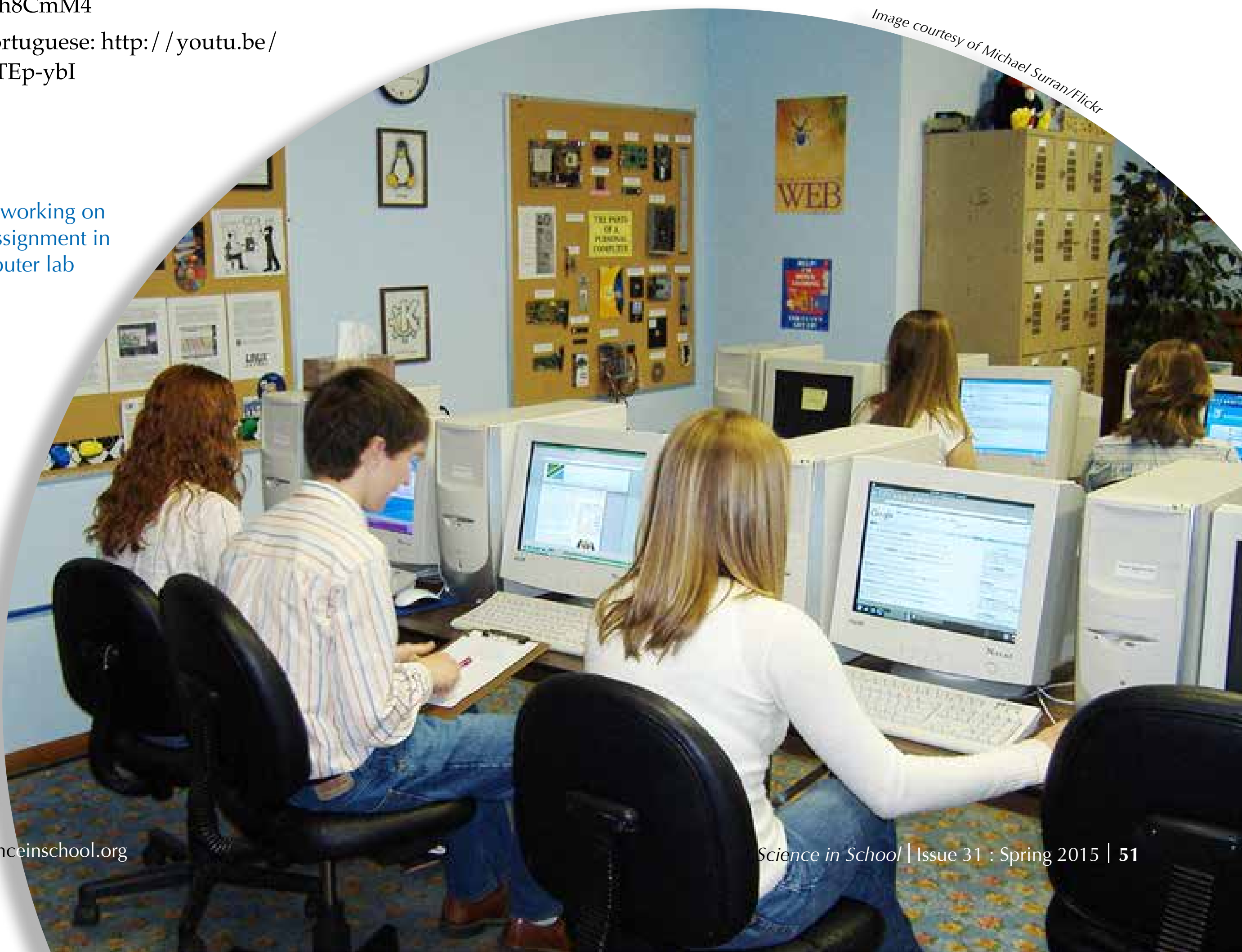


Image courtesy of Michael Surran/Flickr

Students working on a class assignment in the computer lab

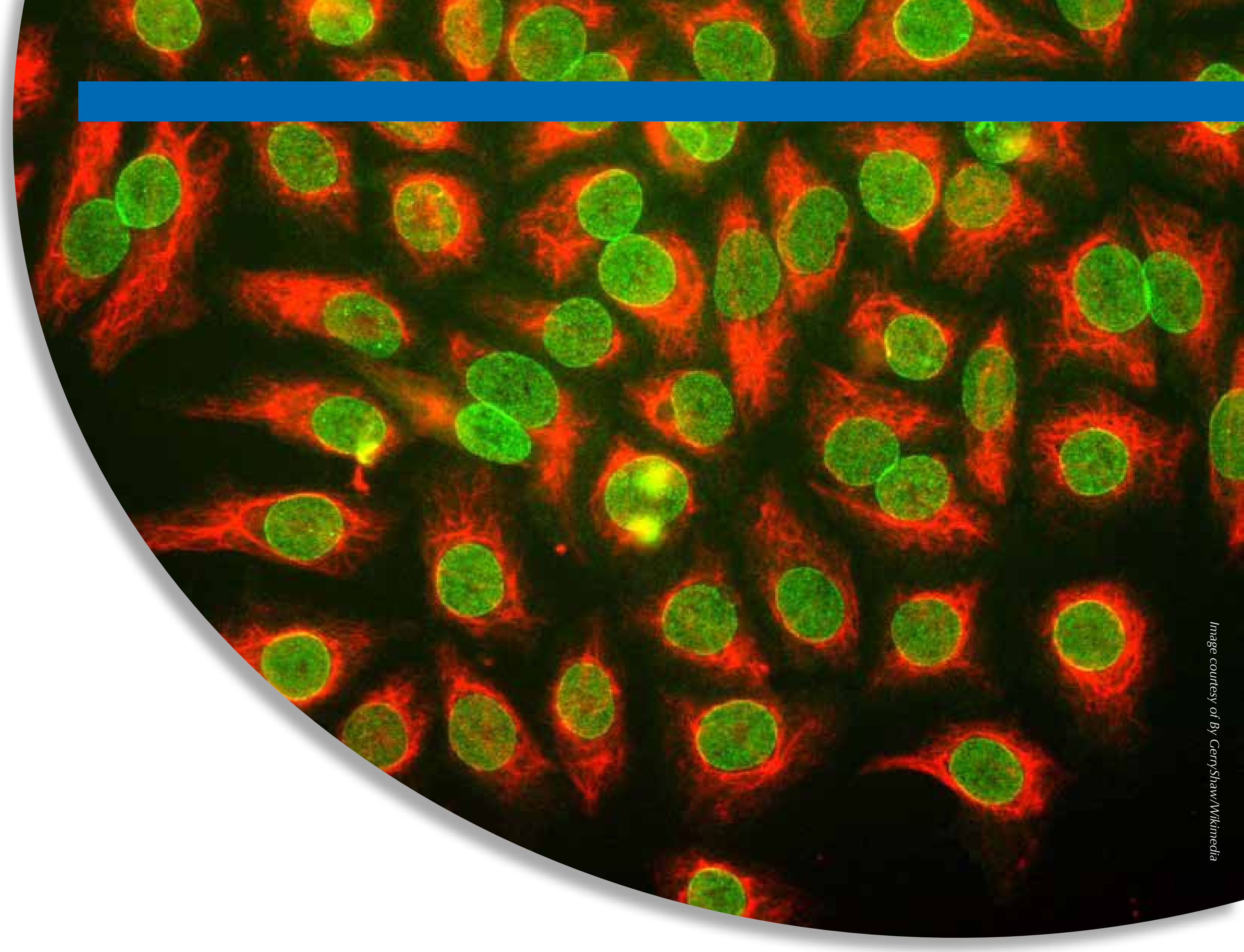


Image courtesy of By GerryShaw/Wikimedia

HeLa cells grown in tissue culture. Red: cytoskeleton; green: nucleus

António Monteiro is a biologist with an MSc in biology and geology teaching. He is actively involved in the citizen science FP7 project 'Socientize – Society as e-Infrastructure through technology, innovation and creativity'. He has worked for the Science Museum of the University of Coimbra in Portugal since 2009 as an exhibition guide and education developer of science activities, mainly for the Researchers Night. He is also involved in promoting the museum via social media.

Cândida G Silva holds a degree in mathematics and computer sciences and a PhD in chemoinformatics. During the past four years, she has been an active collaborator of two citizen science and volunteer computing projects: ibercivis.net and socientize.eu. Her current scientific interests focus on machine learning, data mining, drug discovery, citizen science, e-science, volunteer computing and data warehousing.

José Carrodeguas Villar, PhD, is a researcher at the Institute for Biocomputation and Physics of Complex Systems (BIFI) at the University of Zaragoza in Spain. He leads a research group focused on the study of apoptosis in cancer, the immune system, nervous system and other systems. He is also the principal researcher of the Cell Spotting experiment and is actively involved with citizen science projects and activities at Socientize and Ibercivis.

This is an activity proposed by Socientize, a project funded by the European Union Seventh Framework Programme under contract RI-312902.

Publisher: EIROforum, www.eiroforum.org

Editor-in-chief : Dr Eleanor Hayes European Molecular Biology Laboratory, Germany

Co-editors: Isabelle Kling and Laura Howes, European Molecular Biology Laboratory, Germany

Copy editor: Dr Caroline Hadley

Composition: Nicola Graf, www.nicola-graf.com

Printers: ColorDruck solutions GmbH, Germany, www.colordruck.com

Web developer: Alexander Kubias, Alperion GmbH, Germany, www.alperion.de

ISSN:

Print version: 1818-0353

Online version: 1818-0361

Cover images:

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Girl: Image courtesy of the Royal Institution

Safety note

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

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

Unless the context dictates otherwise, it is assumed that:

- Practical work is carried out in a properly equipped and maintained science laboratory
- Any electrical equipment is properly maintained
- Care is taken with normal laboratory operations such as heating
- Good laboratory practice is observed when chemicals or living organisms are used
- Eye protection is worn whenever there is any recognised risk to the eyes
- Pupils and / or students are taught safe techniques for activities such as handling living organisms, hazardous materials and equipment.

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Science in School is a non-profit activity. Initially supported by the European Commission, it is now funded by EIROforum.

EIROforum

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CERN

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

EMBL

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

ESA

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

ESO

ESO is the foremost inter-governmental astronomy organisation in Europe and the world's most productive ground-based astronomical observatory by far. It operates telescopes at three sites in Chile – La Silla, Paranal and Chajnantor – on behalf of its member states. At Paranal, ESO's Very Large Telescope is the world's most advanced visible-light astronomical observatory. ESO is a major partner in the revolutionary astronomical telescope ALMA and is building the 39-metre European Extremely Large Telescope, the E-ELT. See: HYPERLINK "http://www.eso.org/" www.eso.org

ESRF

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

EUROfusion

The European Consortium for the Development of Fusion Energy (EUROfusion) comprises representations of 28 European member states as well as Switzerland and manages fusion research activities on behalf of Euratom. More than 40 European fusion laboratories collectively use the Joint European Torus (JET), which has remained the world's largest magnetic fusion device since it was built in 1983. Smaller national experiments in Germany, Switzerland, and the United Kingdom complement the experimental programme. The aim is to realise fusion electricity by 2050.

European XFEL

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

ILL

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ISSN: 1818-0353