Spring 2016 | Issue 35

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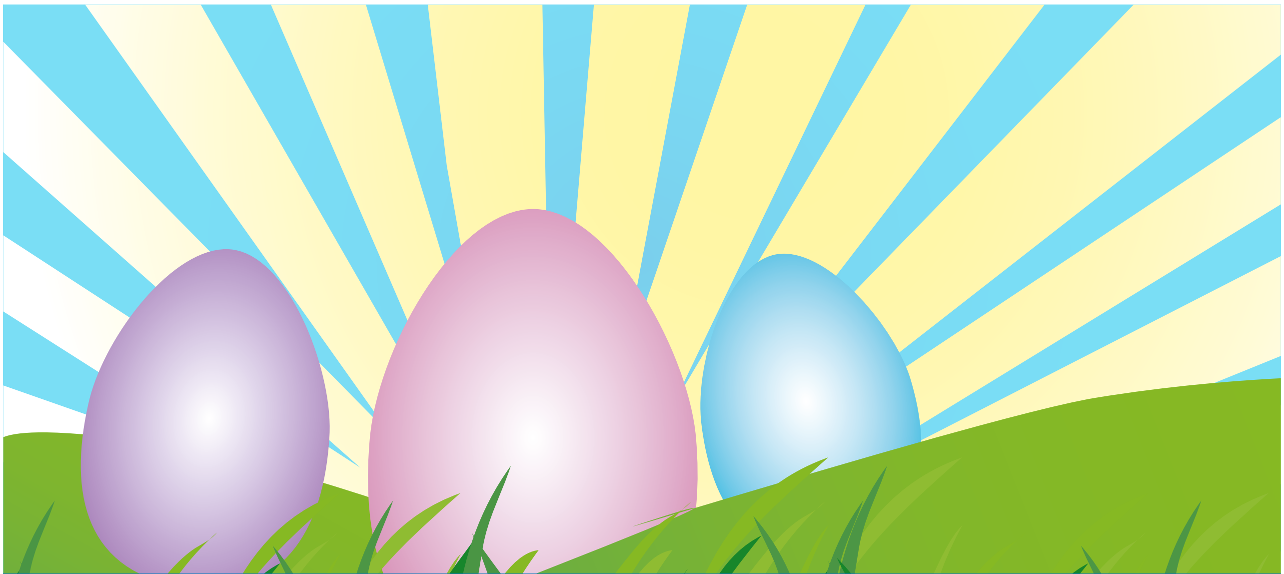

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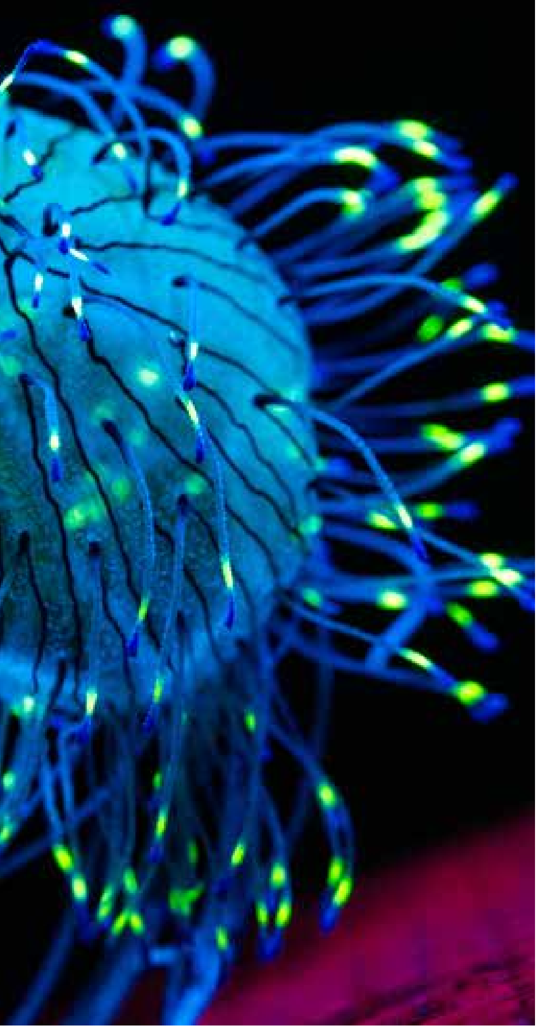

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EDITORIAL

Eleanor Hayes
Editor-in-chief of
Science in School

This issue marks a very special milestone for us: it's ten years since the first issue of *Science in School* was published. Putting together that first issue back in 2006 was enormous fun but at that point I couldn't have imagined what the journal would look like a decade later – or that I would still be leading it.

I well remember sourcing the articles for the first few issues. Teachers, scientists, colleagues, friends, people I met at the airport – I invited, encouraged and occasionally begged them all to contribute content. These days, although we still commission specific articles, we also receive many unsolicited – and often excellent – contributions. It's great to know that over the past ten years, so many scientists and teachers have learned about *Science in School* and now choose to share their ideas with us.

In a recent fit of nostalgia, I browsed our archive of articles, re-reading some of my favourites. I also looked to see which articles have been most popular with our online readers; you can see if your favourite articles made the 'top ten' list on page 25. The funders of *Science in School*, EIROforum, were also in a nostalgic mood and each of the eight research organisations that make up EIROforum has shared some scientific highlights of the past decade on page 21.

Science in School has seen a lot of changes in its first ten years. Not only has our online discussion forum made way for our social media channels, but we've also recently relaunched the website, redesigned the print journal and created a new e-newsletter.

For me, though, the most important change has been the growth of the *Science in School* team – and I don't just mean the editorial team. I mean you: our readers, authors, reviewers and translators. Over the past ten years, our small group of volunteers has grown into hundreds of enthusiastic teachers and scientists who help to make cutting-edge science and inspiring teaching ideas available to your colleagues across Europe and beyond.

One thing, however, has not changed: we welcome direct contact with you all. Which of our articles have you used in your lessons? How did you use them? Have you come across a topic you'd like us to cover? Would you like to share one of your own teaching ideas with our readers? Why not drop us an email and tell us?

Eleanor Hayes

Unpicking scientific mysteries across Europe

CERN
Boosting collision in restarted accelerator

After the successful restart and running of the Large Hadron Collider (LHC) with proton–proton collisions at 13 TeV in mid-2015, CERN collided lead nuclei at a new record energy of 5 TeV per nucleon during a one-month period from 17 November 2015. The experiments aimed at understanding and studying the properties of an extremely hot and dense state of matter consisting of fundamental particles, especially quarks and gluons. The collisions recreated – for an extremely short period of time – the conditions prevailing in the very early Universe about 1 millionth of a second after the Big Bang.

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 courtesy of CERN

Inside the LHC

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

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

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

Image courtesy of Pacific Northwest National Laboratory

EMBL
Drugging bacteria

Gut bacteria are more affected by metformin than by the type 2 diabetes it is prescribed to treat.

Metformin, the drug most often used to treat type 2 diabetes, has a greater effect on gut microbes than the disease itself has. The finding, by scientists at the European Molecular Biology Laboratory (EMBL) in Heidelberg and colleagues in the MetaHIT consortium, has implications for studies searching for links between our microbiomes and disease. Published in *Nature*, the study points to new approaches for understanding how metformin works and for minimising the side effects of a drug that patients take in high doses for many years.

"It's surprising that this single drug triggers such a noticeable change in our microbes," says Peer Bork, who led the work at EMBL. "Now think how many drugs are out there, and how many people take several drugs daily: even if only a fraction of drugs have this big an impact, they could still be dramatically shaping people's gut."

Forslund K, Hildebrand F, Nielsen T, Falony G, Le Chatelier E *et al.* (2015) Disentangling type 2 diabetes and metformin treatment signatures in the human gut microbiota, *Nature* **528**, 262–266: doi:10.1038/nature15766

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

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

ESA
Exploring shooting stars

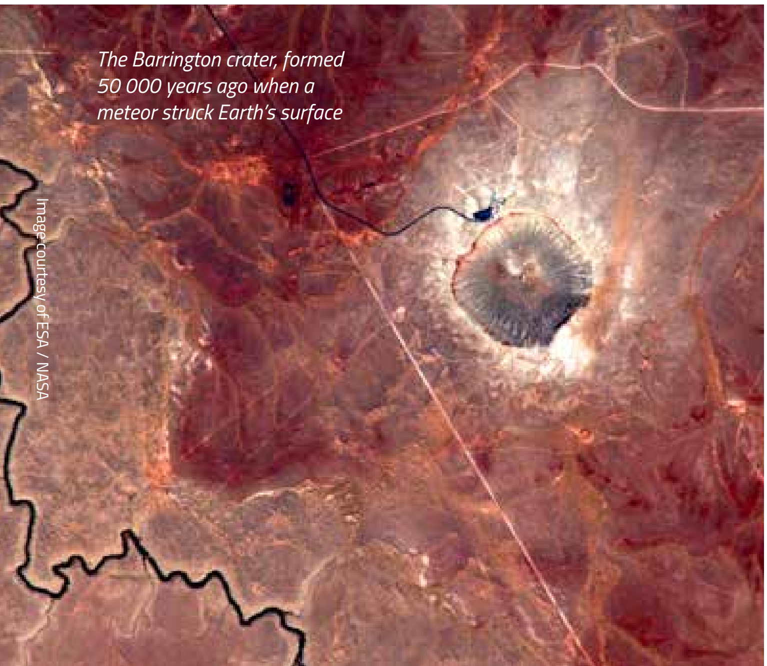
Did you enjoy the Leonid meteor shower in November 2015? Explain this exciting phenomenon to your pupils with the European Space Agency (ESA)'s new teaching resource for primary schools!

'Tell-tale signs of a shooting star' is a new teachers' guide for children aged 10 to 12 that includes pupil activities and a teacher's demonstration. Children can explore what happens when a piece of space rock collides with Earth's atmosphere. Using an inquiry-based approach, pupils then perform experiments using household materials to discover what happens if a space rock survives its journey all the way to the ground. For those who wish to explore this exciting topic further, a series of additional activities is also available in a separate document.

Download the new activity to try with your class today (http://tinyurl.com/jxft5zf) and share the spectacular craters you create via the ESA Education Facebook page (www.facebook.com/ESAeducation).

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



The Barrington crater, formed 50 000 years ago when a meteor struck Earth's surface

Image courtesy of ESA / NASA

ESO
Observatories link to create Earth-sized virtual telescope

The protoplanetary disc surrounding the young star HL Tauri. This is the sharpest image ever taken by ALMA — sharper than is routinely achieved in visible light with the NASA / ESA Hubble Space Telescope.

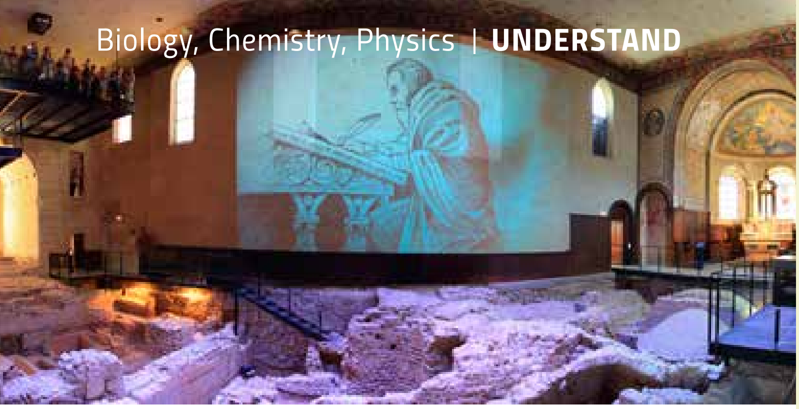
The Atacama Large Millimetre/submillimetre Array (ALMA) continues to expand its power and capabilities by linking with other millimetre-wavelength telescopes in Europe and North America in a series of very long baseline interferometry (VLBI) observations.

In VLBI, data from two or more telescopes are combined to form a single, virtual telescope that spans the geographic distance between them. The most recent of these experiments with ALMA and other telescopes formed an Earth-sized telescope with extraordinarily fine resolution.

These experiments are an essential step in including ALMA in the Event Horizon Telescope, a global network of millimetre-wavelength telescopes that will have the power to study the supermassive black hole at the centre of the Milky Way in unprecedented detail.

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

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



ESRF
X-ray vision deciphers archaeological mystery

The mysteries of a small 17th century metallic box were pierced thanks to X-ray imaging techniques developed at the European Synchrotron Radiation Facility (ESRF) by Paul Tafforeau. Paul was able to virtually reconstitute, in 3D and with astounding resolution, the inaccessible contents of the very fragile and badly damaged box, found in a grave in the St Laurent church in Grenoble. The content (three medals and two pearls) was virtually extracted from the box by 3D segmentation and revealed a multitude of details impossible to see with traditional lighting. These results open new possibilities in the field of archaeological research.

For the full story, read the ESRF news article. See: www.esrf.fr/home/news/general/content-news/general/x-ray-vision-deciphers-archaeological-mystery.html

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

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

The 17th century metallic box and the medals that were virtually extracted from it

Image courtesy of P Tafforeau/ESRF

EUROfusion
A fusion recipe with cored apples

Reading about tokamaks could make you hungry. While the usual tokamaks are shaped like doughnuts, there are some others shaped like cored apples. These cored-apple-shaped tokamaks are known as spherical tokamaks. One such spherical tokamak, MAST (short for Mega Amp Spherical Tokamak), housed at the Culham Centre for Fusion Energy, UK, is getting an upgrade to start experiments in 2017.

Why is it important to conduct experiments on different kinds of tokamaks? Each kind of tokamak gives clues to different questions raised in fusion research, and putting all these clues together will pave the way for the first fusion plant.

For example, due to its spherical shape, MAST will allow the hot plasma, where fusion reactions occur, to be confined into a compressed shape, and it can generate highly pressurised plasma at a relatively low magnetic field. The researchers also want to use MAST to investigate and control turbulence so that they can better understand and control heat loss from plasma. Simply put, the architecture of spherical tokamaks creates some of the conditions that will be experienced in ITER, the next-generation fusion experiment which is currently being built in France. So, here's waiting for the cored apple to start cooking.

To learn more, check out the story *Smart Apples for Fusion Research* in EUROfusion's newsletter, Fusion in Europe: www.euro-fusion.org/newsletters/2015-december/

EUROfusion comprises 29 European member states as well as Switzerland and manages fusion research activities on behalf of Euratom. The aim is to realise fusion electricity by 2050. See: www.euro-fusion.org

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

Image courtesy of EUROfusion

European XFEL
Engaging the public on X-ray free-electron laser science

Image courtesy of European XFEL

The European XFEL exhibition at the Hamburg Night of Science

While the European X-ray Free-Electron Laser (European XFEL) is very busy with construction and technical preparations, its employees have been engaged in several outreach and education activities. In late September 2015, for example, European XFEL scientists led an intensive graduate-level lecture course on X-ray free-electron science in materials research to students from the Technical University of Freiberg in Germany.

In early November, European XFEL opened its doors to the public on a Saturday, offering interactive activities to demonstrate the facility's research aims and technology, as well as showcasing its construction progress. The event was part of the Hamburg Night of Science and an open day on the campus of the German research centre DESY. Over the course of the day, 18 000 people came to the campus.

Finally, in early December, as a follow-up to the 2014 German–Turkish Year of Research, Education and Innovation, European XFEL participated in an outreach event with the Turkish community in Hamburg, which demonstrated the facility's science goals. As the facility comes closer to opening for users in 2017, it's not only the scientific community that is becoming more and more interested and excited about the new research perspectives and possibilities at what will be the world's brightest light source.

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. Learn more at: www.xfel.eu

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

ILL
Paving the way to the neutrino mass

Neutrinos are everywhere. Over one hundred trillion neutrinos pass through your body every second, but one of their fundamental properties, their mass, is still unknown. Although the standard model of particle physics predicts neutrinos to be massless, observations prove that neutrinos must have a tiny mass. To find out, scientists study radioactive decays that emit neutrinos and measure the decay energy, which corresponds to the mass difference between the mother and daughter nuclei. One such decay involves an artificial isotope of holmium, with mass number 163, which produces the stable 163Dy. Samples of 163Ho are prepared from natural erbium enriched in 162Er by intense neutron irradiation in the high-flux research reactor at the Institut Laue-Langevin (ILL) in Grenoble, France.

After sample purification and processing at Paul Scherrer Institute Villigen, Switzerland, and Johannes Gutenberg University in Mainz, Germany, the atomic mass difference between 163Ho and 163Dy was directly measured using a very sensitive mass spectrometer at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany. Based on the equivalence of mass and energy according to Einstein's famous equation E = mc2, the mass difference translates into the energy available for the decay. Averaging many measurements gave a final value of 2833 eV with an uncertainty of only a few tens of eV, confirming the recent results and providing a new baseline to further refine the neutrino mass search.

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

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

The inner part of the high precision mass spectrometer used in the research

Image in the public domain; image source: Wikimedia Commons

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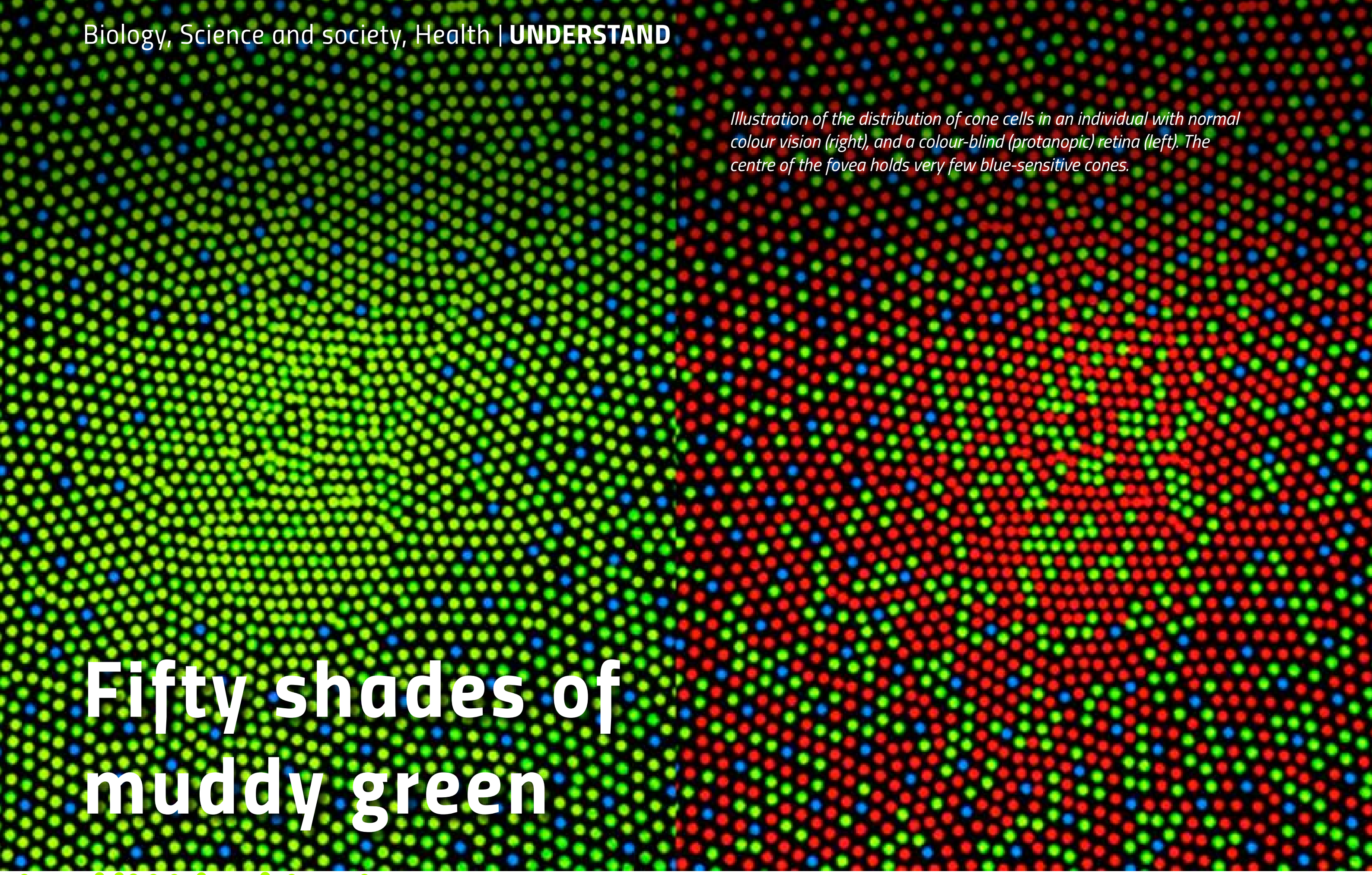


Illustration of the distribution of cone cells in an individual with normal colour vision (right), and a colour-blind (protanopic) retina (left). The centre of the fovea holds very few blue-sensitive cones.

Image courtesy of Mark Fairchild

Fifty shades of muddy green

To support children with colour vision deficiency in our classrooms, we have to understand their condition.

By Louise Maule and David Featonby

As we teachers become more aware of the ways in which some children are held back in school, one group of children that is often overlooked are those with colour vision deficiency (CVD), often referred to as colour blindness. CVD is the inability or decreased ability to see colour, or perceive colour differences, under normal lighting conditions. It is estimated that 1 in 12 boys and 1 in 200 girls suffer from some kind of CVD, which suggests there is at least one such child in every classroom.

There are different forms of CVD but all of them cause some difficulty with colour-related tasks, from playing in sports teams or filling in worksheets and maps, to refusing to eat something that looks particularly unappealing (Holmes, 2011). Many children adopt strategies to cope with CVD, so much so that as many as 80% leave primary school not knowing that they have this condition. As far as we can determine, primary schools across Europe do not routinely test pupils for CVD. Instead, children may be incorrectly labelled as lazy, disruptive or inattentive. Although most teachers know of colour blindness, few of us understand the real problems associated with it or have strategies to deal with students who have CVD.

What is CVD?

Colour blindness is usually a genetic condition that you are born with. The gene for red/green and blue colour blindness, which is carried on the X chromosome, is inherited from your parents. Because women have two X chromosomes, most women with the gene for colour blindness also have a healthy copy of the gene. Men, who have only one X chromosome,

Image courtesy of David Featonby

Figure 1: The left image shows what the child with CVD drew, and the right is what he saw, simulated by Vischeck.

have no 'spare' healthy copy; this is why many more men are affected by colour blindness than women.

Not all CVD is inherited: some people acquire the condition as a result of chronic diseases such as diabetes, multiple sclerosis, some liver diseases and many eye diseases.

The retina at the back of the eye has two types of light-sensing cells: rods and cones. Rods detect light in low-light environments, like at night, and cones detect colour. When you look at an object, light enters your eye and stimulates both the rod and the cone cells. Your brain then interprets the signals from the cones so that you can see the colour of the object. Our eyes have three basic cones that are sensitive to different wavelengths of light. These cones are traditionally referred to as red, green and blue cones, because their sensitivity corresponds primarily to these colours, although they are actually sensitive to a wide range of colours. By combining the sensitivities of these cones, our optic system allows us to perceive different colours. For example, when the red and blue cones are stimulated in a certain way, you will see the colour purple.

The exact physical causes of colour blindness are still being researched but it is believed that colour blindness is usually caused by faulty cones or sometimes by a fault in the pathway from the cone to the brain.

Someone with CVD will have cones or pathways that function differently to someone with 'normal' sight. For example, someone with deficient red or green cones will see reds and greens as two very similar muddy green colours. People with red or green deficiencies will see the world in a similar way to each other because red and green are very close together on the light spectrum. This red/green deficiency is known as protanopia (a reduced sensitivity to red light) or deuteranopia (a reduced sensitivity to green light). These types of CVD could be particularly relevant when looking at ripe and unripe fruits, traffic lights, or marked schoolwork that uses red and green as a contrast.

In figure 1, a 5-year-old pupil who suffers from protanopia (red deficiency) has been asked to order numbers in ascending value by colouring each group of balloons in green, yellow and blue. This child is a bright boy who has very good number sense but we can see that he has difficulty detecting red. The first blue balloon was coloured

REVIEW

✓ General science

✓ All ages

A very enlightening article which sheds light onto a little-known problem and which could help teachers really support students. The article provides information that should be provided to every teacher at any educational level. It is an easy-to-read resource to help teachers identify students with CVD and, more importantly, help them overcome difficulties caused by CVD in the learning environment.

Christiana Th Nicolaou, Cyprus

Image courtesy of David Featonby

Would you want to eat these?

Colour	Colour name	RGB (1–255)	CMYK (%)	P	D
	Black	0, 0, 0	0, 0, 0, 100		
	Orange	230, 159, 0	0, 50, 100, 0		
	Sky blue	86, 180, 233	80, 0, 0, 0		
	Bluish green	0, 158, 115	97, 0, 75, 0		
	Yellow	240, 228, 66	10, 5, 90, 0		
	Blue	0, 114, 178	100, 50, 0, 0		
	Vermillion	213, 94, 0	0, 80, 100, 0		
	Reddish purple	204, 121, 167	10, 70, 0, 0		

Figure 2: Colour palette optimised for colour-blind individuals. P and D indicate simulated colours as seen by individuals with protanopia and deuteranopia, respectively. Taken from Wong 2011

Images courtesy of David Featonby

purple before it was corrected to blue (maybe he saw another pupils' work) but the balloons that should have been green were coloured red. Unfortunately, the teacher incorrectly diagnosed the problem as being with number sense. If we simulate what the child saw, the balloons appear to be correctly coloured. Confusion only occurs in the last images when the teacher intervened and probably confused the boy even more! We can all imagine how such a misdiagnosis will undermine a child's confidence, cause confusion and even have a long-term effect on their progress.

It will be clear to teachers that many different areas of the curriculum and beyond will be affected for someone with CVD. Often those effects are hidden because of coping strategies, but many tasks will become significantly more difficult as a result of CVD.

It is not the teacher's role to diagnose CVD in a child, but if we are aware of mistakes that a child with CVD may make, we can perhaps alert parents to potential problems. We can all recognise signs that children find certain tasks extra challenging and identify where these are associated with colour. Any mixing up of colour is a sure giveaway; people with CVD are not *blind* to colour, they just see colours differently to the rest of us and may avoid tasks that involve colour selection.

There are an increasing number of useful websites[w1] and technology[w2] that can help teachers understand CVD, such as the programmes used to produce some of the images in this article[w3]. You could also use them with your students to explore colour blindness.

It is to everyone's benefit that teachers are aware of the possible difficulties that their students can face, both in lessons and in life. We hope that this article gives insight into the challenges posed by CVD. It is likely that we can help at least one child in every classroom this way.

References

Holmes W (2011) Colour vision testing: what can be achieved in everyday practice? *Optometry in Practice* **12**(4): 167–178. Visit the journal website (http://www.college-optometrists.org/en/CPD/OIP/) or use the direct link: http://tinyurl.com/ho6dm3g

Wong B (2011) Color blindness. *Nature Methods* **8**: 441. doi:10.1038/nmeth.1618

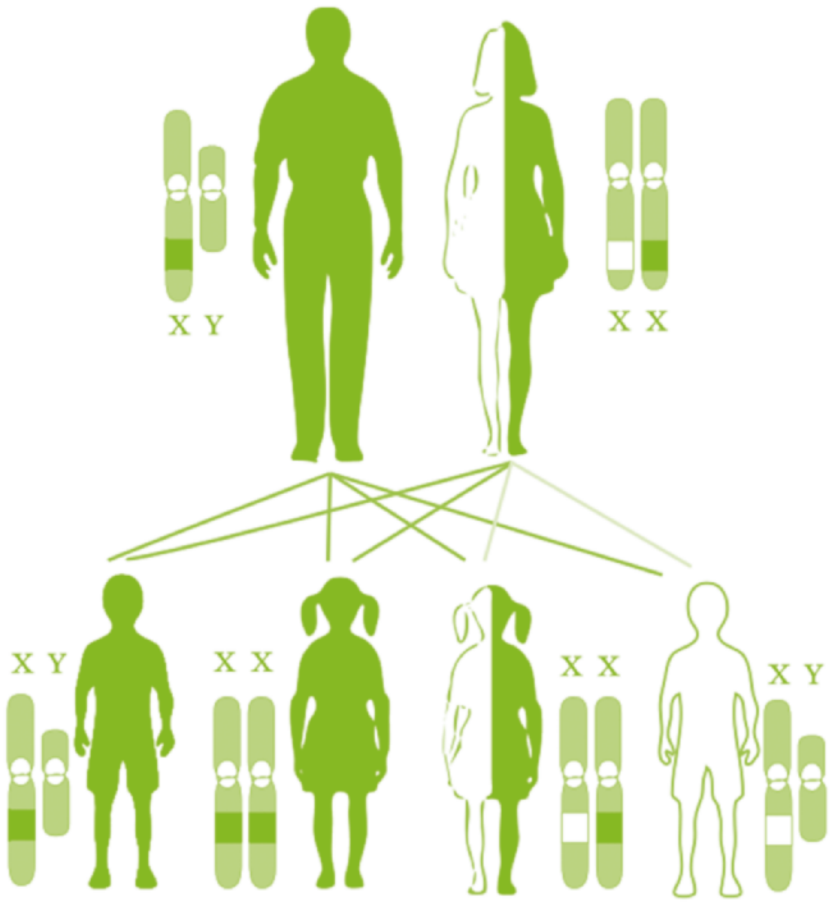


Image courtesy of OpenStax College; Image source: Wikimedia commons

X-linked inheritance means that men are more likely than women to suffer from CVD.

BACKGROUND

How to help children with CVD

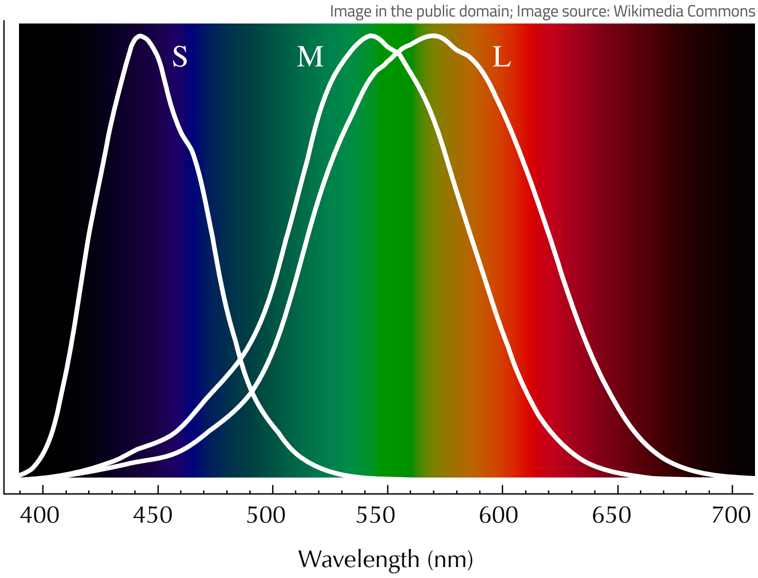
Do:

- Be aware of CVD and how it can manifest.
- Use natural light where possible.
- Use **secondary** indicators, e.g. signs on labels, or underline words.
- Use yellow, blue and white as contrast colours.
- Have a colour buddy to identify colours for CVD students.
- Use clear lines between colours.
- Label coloured pencils with the names of their colours.
- Use large objects, held apart.

Don't:

- Highlight teaching points in red and green on the white board or in books.
- Use worksheets/software that rely on colour.
- Use pots of mixed, unlabelled coloured pencils/ crayons.
- Use coloured labels on library books to indicate different reading levels.
- Use a traffic light system for assessment.
- Use plain-coloured counters in games, e.g. counting games.
- Use books that highlight familiar sounds using colours.

Image in the public domain; Image source: Wikimedia Commons



The sensitivity of different light sensitive cells in the eye to short (S), medium (M) and long (L) wavelengths, overlaying the colour spectrum.

Web references

w1 In the UK, Colour Blind Awareness produces useful information for both teachers and parents as well as running workshops for groups of teachers. Similar organisations may exist in your country. See: www.colourblindawareness.org.

w2 Together with the University of East Anglia, UK, Spectral Edge has pioneered new approaches to image fusion, colour perception-based processing and image enhancement: www.spectraledge.co.uk

w3 In making the images for this article, the authors used two programmes to alter the images and show how children with different degrees of CVD perceive coloured objects and pictures:

The iDalonizer app for smartphones uses the inbuilt camera and enables teachers to check instantly that what they are showing is clear to anyone with varying degrees of CVD: www.idaltonizer.com

The Vischeck programme takes uploaded image files and produces the image as seen by someone with different types of CVD: www.vischeck.com

Resource

In this video from *Washington University in St. Louis* in the USA, Amanda Melin explains that colour vision deficiency can have other benefits, such as seeing through camouflage: www.youtube.com/watch?v=9NrmH039ffI

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Rings on the shells of ocean quahogs depend on the environmental conditions they grew in.

Image courtesy of Hans Hillewaert; image source: Wikimedia Commons

Opening seashells to reveal climate secrets

Sea shells are more than just pretty objects: they also help scientists reconstruct past climates.

By Anne Korn

Seashells – the protective armour of marine molluscs – have a lot in common with trees. When molluscs grow, their shells grow with them, developing a pattern that is similar to tree rings. In shells, these rings are called increments and they record information about the environment in which the organism grew. Moreover, like trees, molluscs can live for a long time, so they can contain climate records that span many years.

The ocean quahog (*Arctica islandica*), for example, can live up to 500 years. Bivalves in general have inhabited the oceans for more than 500 million years and have fossilised in sedimentary rocks.

Bernd Schöne, a palaeontologist at the University of Mainz, Germany specialises in mollusc sclerochronology (or ‘shell-ring research’), a rather young discipline that uses methods similar to those used in tree-ring research. Bernd, who has been studying shells for 15 years, calls them “a

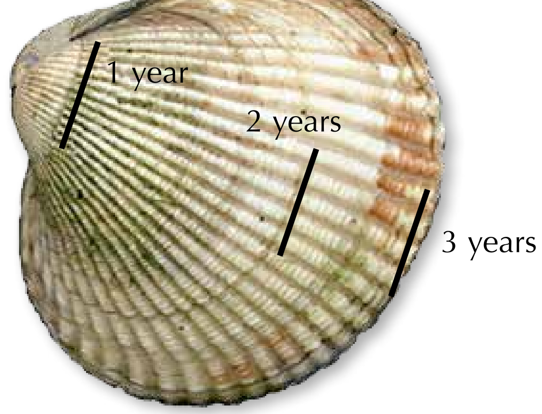


Image courtesy of www.asnailsodyssey.com

A specimen of cockle, Clinocardium nuttallii, *with the most obvious growth lines indicated, suggesting an age of three years*

REVIEW

- Biology
- Chemistry
- Geology
- Ages 14-16

This article helps students to realise that molluscs, like every living being, are open systems that interact constantly with the surrounding environment. It explains how the shells of molluscs are formed and how this can be used in climate research (in order to understand the causes and consequences of it). Secondary teachers can also use this article as a primer for discussion about the interactions between the subsystems of earth (biosphere, geosphere, hydrosphere and atmosphere). Potential other topics for discussion include:

- How does this research area exemplify the interaction between Biosphere – Geosphere – Hydrosphere – Atmosphere?
- Considering the present climate change. Predict the ratio of oxygen 16/18 in the ocean water. Explain your reasoning.
- “It seems that molluscs are here to stay, despite the climate changes”. Discuss this sentence according to the evolutionist perspective of Charles Darwin.

Betina Lopes, Portugal

unique climate archive”. “The way that shells grow varies depending on environmental conditions like temperature, food availability and water conditions,” he explains. “So studying them can give us clues on what these conditions were in the past.”

Image courtesy of Bernd Schöne

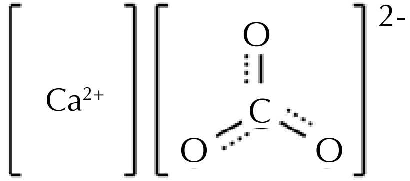
Bernd Schöne studying a shell with a magnifying glass

Reconstructing environmental change

Like teeth and bones, shells are composite materials made of calcium carbonate ($CaCO_3$) and large organic molecules (polymers) such as proteins. Calcium carbonate is the inorganic substance that accumulates in our washing machines and kettles in the form of limescale. In shells, it is present as calcite or aragonite and forms crystals that molluscs mould and ‘glue together’ with the organic polymers. As they grow, bivalve molluscs add layers of this mixture of calcium carbonate and polymers to their shells.

However, this shell growth isn’t continuous. “When molluscs encounter a limited supply of food or changed temperatures or water quality, shell growth slows down and a line forms,” explains Bernd. “When conditions improve, the shell grows again.” The result is a regular pattern of growth lines (due to slow growth) and increments

Image courtesy of Nicola Graf



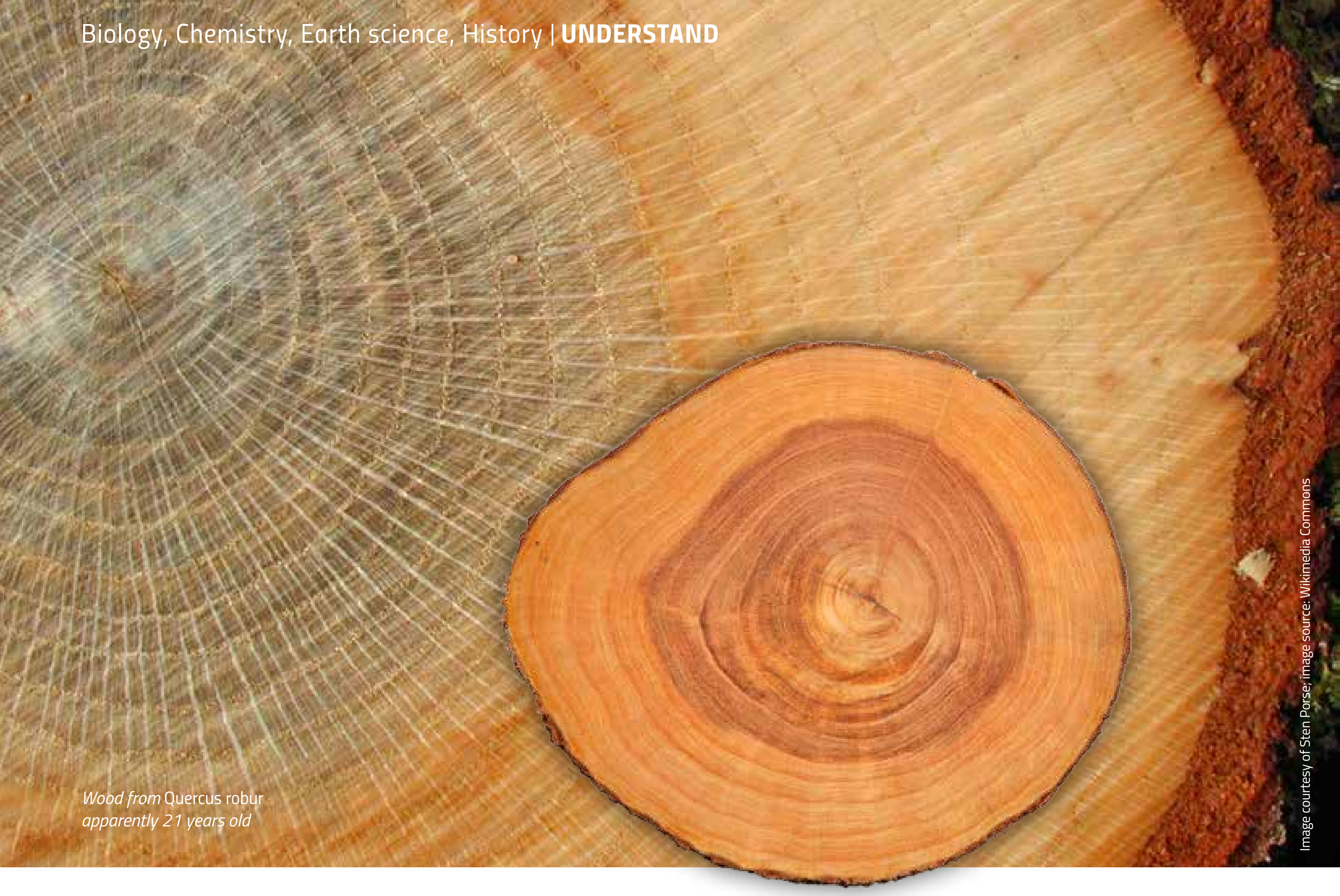
Structure of calcium carbonate

(due to rapid growth), which can be used like a calendar to reconstruct and date environmental change. If the exact date when the mollusc died is known, for example, scientists can count backwards to date the other lines.

Another way to deduce environmental change from shells is to analyse their chemical composition. Oxygen has three forms (isotopes): oxygen-16, oxygen-17 and oxygen-18, which are determined by the number of neutrons in the nucleus. In cold water, the proportion of oxygen-18 to oxygen-16 is higher than it is in warm water and the oxygen-18 is more easily incorporated into shells than oxygen-16. By analysing the ratios between oxygen isotopes in a shell, therefore, scientists can tell what water temperatures were like at the time when the shell grew.

But how can scientists tell when that was? They do so by counting the number of increments and lines, just as the age of a tree can be measured by counting its rings. However, shells have an advantage over trees: they form daily rings instead of the annual rings of trees. This can give a much more detailed picture of the environmental conditions that influenced their growth. Because different specimens of the same species record environmental conditions in the same way, their individual records can be combined into a master chronology of climatic events. This calendar not only can help to make other environmental records more accurate but also can be extended back in time to before humans started recording the climate.

Using shells as records, Bernd and his team have managed to reconstruct the climate in the North Atlantic region over the past 500 years. More precisely, they determined that the North Sea



Wood from Quercus robur *apparently 21 years old*

Image courtesy of Sten Porse; image source: Wikimedia Commons

warmed up by one degree Celsius in the past 150 years. More broadly, Bernd used specimens of *Arctica islandica* to measure how levels of carbon dioxide and temperatures in the world's oceans changed thousands of years ago, finding clear evidence of extreme weather events, such as the Little Ice Age (1300–1850), and variations in recurring weather phenomena such as El Niño.

What does the future hold for molluscs?

Molluscs can help us to reconstruct past climates, but what about predicting the evolution of climate change? Climate predictions, Bernd points out, are the domain of climatologists, but the study of past shell growth may help to predict how current and future climate change could affect shell-growing animals. Because shell growth depends on very specific environmental conditions, Bernd warns that climate change "could have a negative effect on the animals' ability to build their shells".

For example, Bernd and his colleagues have found a correlation between shell growth and water temperature. "Each species is adapted to its own, specific temperature range: the animals' metabolism works best within that range," he explains. "If temperatures are above or below that range, their shells stop growing."

Ocean acidification – the decrease in oceanic pH value caused by dissolved carbon dioxide from the atmosphere is another variable that could affect molluscs. "The pH value is currently 7.9 to 8.0," explains Bernd. "Over the next century, it could drop by 0.1 to 0.3 units." If this trend continued for several centuries, the water would become more and more acidic, and some species could have difficulties forming shells at all. "This doesn't necessarily mean that these animals will die out," says Bernd. "It is too early to tell because studies on the effects of the changed pH value on molluscs are still rare and somewhat contradictory." But climate change might favour some species over others.

Even though molluscs are very sensitive to changes in their environment, they have adapted to all of Earth's main environments (marine, freshwater, terrestrial) and are currently the second largest group of invertebrates. Some even live in unusually acidic environments, such as oceanic volcanic areas, and might hold clues on how to mitigate the effect of oceanic acidification in the future.

Resources

Check the Tara expedition website for activities to do in the classroom to explain the various physico-chemical properties of the ocean: http://oceans.taraexpeditions.org/en/m/education/educational-resources/

The international agreement on climate reached during the COP21 (December 2015) may have an impact on the current ocean acidification: http://tinyurl.com/hjnwwce

Anne Korn is a science communicator, freelance journalist and blogger. She writes about science, politics, civil rights and culture. You can find her on Twitter: @morethanannie

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Sports in a spin

Image courtesy of Ronnie Macdonald; image source: Wikimedia Commons

Sporting success requires hard work and talent, and there's an awful lot of physics determining the perfect shot

By Laura Howes

A football flies through the air and seems to swerve magically past the defenders and goalkeeper. They turn just in time to see it swoop into the back of the goal. Skilful players know just how to hit the ball to try and beat the opposition but what is going on? The answer is down to aerodynamics.

A fluid game

Aerodynamics is a subset of fluid dynamics that allows us to understand the flow of gases, and so understand a vast array of everyday phenomena. That does not just help in the design of aeroplanes and cars, but also helps us understand balls in flight, from footballs and basketballs to fast flying table-tennis balls.

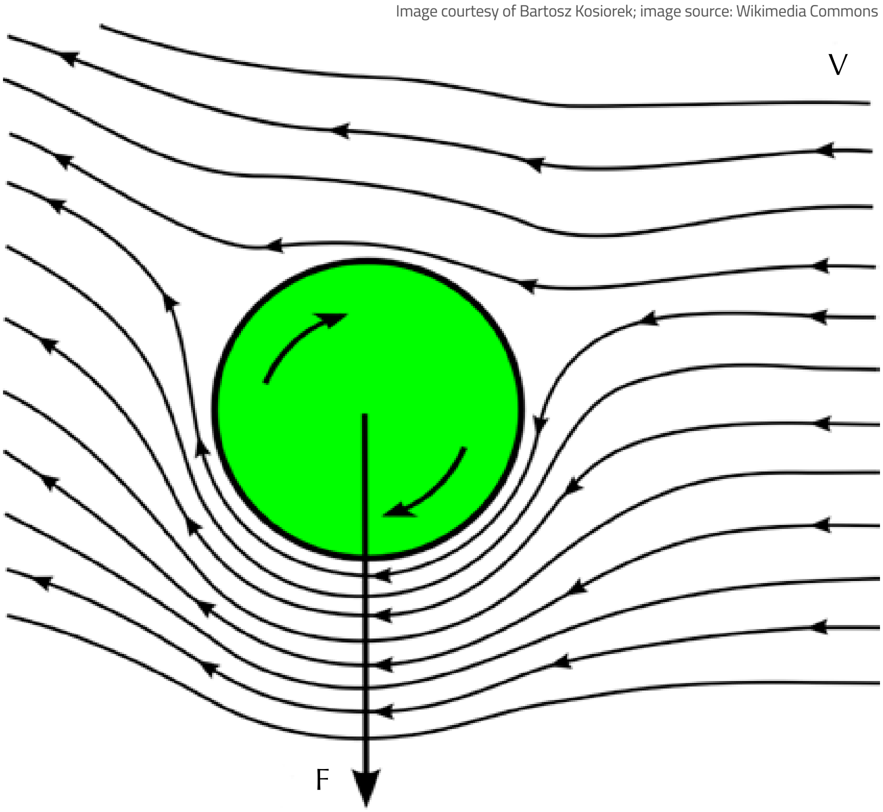
We often model balls in flight as projectiles, but a kick can be more complicated than you might first think. For a straight kick through the air the initial speed of the ball is approximately 30m/s. Assuming an angle of 45° that would suggest that the ball will travel 120 m, based on a parabolic flight. But instead, the ball will often travel a much shorter distance, with the ball falling more steeply at the end. The key factor is the influence of the air, which adds drag slowing the ball down.

However, there are tricks that players can use to make a ball move in different ways. For example, experienced football players know that the range of a kick may be extended by imparting backspin to the ball. Similarly, top-spin and side spin can be used to get a ball to drop behind a wall of defenders or curve around from a corner kick. This is because the spinning ball is subject to a phenomenon known as the Magnus effect, named after the 19th century German scientist Gustav Magnus, although the affect had been observed previously, including by a tennis-playing Isaac Newton.

The Magnus effect

When a ball is kicked through the air the air around it is turbulent and only imposes a little drag on the ball. However, that drag still exists and will cause the ball to start to slow. Below a certain speed, the air moving around the ball

Image courtesy of Bartosz Kosiorek; image source: Wikimedia Commons



As the spinning ball moves to the right the air flow causes a slight pressure difference so that the ball experiences a downward force.

becomes laminar, rather than turbulent, meaning that it flows in smooth lines around the ball and stays close to the surface. If the ball is not spinning as it flies then this transition is not so important, but if the ball is spinning, then the transition to laminar flow means that spin effects can take over and the ball will start to swing.

How does this work? Imagine a ball spinning as it moves through the air. As it spins, some of the ball's surface is moving with the ball's direction of travel and so is moving 'faster' and some of the ball is moving in the opposite direction to the direction of travel and so it moving 'slower' with respect to the speed of the centre of the ball.

As the surface of the ball spins in the direction of the ball's flight it 'scoops up' the air travelling past it using friction, increasing the air pressure on that side of the ball. Meanwhile, on the other side of the ball the surface is moving in the opposite direction to the trajectory of the ball in flight, and helps whip the air away, reducing the air pressure on that side of the ball. The air pressure on one side is increased, and the air pressure on the other side is decreased. This difference in air pressure results in a net force at right angles to the motion of the ball, and so the ball swings in the air. The direction of spin determines the direction of the force and so what way the ball travels.

Of course, in football the phenomenon of balls' flight bending in the air is well known and you can often see the results as the ball confounds defenders, but the Magnus effect will be seen to greater and lesser degrees in all ball sports in this year's Olympics. Table tennis players, for example, are masters of using the Magnus effect to outwit their opponents: if you watch a game on television, a view of a game from above can reveal the side-to-side curving of serves with different spins.

Image courtesy of DerHans04; image source: Wikimedia Commons

Free kicks can often use spin to confound defenders

Acknowledgement

This article was inspired by the work of John Bush of the Massachusetts Institute of Technology, US, whose chapter 'The aerodynamics of the beautiful game' (Bush 2013) provides much more information on the physics involved in football and gives the reader opportunity to dig a little deeper into the relevant fluid mechanics. Professor Bush was also kind enough to advise in the drafting of this article.

Reference

Bush JWM (2013) The aerodynamics of the beautiful game, in *Sports Physics*, Ed. C. Clanet, Les Editions de l'Ecole Polytechnique, p.171–192

Classroom activity

Back to ball games

You can explore spins and the Magnus effect in collaboration with your school's sports department by trying to kick balls in different ways and seeing what happens. If you have less space for a spin based experiment you could also build a spinner with simple materials, as explained as part of the Institute of Physics resource 'Thinking on your feet'[w1].

Materials

- 2 polystyrene or polythene cups
- Sticky tape and scissors
- 2 elastic bands
- Cling film (optional)
- Paper and pencils
- A mobile phone or camera with slow motion video function (optional)

Procedure

1. Tape the cups together at the base to make the spinner.
2. Tie the elastic bands together.
3. Hold one end of the elastic on the spinner where the cups join and wind it around a few times until the other end of the elastic is at the bottom and pointing away from you.
4. Hold the spinner in one hand and stretch the elastic with the other then fire the spinner like a catapult to get backspin. Which way does the spinner bend?
5. Now launch the spinner upside-down to get topspin. Which way does the spinner bend?
6. For sidespin, you need to launch the spinner on its side, and at an upwards angle so it doesn't fall too quickly to the ground. (Putting cling film over the ends of the cups also increases the time in the air.) Which way does the spinner bend?
7. If you have a camera, try to capture the most dramatic video footage of each type of spin and the resulting motion.

Images courtesy of the Institute of Physics

Web reference

w1 Developed in collaboration with Arsenal Football Club, the UK's Institute of Physics has published eight physics activities linked to the beautiful game. Find the resources at www.iop.org/football.

Resources

For more information on the motion of projectiles see:

Kalogirou and Francis (2010) Going ballistic: modelling the trajectories of projectiles, *Science in School*, **17**, 23. http://www.scienceinschool.org/2010/issue17/projectiles

In his TED talk, Erez Garty explores the physics of an amazing free kick by Brazilian football player Roberto Carlos. See: http://ed.ted.com/lessons/football-physics-the-impossible-free-kick-erez-garty

Visit the Wolfram Demonstrations Project website for a demonstration of how laminar flow travels around a spinning cylinder: http://demonstrations.wolfram.com/StreamlinesForLaminarFlowPastARotatingSolidCylinder/

Laura Howes is one of the editors 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*.

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Analysing art in the Louvre

Claire Pacheco explores ancient art puzzles with modern techniques.

By Laura Howes

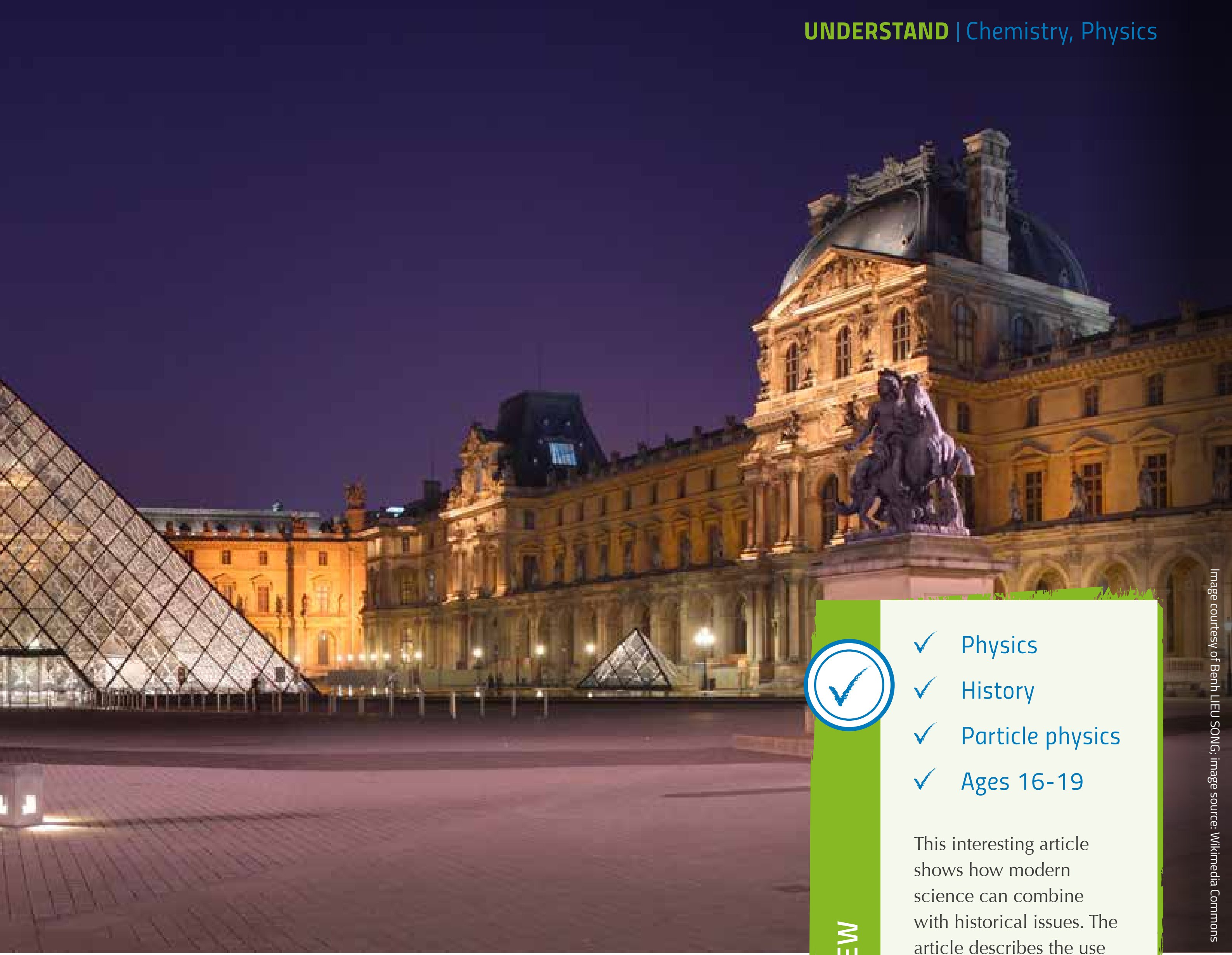
In the basement of the Louvre Museum in Paris, France, sits a much more modern artefact than the artworks on display upstairs: the museum's particle accelerator. The *Accélérateur Grand Louvre d'analyse élémentaire* (AGLAE) produces beams of protons and alpha particles (helium nuclei) to look into the artworks of the museum. For example, scientists have used AGLAE to check whether a scabbard given to Napoleon Bonaparte by the French government was actually cast in solid gold (it was) and to identify the minerals in the hauntingly lifelike eyes of a 4500-year-old Egyptian sculpture known as The Seated Scribe (transparent rock crystal and white magnesium carbonate veined with thin red lines of iron oxide).

Helpfully, the techniques used by AGLAE are non-invasive, which is a top priority for cultural heritage, says Claire Pacheco, who leads the team that operates the machine.

The techniques used by AGLAE include particle-induced X-ray and gamma-ray emission spectrometries to identify the slightest traces of elements ranging from lithium to uranium. Claire explains that the positive ions from the accelerator are thrown onto the artwork at around 10% the speed of light exciting electrons in the inner orbitals of the atoms in the artworks. When the remaining electrons from the collided atoms recombine, X-rays are emitted. This is called PIXE (particle-induced X-ray emission). When the beam bumps into the nuclei of the atoms, other electromagnetic rays – gamma-rays – can be emitted. This is called PIGE (particle-induced gamma-ray emission).

Together these techniques excite the atoms within the artwork or artefact and the resulting spectra are picked up by AGLAE detectors. This enables Claire's team, with the proper analysis, to identify and quantify the chemical elements present in the artefact, even in small amounts.

These trace elements and the ratios between them, says Claire, can be geochemical signatures of mineral ores, for example. Identifying the amounts and combinations of elements that an object contains can serve as a fingerprint, telling researchers where minerals were mined – and how, and therefore when, an item was made. PIXE and PIGE are now used routinely by geologists, archaeologists, art conservators and others to help answer questions of provenance, dating and authenticity. The techniques are best suited to inorganic compounds such as stones, ceramics, glasses and metals.



The courtyard of the Louvre

Image courtesy of Benh LIEU SONG; image source: Wikimedia Commons

Because the valuable nature of the works of art at the Louvre means they must stay inside the security area of the museum, AGLAE was installed in 1988 and is solely dedicated to museum analyses. Today, beamtime is split between research on objects from any of the 1220 national French museums and objects from further afield as long as the investigation deals with cultural heritage. The physicists and engineers who conduct AGLAE experiments typically work in collaboration with curators and art historians. AGLAE is the only particle accelerator that has been used solely for this field of research.

Before AGLAE, research facilities typically required samples to be placed in a potentially damaging vacuum. Researchers hoping to study large pieces were out of luck because the objects were too large for a vacuum chamber.

However, while the accelerator in AGLAE needs a vaccum inside it, the particles can pass from that vacuum to the atmosphere and then into the sample. Because the beams work outside the vacuum, researchers can study objects of any size and shape; the beam just has to be aimed at the object to be studied.

Claire began working with ion-beam analysis at AGLAE while pursuing her doctorate in ancient materials at the University of Bordeaux in France, where she specialised in Islamic ceramics. She took over as lead scientist in 2011 and now operates the particle accelerator with a team of three engineers.

While AGLAE frequently studies items from the local collection, it has a larger mission to study art and relics from museums all around France and beyond. This means that Claire has seen

REVIEW

✓ Physics

✓ History

✓ Particle physics

✓ Ages 16-19

This interesting article shows how modern science can combine with historical issues. The article describes the use of modern particle physics tools to work on historical paintings or other material. AGLAE the novel system at the Louvre in Paris, uses a particle accelerator to identify properties of historic objects.

Questions for you to discuss with your students could be:

- How does AGLAE work?
- Describe an application for AGLAE.
- Describe some limitations of the AGLAE procedures.

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

Image courtesy of Jean-Pierre Dalbéra

AGLAE, the particle accelerator at the Louvre

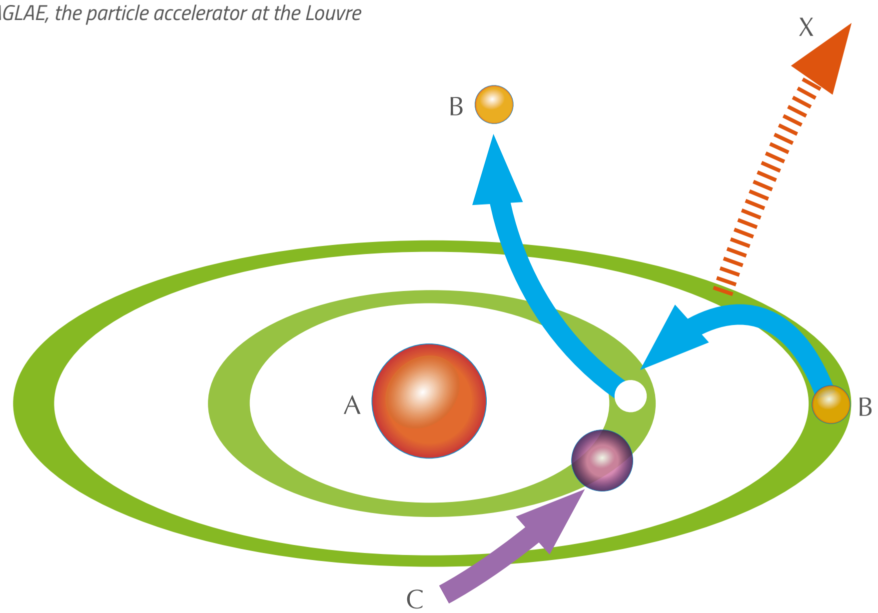


Image courtesy of Nicola Graf

PIXE: an inner-shell electron is removed by a particle beam and the vacancy left behind is filled by an electron from an outer shell, giving rise to the emission of characteristic X-rays. A: atomic nucleus; B: electron; C: particle beam; X: characteristic X-ray emission

a wide variety of artefacts and artworks in her work.

"I couldn't help shivering in front of a perfectly preserved Neolithic necklace (4000 BC) found in a grave in Brittany," explains Claire. The necklace was made of variscite – a green stone – that the AGLAE analyses revealed came from the Iberian peninsula. Sometimes what she learns during the investigation, or the context of the piece being studied, can affect Claire. Another artefact that made an impact was an ancient Greek doll made of clay. It was found in a little girl's grave.

Ion beam analysis gives specific information that can be very helpful in answering questions dealing with humanities or conservation science, explains Claire. It can really add extra context, she adds: "Determining the origin of the raw materials can be useful to understand the trade routes of a specific civilisation and can provide clues to the making process." This can help researchers understand the interactions between different manufacturers or confirm a loss of know-how at a particular time and place. "It's so marvellous," she says. "We are very, very lucky to work in this environment and study these objects."

However, one thing that AGLAE is not so good at analysing is paintings like the Louvre's most famous resident, the Mona Lisa. Whereas the pigments used in the paints are often inorganic, the binders used to mix up the paints are often organic. Therefore the instrument's particle analysis techniques carry a slight risk of damaging the paints through chemical modification. This, says Claire, is a burning issue that is being studied at an international level and the subject of recent technical meetings.

Back at AGLEA, an upgrade is now in progress to add more sensitive detectors so a lower-powered particle beam could be used. The new system will also allow for automation so that more analyses can take place. In the future, even more artworks could be under the care of Claire and her team as they work to discover just how the great masters of the past wove their magic.

Resources

To read a report (in French) about the Neolithic necklace that Claire analysed, you can visit the *Centre de Recherche et de Restauration des Musées de France* (C2RMF) website: http://en.c2rmf.fr/node/570

To learn more about the application of science to art conservation, see:

Leigh V (2009) The science of preserving art. *Science in School* **12**: 70-75. www.scienceinschool.org/2009/issue12/katylithgow

Laura Howes is one of the editors 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*.

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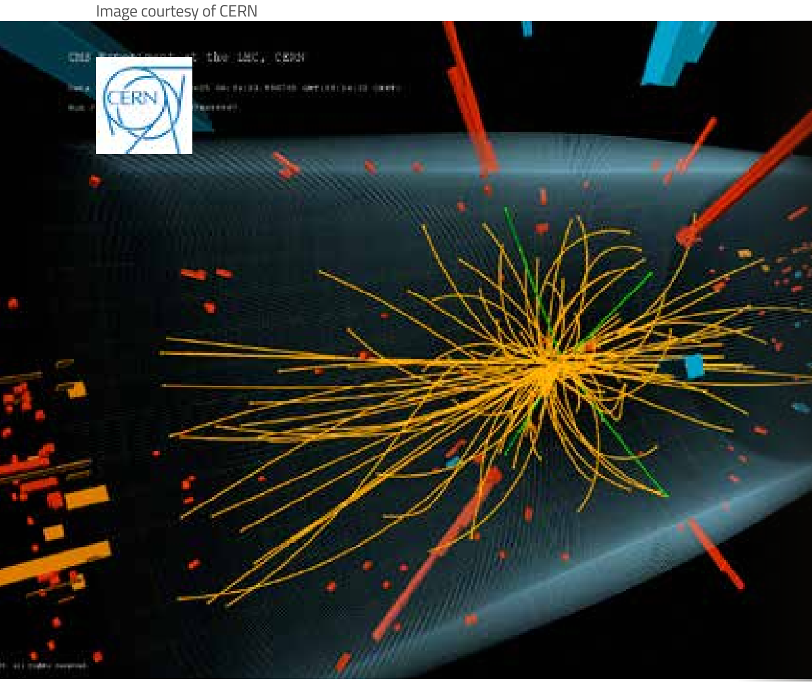
10 years of Science in School

A decade in review

How ten years of science at the EIROforum member institutions has led to many new discoveries.

Image courtesy of CERN



CERN

On 4 July 2012, the ATLAS and CMS experiments at CERN's Large Hadron Collider announced they had each observed a new particle in the mass region around 126 GeV. This particle is consistent with the Higgs boson predicted by the standard model: the simplest manifestation of the Brout-Englert-Higgs mechanism. Other types of Higgs bosons are predicted by other theories that go beyond the standard model.

On 8 October 2013, the Nobel Prize in Physics was awarded jointly to François Englert and Peter Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

Learn more about the Higgs boson and the Brout-Englert-Higgs mechanism on the CERN website: http://home.cern/topics/higgs-boson

EMBL

The 1000 Genomes Project, the most comprehensive fully open survey of human genetic variation ever performed, hit the headlines in 2015 when scientists announced the final set of results from the eight-year international research effort. As well as exceeding its aim – the team studied the DNA of more than 2500 people, instead of the 1000 originally envisaged – the project pushed technologies and knowledge forward to understand what is 'normal' human genetic variation.

Among other notable achievements, the project generated the most extensive catalogue of structural variations – changes in large sections of a person's DNA sequence – to date. Created by researchers at the European Molecular Biology Laboratory (EMBL), the University of Washington and collaborators, this reference catalogue shows how these large-scale genetic alterations vary in populations across the globe, and will help guide future studies of genetics, evolution and disease. "When we analysed the genomes of 2500 people, we were surprised to see over 200 genes that are missing entirely in some people," says Jan Korbel, who led the work at EMBL in Heidelberg, Germany. This, the scientists say, could help narrow down diagnostic efforts: if doctors find that a patient is missing one of these 200 genes, that absence is probably *not* what is causing the disease, so it would be advisable to look for other causes.

Learn more about the 1000 Genomes Project:

The 1000 Genomes Project Consortium (2015) A global reference for human genetic variation. *Nature* **526**: 68–74. doi: 10.1038/nature15393

Sudmant PH et al. (2015) An integrated map of structural variation in 2,504 human genomes. *Nature* **526**: 75–81. doi: 10.1038/nature15394

Ainsworth C (2015) A lasting legacy. *EMBL etc.* 2 Oct. http://news.embl.de/science/1510-1000genomes/http://news.embl.de/science/1510-1000genomes/

Birney E, Soranzo N (2015) Human genomics: The end of the start for population sequencing. *Nature* **526**: 52–53. doi: 10.1038/526052a

Furtado Neves S (2015) Finding links and missing genes. *EMBL etc.* 30 Sep. http://news.embl.de/science/1509-structural-variation/

Download the *Nature* articles free of charge on the *Science in School* website (www.scienceinschool.org/2016/issue35/eirohighlights), or subscribe to *Nature* today: www.nature.com/subscribe

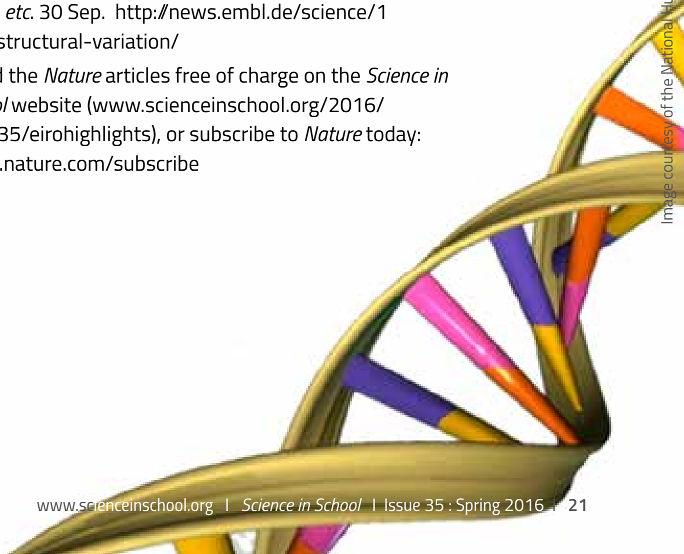


Image courtesy of the National Human Genome Research Institute; image source: Wikimedia Commons

ESA

Taken by Rosetta's Navcam, this image of comet 67P / Churyumov-Gerasimenko shows how it comprises two comets that collided at low speed in the early Solar System, giving rise to the comet's distinctive 'rubber duck' shape.

The Rosetta mission has captured the public's imagination over the past 10 years. The Rosetta spacecraft was launched in 2004 and arrived at comet 67P / Churyumov-Gerasimenko on 6 August 2014. After an initial survey and selection of a landing site, the Philae lander was delivered to the surface on 12 November.

The Rosetta mission is the first mission in history to rendezvous with a comet, escort it as it orbits the Sun, and deploy a lander to its surface. Rosetta is a European Space Agency (ESA) mission with contributions from ESA's member states and NASA.

The 'Once upon a time… Living with a comet' video explains what Philae and Rosetta have learnt in the first year of studying comet 67P / Churyumov-Gerasimenko.

You can view more images of the comet on the ESA website: http://sci.esa.int/comet-viewer/ and also find out more about the Rosetta project and watch the video itself at: http://rosetta.esa.int/

See also:

Roberti J (2015) Out of the darkness: tweeting from space. *Science in School* **32**: 20-25. www.scienceinschool.org/2015/issue32/ranero

Image courtesy of ESA/Rosetta/NavCam

ESO

Observations with the of the telescopes European Southern Observatory (ESO) have led to many breakthroughs in astronomy. Just over 20 years ago, the detection of the first planet orbiting a Sun-like star was announced, and in the past 10 years we've found out more and more about planetary systems other than our own.

In 2010, scientists using ESO instruments and telescopes began to measure the spectra of planets orbiting distant stars. The spectrum of a planet is like a fingerprint providing key information about the chemical elements in the planet's atmosphere. Spectral information can help us better understand how the planet was formed. More evidence for this also came from ALMA, the Atacama Large Millimeter/submillimeter Array, in 2014, which revealed remarkable details of the formation of a solar system. The images show how forming planets are possibly vacuuming up the dust and gas of the protoplanetary disc faster than was previously thought. And at the end of 2014, the green light was given to start the construction of the 39-metre European Extremely Large Telescope, which will be the world's biggest eye on the sky when it is completed in the middle of the next decade.

You can read more of ESO's highlights at www.eso.org/public/science/top10/

Image courtesy of ESO/C. Malin

Image courtesy of Jonathunder

ESRF

Among the highlights of the last ten years for the European Synchrotron Radiation Facility (ESRF) are two Nobel Prizes.

Two long-term ESRF users, Ada Yonath from the Weizmann Institute (Israel) and Venkatraman Ramakrishnan of the MRC Laboratory of Molecular Biology in Cambridge (UK), were awarded the 2009 Nobel Prize in Chemistry for the study of the structure and function of the ribosome, the protein factory in the cell. They shared the prize with Thomas Steitz, from Yale University (USA).

Brian Kobilka of Stanford University (USA) and Robert Lefkowitz of the Howard Hughes Medical Institute (USA) were awarded the 2012 Nobel Prize in Chemistry for groundbreaking discoveries that reveal the inner workings of an important family of G-protein–coupled receptors (GPCR). In 2006-2007, Kobilka and his colleagues solved a key GPCR structure at ESRF that is highlighted in the Nobel Prize announcement.

Thanks to the upgrade of ESRF that is currently underway, we hope that more of our users will be rewarded for their outstanding results.

Find out more about the work behind these and other Nobel Prizes. See: www.nobelprize.org

EUROfusion

No place on Earth is as hot as the inside of a fusion device. The plasma, where fusion reactions occur, reaches 150 million degrees Celsius, which is higher than the Sun's temperature! Very little plasma, around a few grams, is required as fuel in a working fusion reactor. Although the plasma is kept away from the inner plasma-facing walls of the fusion device by magnetic forces, the walls must be able to withstand temperatures in the range of around 1000 degree Celsius. "A crucial aspect of a fusion experiment is to find the right kind of materials to build the plasma-facing walls," says Tony Donné, the EUROfusion programme manager.

Until 2011, EUROfusion's flagship tokamak JET had inner walls made of carbon fibre composites. "Carbon fibre composites, though heat resistant, are not ideal materials for the wall," says Donné. A disadvantage of carbon is that it forms dust when exposed to the hot plasma. Additionally it binds the ions comprising the fusion fuel: deuterium and tritium. Only a limited amount of the radioactive isotope tritium is allowed at one time in the fusion device. If too much tritium is bound by the dust, none is available for the fusion reactors and the machine needs to be stopped to remove the dust. Therefore, the decision was made to replace the carbon tiles with beryllium and tungsten tiles. "This heralded the fine-tuning of fusion experiments; beryllium is a very light metal and absorbs almost no tritium, nor does it impact the plasma operation," he says. "Tungsten, which is used in the parts of the vessel where the chances of plasma touching the wall are high, has a melting point of 3422 degrees Celsius and has exceptional resistance to heat erosion. The use of this beryllium–tungsten combination for plasma-facing walls is one of the biggest achievements in the fusion world. It helped overcome challenges in material science, engineering and plasma physics, and it is the same configuration that is planned for use in the walls of future fusion devices such as ITER."

Image courtesy of EUROfusion

Image courtesy of © European XFEL / Heiner Mueller-Elsner

European XFEL

Construction of the European X-ray Free Electron Laser (European XFEL) started in early 2009. European XFEL will generate ultrashort X-ray flashes – 27 000 times per second and with a brilliance that is a billion times greater than that of the best conventional X-ray radiation sources. Starting in 2017, it will open up completely new research opportunities for scientists and industrial users.

To generate the X-ray flashes, bunches of electrons will first be accelerated to high energies and then directed through special arrangements of magnets. In the process, the particles will emit radiation that is increasingly amplified until an extremely short and intense X-ray flash is finally created.

Find out more about the construction of XFEL at www.xfel.eu/overview/in_brief/ and look out for a longer article in the next issue of *Science in School*.

ILL

Have you ever imagined a world where properties exist independently of their objects? All of this is possible in the quantum world. The idea was predicted by theoretical physicist Sandu Popescu of the University of Bristol, UK, and his colleagues. They have posited that – on a quantum level in which one considers very small particles – a particle can be separated from one of its physical properties: much as Lewis Carroll's Cheshire Cat becomes separated from its own grin.

An experiment performed at the Institut Laue-Langevin (ILL), using an experimental set-up known as an interferometer, provided the evidence. Scientists showed for the first time that a neutron's magnetic moment could be measured independently of the neutron itself, thereby marking the first experimental observation of a new quantum paradox known as the Cheshire Cat.

The research into the quantum Cheshire Cat is said to have the potential for technology in which unwanted magnetic moments can be separated from their original object to another region where they do not disturb the high-precision measurements being taken of other properties.

Image courtesy of RM Vollmer; image source: Wikimedia Commons

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For more information:

www.ill.eu/press-and-news/press-room/press-releases/scientists-separate-a-particle-from-its-properties-29072014/

www.bbc.com/news/science-environment-28543990

Ten years: ten of our most popular articles

Enjoy a nostalgic look back at some of your favourite articles from the *Science in School* archive.

By Eleanor Hayes

While preparing this tenth birthday issue of *Science in School*, I spent several happy hours browsing through the journal archive, reminding myself of some of my favourite articles – those that had impressed me, fascinated me or made my fingers itch to try the activity myself. And then I looked at our online statistics to see which had been *your* favourites.

The most popular articles on the *Science in School* website cover the full range of our articles, including in-depth articles about recent discoveries, discussions of important science topics, simple hands-on activities for science lessons, more adventurous school science projects, and reviews of resources for the classroom. Our readers also appreciate the broad spectrum of target ages, ranging from materials for primary-school pupils to articles for pre-university school students.

I was pleased to see that among the most popular articles were some of my personal favourites.

Understand

Unsurprisingly, our readers – mostly science teachers – are not put off by 'hard' science, including articles that present detailed explanations of scientific techniques or concepts.

✓ Biology, Health

✓ Ages 14-19

One of the most popular biology articles investigates the technique of genetic fingerprinting. In detective stories, the criminal is often identified by a drop of blood, a hair or other forensic evidence left at the scene. But how does this actually work? How was the technique of genetic fingerprinting developed? What else is it used for, and how can you try it in the classroom?

Image courtesy of Darryl Leja, NHGRI / NIH

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

✓ Biology, Chemistry

✓ Ages 14-19

Did you know that another technique used by forensic scientists can make blood glow in the dark? Have you ever wondered what makes fireflies glow? Or those glow-in-the-dark sticks? Find out how chemiluminescence works, how common it is in nature and how it's applied by humans.

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

For a hands-on activity about luminescence in biological organisms, see:

Farusi G, Watt S (2016) Living light: the chemistry of bioluminescence. *Science in School* **35**: 30-36. www.scienceinschool.org/2016/issue35/luminescence

✓ Biology, Physics

✓ Ages 11-19

Talking of objects that shine in the dark, have you ever gazed up at the Moon and asked yourself what Earth would be like without it? Perhaps you should. Not only does the Moon affect the tidal movement of the oceans, the length of the days and the weather on Earth, but without the Moon, we might not even exist.

Tranfield E (2013) Life without the Moon: a scientific speculation. *Science in School* **26**: 50-56. www.scienceinschool.org/2013/issue26/moon

Image courtesy of Erin Tranfield

Teach

Among the most-read articles were very simple hands-on experiments using everyday materials, but also more demanding activities requiring a little more preparation, such as sourcing material not usually found in the science department. Activities with an interdisciplinary aspect (for example, a link to history or music) also proved popular.

✓ Biology, Physics

✓ Ages 14-19

Back in the 1600s, Robert Hooke built his first microscope. Today it's surprisingly easy to build your own from simple materials – and then use it in the classroom to investigate the microscopic world around us.

Tsagliotis N (2012) Build your own microscope: following in Robert Hooke's footsteps. *Science in School* **22**: 29-35. www.scienceinschool.org/2012/issue22/microscope

If you prefer something more challenging, you could even build your own digital microscope or atomic force microscope.

Singh AP et al. (2015) Doing is understanding: science fun in India. *Science in School* **34**: 45-51. www.scienceinschool.org/2015/issue34/india

Theer P, Rau M (2011) Single molecules under the microscope. *Science in School* **18**: 60-64. www.scienceinschool.org/2011/issue18/afm

✓ Biology, Chemistry, Physics

✓ Ages 16-19

Staying at the microscopic scale, you could introduce your students to how the structure of proteins is used to investigate their function. Learn how proteins are crystallised and analysed using X-rays – and then grow your own protein crystals.

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

Image courtesy of Gaby Sennhauser, University of Zürich

✓ Physics, Astronomy / space

✓ Ages 11-19

If you prefer the larger scale, perhaps you'd like to build your own radio telescope? Astronomers use giant radio telescopes to observe black holes and distant galaxies, but a homemade radio telescope can be used to examine objects closer to home, including communication satellites and the Sun.

Malański B, Malański S (2012) Build your own radio telescope. *Science in School* **23**: 38-42. www.scienceinschool.org/2012/issue23/telescope

To learn more about how radio telescopes work, see:

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

Image courtesy of Ugur Evirgen/iStockphoto

Inspire

Science in School also publishes reviews of materials that are useful for teachers – such as books, websites or other resources. One of the most popular reviews was of science comics and cartoons. Often considered to be little more than a cheap pastime, they can in fact be very effective teaching materials.

Tatalovic M (2010) Science comics and cartoons. *Science in School* **14**. www.scienceinschool.org/2010/issue14/web

✓ Biology, Chemistry, General science, History

✓ Ages 4-14

Radio telescopes may be a bit advanced for primary-school pupils, but more familiar objects – such as a loaf of bread – also offer a wide range of interdisciplinary teaching opportunities. Investigating micro-organisms, pretending you're invading an unknown land, and making your own bread are just some of the ideas suggested in this article.

Lewis D (2012) Bread-making: teaching science in primary school. *Science in School* **23**: 33-37. www.scienceinschool.org/2012/issue23/bread

Image courtesy of foonus; image source: Flickr

Translations

From A for Albanian to U for Ukrainian, via Greek, French, Polish and Spanish: thanks to the efforts of our volunteer translators – over 200 scientists and teachers – you can read *Science in School* articles in 31 European languages.

Physics

Ages 4-14

Particularly popular among our Spanish-speaking readers was a collection of simple experiments to enable primary-school pupils to investigate what happens to solids, liquids and gases when we heat them.

Andersen E, Brown A (2012) El efecto del calor: experimentos sencillos con sólidos, líquidos y gases. *Science in School* **24**. www.scienceinschool.org/es/2012/issue24/energy

In English:

Andersen E, Brown A (2012) The effect of heat: simple experiments with solids, liquids and gases. *Science in School* **24**: 23-28. www.scienceinschool.org/2012/issue24/energy

Biology, Chemistry

Ages 14-19

Did you know that what you eat can affect your genes, making you more susceptible to diabetes, cardiovascular disease or obesity? Our diet influences not only our own health in this way, but can also affect that of our unborn children. This topic proved to be of particular interest to our Portuguese-speaking readers.

Florean C (2014) Alimentos que nos moldam: como a dieta pode mudar o nosso epigenoma. *Science in School* **28**. www.scienceinschool.org/pt/2014/issue28/epigenetics

In English:

Florean C (2014) Food that shapes you: how diet can change your epigenome. *Science in School* **28**: 34-45. www.scienceinschool.org/2014/issue28/epigenetics

Is your favourite article available in your native language? Perhaps you'd like to join our team of volunteer translators and make it – or other articles – available to a wider readership.

How do you use our articles?

Web statistics can tell us how many people visit each page, how long they stay, and how they found our website – but they can't tell us what we really want to know: how do you, our readers, use our articles? Which activities have you tried in the classroom? How did you adapt or extend them? Have any of our articles changed what you teach or how you teach it?

We'd love to hear from you, so do send your feedback to editor@scienceinschool.org

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

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Success with STEM: Ideas for the classroom, STEM clubs and beyond

by Sue Howarth and Linda Scott

Reviewed by Marie Walsh, Limerick Institute of Technology

Success with STEM: Ideas for the classroom, STEM clubs and beyond is an excellent resource, brimming with ideas to support teachers of science, technology, engineering and maths (STEM). Authored by two science education lecturers with significant experience in teaching and professional development, the book is designed to inform and enthuse both experienced and newly qualified teachers, giving guidance and explanations of initiatives that engage students and teachers in a more positive learning experience.

The book is divided into 11 chapters plus a glossary, and an extensive range of figures and tables supports each topic. *Success with STEM* also describes real-life examples of successful projects in schools that have supported both formal and informal STEM education – hence the title referring to the classroom and beyond. Although the book starts in the context of the British national curriculum and the needs-driven STEM agenda in the UK, it expands to encompass international ideas, and is a useful text for STEM teachers no matter where they are based.

The 5Es approach is advocated in the chapter on making lessons 'buzz': enrich, enhance, engage, experience, enjoy! Authors Sue Howarth and Linda Scott acknowledge that it is not necessary to have all of these in every lesson but they illustrate ways in which one or more of them can be incorporated using everyday examples, current issues, case studies or project work. They go on to describe ways in which teachers can provide opportunities for students beyond the classroom, from work in the school grounds and with the local community, including site visits to more formally in competitions, fairs and festivals. They give comprehensive lists of examples of activities – not just for students but also for teachers in the context of continuing professional development.

There is a chapter on encouraging STEM careers, but one important point made early in the text is that while not all students will engage with STEM, all students should have some scientific literacy and an awareness of the role of science in modern society. If students take nothing else from compulsory curriculum subjects, they should leave with transferable skills such as communication, problem-solving and literacy, and an appreciation of STEM, which provides opportunities for the development of such skills.

Needless to say, funding can be an issue and the authors provide advice on sources of funding as well as free resources. Chapter 9 includes some ten pages of website links and advice on social media such as Twitter.

Howarth and Scott give advice on setting up a STEM club in school as well as ways to enhance existing clubs and increase involvement with competitions, fairs and festivals. Throughout the text, it is obvious that the authors are sharing actual experiences rather than writing theoretically. Key information on health, safety and legal issues is given in a factual way – again with lists of resources that can help teachers navigate these highly important areas.

The book concludes with ideas from international projects and an 'ideas bank' for all projects. This book is a valuable resource, easy to read and a fountain of information. It is highly recommended for all teachers.

Details:

Publisher: Routledge
Publication year: 2014
ISBN: 978-0-415-82289

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Illusioneering

by Peter McOwan and Matt Parker

Reviewed by Daniel Gomez-Dominguez

At first glance, science and magic seem like chalk and cheese, but as the writer Arthur C Clarke pointed out, "any sufficiently advanced technology is indistinguishable from magic." The feeling of wonder that keeps scientists hooked to their research can also captivate a magician's audience. Illusioneering, an online resource created to teach science, technology and engineering using magic tricks, aims to use this same emotion to keep students interested in science.

On the *Illusioneering* website you will find ten magic tricks with detailed explanations of the science behind them in PDF guides and Youtube videos. The tricks are all easy to perform and cover diverse science topics suitable for students over 8 years old. More importantly, the tricks are amazing. Making a coin disappear inside a glass of water can help to explain the optical distortion of light in liquids, while inflating an unburstable balloon can lead the class to a multidisciplinary discussion of air pressure dynamics, topology and sight.

The website's authors, Peter McOwan and Matt Parker, are magicians and experienced scientists at Queen Mary University of London, UK. They have been exploring their shared interest in science education with magic for some years now and have published two books together on the subject: *The Manual of Mathematical Magic* and *The Magic of Computer Science*. Both resources are downloadable free on their personal websites.

Over the centuries, magicians have been inspired by the latest scientific discoveries to develop new tricks, and in the process learned basic science. *Illusioneering* can help you to reproduce that learning process in a classroom setting, offering students the opportunity to experience the full wonder of science.

Details

Website: www.illusioneering.org

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Image courtesy of Nicola Graf

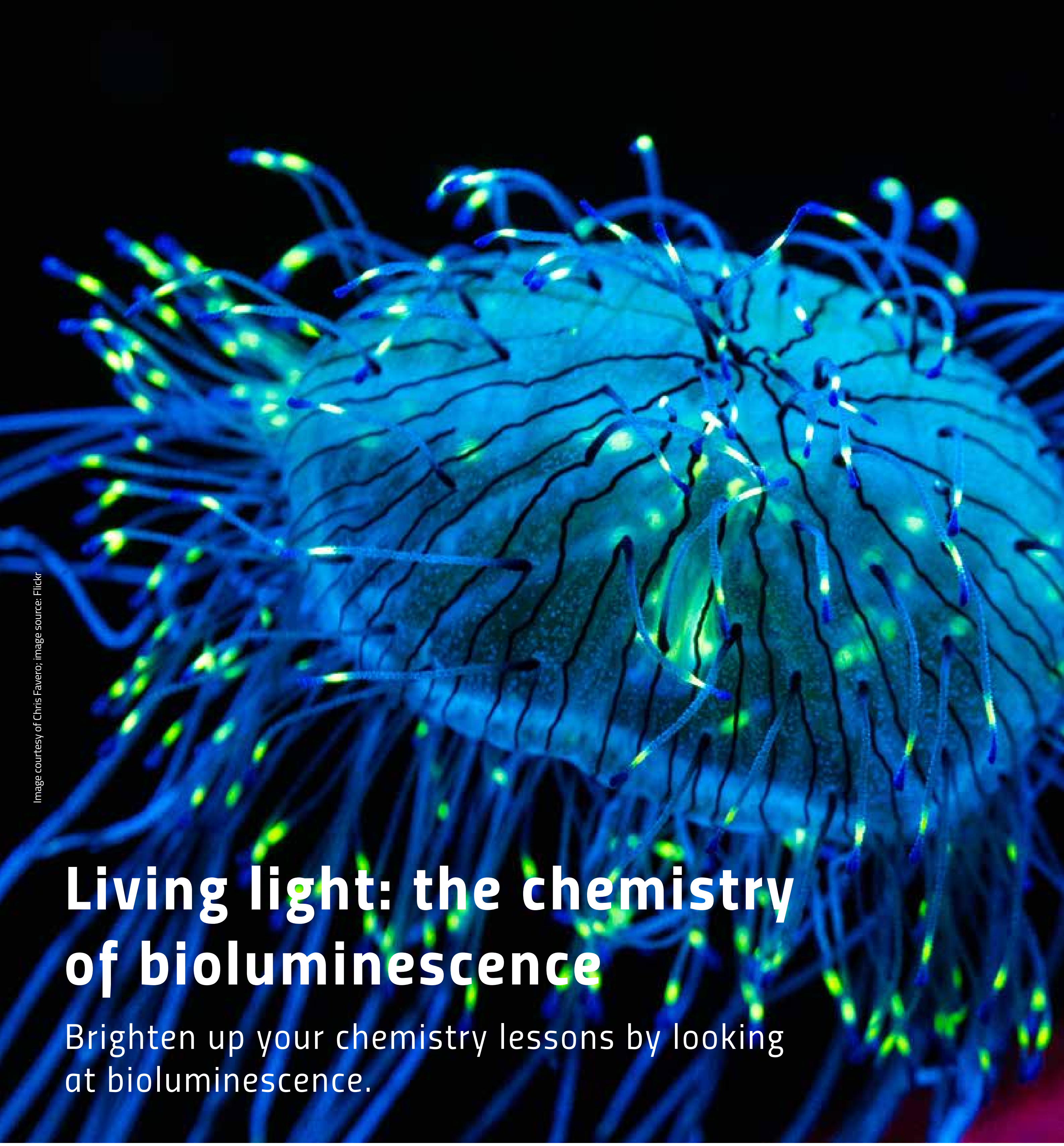


Image courtesy of Chris Favero; image source: Flickr

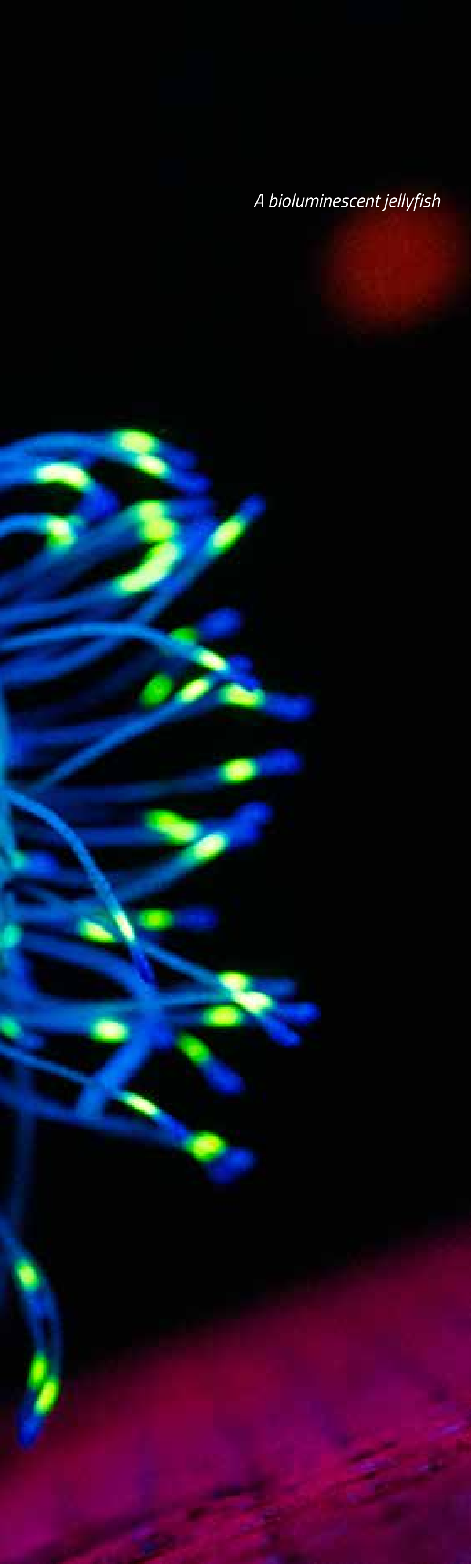
Living light: the chemistry of bioluminescence

Brighten up your chemistry lessons by looking at bioluminescence.

By Gianluca Farusi and Susan Watt

Bioluminescent displays are one of the world's natural wonders. The sheer beauty of the dancing lights from fireflies, or the glowing blue waves caused by ocean plankton, have fascinated people for millennia. While we still find visual delight in such displays today, we are now able to understand the chemistry that makes them happen – and even adapt it for use in the laboratory and elsewhere.

A wide range of organisms, from insects, fish and molluscs to bacteria and plankton, can produce light – as has been known for thousands of years. The Roman author Pliny the


A bioluminescent jellyfish

Elder described an edible shellfish, *Pholas dactylus*, that, rather unnervingly, emits light when it is eaten. He also noted that a tree fungus, *Omphalotus olearius*, produces a brilliant glow at night.

Perhaps the most spectacular bioluminescence displays come from dinoflagellate plankton, which cause the glowing blue waves sometimes seen on the ocean's surface. More exotic forms of bioluminescence are found in the ocean depths; where there is no sunlight at all, many species make their own illumination. Famously, angler fish use a dangling light to lure their prey straight to their teeth.

Bioluminescence – light produced by living organisms – is widespread in nature, but what advantage does it give the species that use it? In fact, there are many, including:

- Aposematism (toxic appearance) – to look inedible to potential predators. Example: the fireflies *Photinus ignitus* and *Lucidata atra*.
- Defence – to startle predators by emitting a bright flash at close range. Example: sternchasers, a type of myctophid or lanternfish.
- Courtship – to communicate before or during mating. Example: fireflies.
- Lures – to attract prey to the light source. Example: the angler fish.
- Camouflage – to help the animal to blend in with its background. As seen from below, a sea animal will look dark against the brightness of the water surface above, so producing its own light will help it to hide from potential predators. Example: squids such as *Abralia verany*.

Glowing colours

In nature, bioluminescence produces different colours: mainly blue, green and yellow. The distinctive colour of light that a species emits depends on the environment in which it has evolved. Blue emissions usually occur in the deep ocean, green emissions in species that live along the coastline, and yellow (and also green) emissions typically in freshwater and terrestrial species.

What is the chemistry that makes bioluminescence happen? And how are the different colours – blue, green, yellow – obtained?

Chemically, most bioluminescence is due to oxygenation reactions: oxygen reacts with substances called luciferins, producing energy in the form of light. The reactions are catalysed by enzymes known as luciferases. In this process, the luciferins become oxygenated to form oxyluciferins. As table 1 shows, the luciferins used by different species and the resulting oxyluciferins can be quite varied chemically.

These reactions are very efficient, with about 98% of the energy involved being released as light. This compares with an efficiency as low as 2% for a traditional

REVIEW

- ✓ Chemistry
- ✓ Biology
- ✓ Luminescence
- ✓ Ecology
- ✓ Ages 16-19

Bioluminescence has fascinated people for thousands of years and continues to be a popular subject of research, particularly in oceanic exploration projects. The chemical reactions that lead to the production of light by organisms are a great example of biochemistry. The practical activity described in this article is useful for engaging and entertaining students and provoking scientific discussion.

Marie Walsh, Limerick Institute of Technology, Ireland

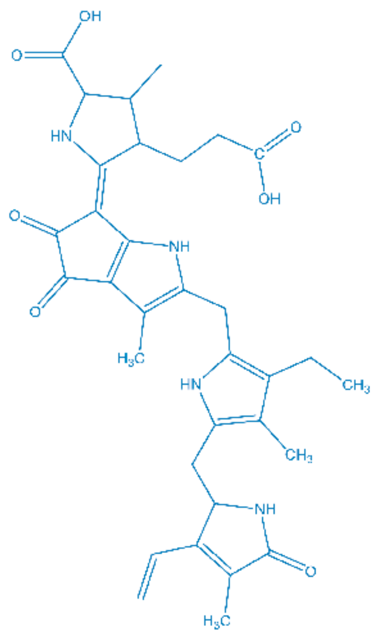
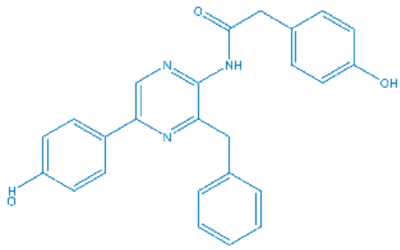
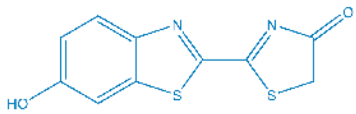
Bioluminescent species	Luciferin	Oxyluciferin
Dinoflagellates	Dinoflagellate luciferin $C_{33}H_{38}0_6N_4Na_2$	
Squid, some shrimps, some fish	Coelenterazine $C_{26}H_{21}0_3N_3$	
Fireflies	Firefly luciferin $C_{11}H_8N_2O_3S_2$	

Table 1: The different luciferins and oxyluciferins found in various bioluminescent species

filament light bulb, which also releases large amounts of energy as heat.

As well as occurring in different species, some luciferins can produce more than one colour of light (see table 2). Additional light-emitting substances, or fluorophores, can also change the colour of the luminescence. The jellyfish *Aequorea victoria* contains one such fluorophore, known as green fluorescent protein (GFP). GFP absorbs the blue light produced by the initial reaction and re-emits it at a longer wavelength as green light, so the jellyfish produces a green bioluminescence.

In recent decades, this particular bioluminescence system has found an important use in scientific research: the gene that encodes GFP is now used as a genetic 'tag' to trace specific proteins and to reveal when particular genes are expressed. Because GFP glows green under blue or UV light, it is very easy to detect (see Furtado, 2009). This work was considered so important that it was awarded the Nobel Prize for Chemistry in 2008[w2].

Fortunately for us, it is quite easy to replicate in the laboratory the type of chemical reaction that causes bioluminescence, as the activity below demonstrates.

Student activity: bioluminescence in the laboratory

In this activity, students can see a luminescence reaction take place when chemical reagents are mixed together. The key ingredient is luminol, a synthetic chemiluminescent substance that produces a blue glow when it reacts chemically. Although the reactions of luminol and luciferin are different – the oxidation reaction of luminol is catalysed by potassium ferricyanide rather than by an enzyme (for more details, see Welsh, 2011) – the result is the same: luminescence.

The final step in the activity should be carried out in a dark place to make the most of the light show.

Materials

- 1 g luminol (5-amino-2,3-dihydroph-thalazine-1,4-dione)
- 50 ml sodium hydroxide (NaOH) 10% w/w solution
- 50 ml potassium ferricyanide ($K_3[Fe(CN)_6]$) 3% w/w solution
- Approximately 0.5 g potassium ferri-cyanide ($K_3[Fe(CN)_6]$)
- 3 ml hydrogen peroxide (H_2O_2) 30% m/m solution
- Distilled water
- Beakers
- Funnel
- Cylinders
- Flask

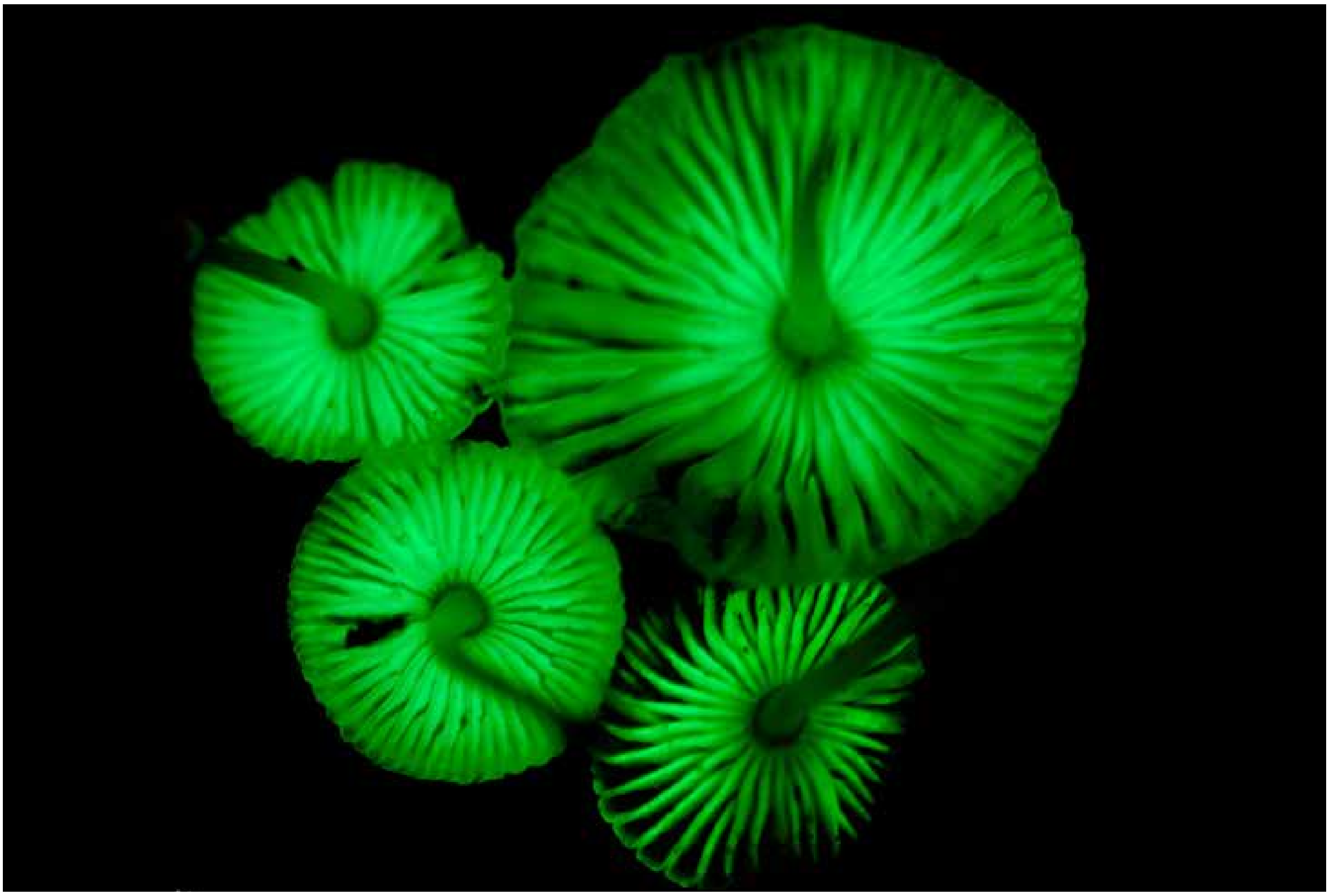
Procedure

Safety note: Safety glasses, a lab coat and safety gloves should be worn. Care should be taken when handling the 30% hydrogen peroxide solution, as this can react violently in the presence of a catalyst. Close the bottle as soon as you have removed your 3 ml of solution.

See also the general *Science in School* safety note on the journal website.

1. In a beaker, dissolve 1 g luminol in 450 ml distilled water.
2. Add 50 ml 10% sodium hydroxide solution and mix.
3. Take 50 ml of the resulting solution

Image courtesy of Paul Williams; image source: Flickr



Bioluminescent fungi

Luciferin	Luminescence maximum (nm)	Approximate colour[w1]	
Firefly luciferin	560 (at pH=7.1)	Green	
	615 (at pH=5.4)	Orange	
Bacterial luciferin	490	Turquoise	
Dinoflagellate luciferin	474	Blue	
Coelenterazine	450-480 as an anion	Blue to turquoise	
	400 in the – COOH form	Purple	

Table 2: The colours of some specific luciferins

and add it to 350 ml distilled water in another beaker. This is now Solution A.

4. In a third beaker, mix 50 ml 3% potassium ferricyanide solution with 350 ml distilled water and 3 ml 30% hydrogen peroxide solution. This is Solution B.
5. Pour equal amounts of Solutions A and B into separate cylinders.
6. Put some potassium ferricyanide into the flask, and place the funnel on the flask.
7. Move the flask to a dark place.
8. Pour Solutions A and B into the flask **at the same time**, and watch what happens.

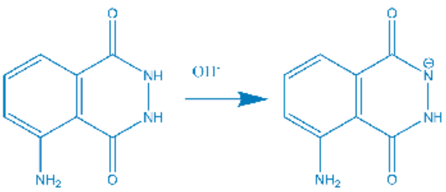
A wonderful light-blue luminescence will start at once!

9. Disposal: heat the solution in a fume cupboard to concentrate it until the volume is 1/8 of the initial amount, then pour the remaining solution into the heavy metal residuals tank.

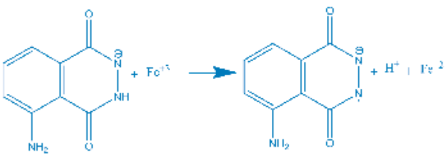
What is happening?

The oxidation of luminol occurs in several steps.

1. While Solution A is being prepared (step 2), luminol reacts with the base (OH^-):

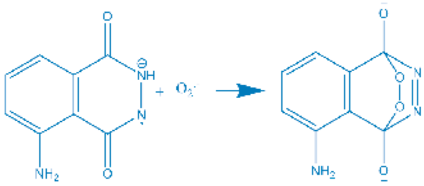


2. When Solution B is prepared (step 4), hydrogen peroxide decomposes to form the superoxide radical anion $O_2^{\cdot-}$. This reaction is catalysed by the hexacyanoferrate (III) ion.
3. When Solutions A and B are mixed (step 8), luminol is oxidised by the hexacyanoferrate (III) anion, forming a radical anion:

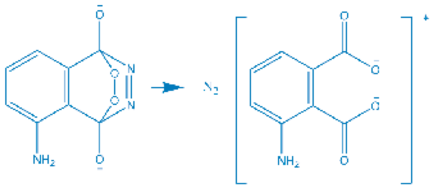


The hexacyanoferrate ion therefore has a dual role: it catalyses the formation of the superoxide radical anion, $O_2^{\cdot-}$, and also oxidises luminol into a radical anion. The iron needs to be in the form of a complex such as $[Fe(CN)_6]^{-3}$, to prevent the precipitation of $Fe(OH)_3$ in the strongly alkaline environment.

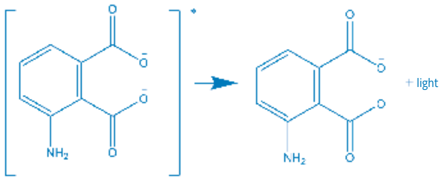
4. The luminol radical anion and the superoxide radical anion, $O_2^{\cdot-}$, then react:



5. The resulting compound is unstable and decomposes to produce nitrogen and an excited form of the aminophtalate ion:



6. The excited form then transforms and decays into a stable form, emitting the energy difference as light:



Questions for discussion

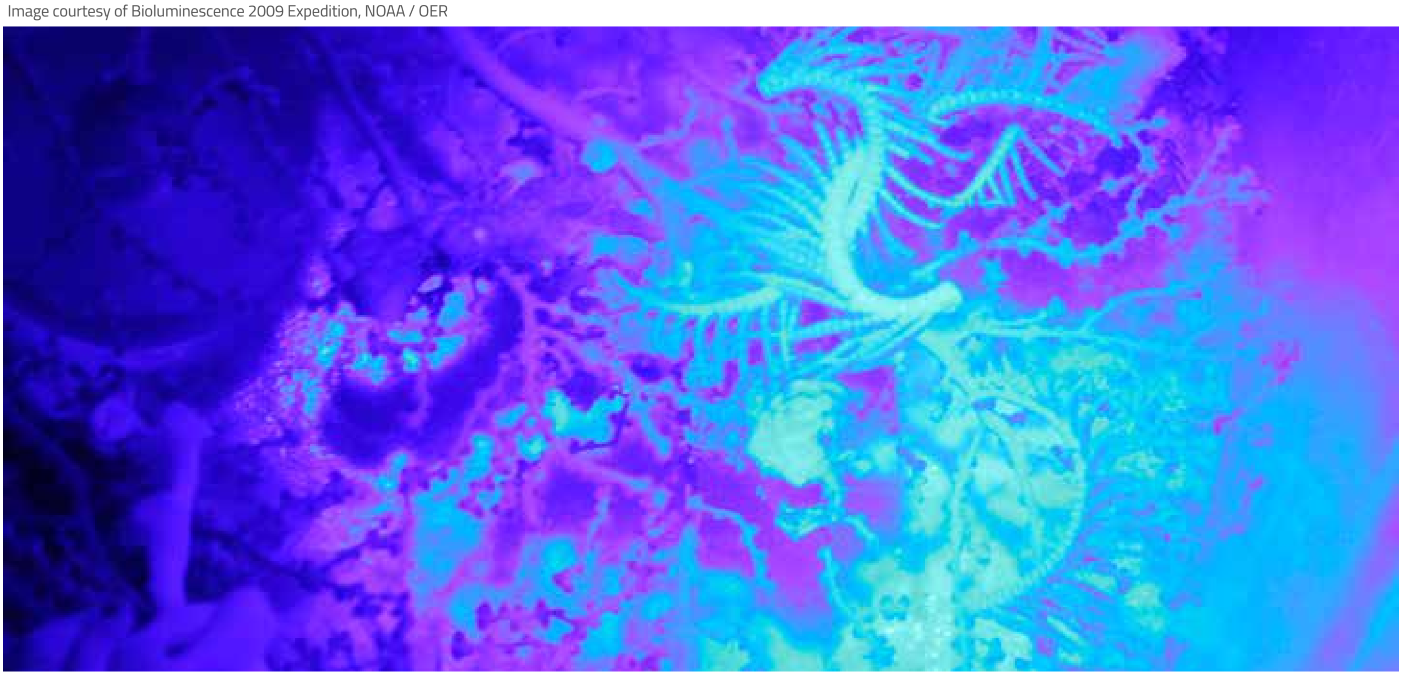
- In the luminol reaction, where does the energy for the light come from?
- What is the role of the potassium ferricyanide? In natural luminescence reactions, what substance performs this role?
- Which substance is responsible for oxidation in the luminol reaction? Is this the same in nature?

Extension

There is a great deal of information available about bioluminescence (see the resources section for examples). Students can follow up this activity with some research of their own. For example:

- Uses of bioluminescence in nature. Find more reasons why bioluminescence is a useful adaptation. For each adaptation, identify some species that benefit from it.
- Bioluminescence chemistry. Find out about some specific chemiluminescence reactions that occur in nature.

Image courtesy of Bioluminescence 2009 Expedition, NOAA / OER



Bioluminescing coral and crinoids (sea lilies) in the North Atlantic

Image courtesy of Terry Priest; image source: Flickr

A firefly, Photinus pyralis

How similar are they to the luminol reaction?

- Bioluminescence colours. Find out more about how they are produced.
- Evolution of bioluminescence. Has it evolved many times or just once?
- Uses of luminol in crime-scene investigations. Find out how luminol is used forensically and the chemistry of this use (e.g. see Welsh, 2011).

References

Farusi G (2006) Teaching science and humanities: an interdisciplinary approach. *Science in School* **1**: 30-33. www.scienceinschool.org/2006/issue1/francesca

Farusi G (2007) Monastic ink: linking chemistry and history. *Science in School* **6**: 36-40. www.scienceinschool.org/2007/issue6/galls

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

Background

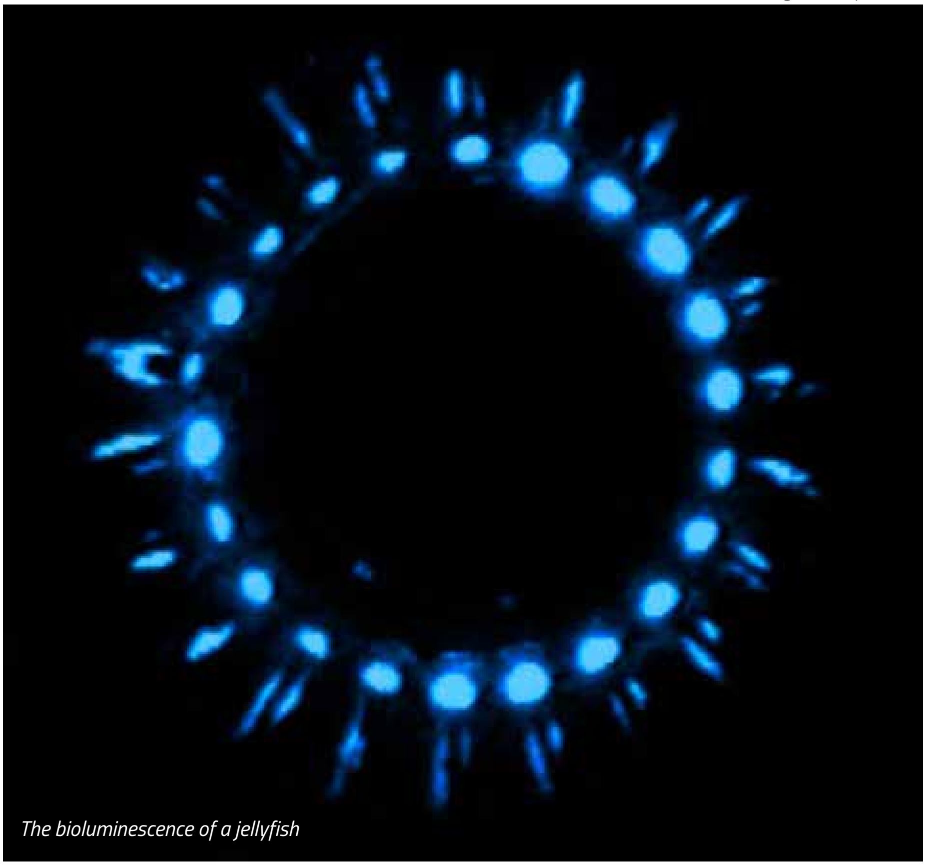
Studying chemistry with Pliny the Elder

This activity is part of a larger interdisciplinary project, developed together with 14- to 15-year-old students, to explore ancient scientific techniques. Pliny the Elder (23-79 AD) was a Roman author and naturalist whose encyclopaedia, *Naturalis Historia*, brought together much of the scientific knowledge of the time. We began each topic by discussing a passage from *Naturalis Historia* and then worked out how to recreate either the experiment described in the text or something similar.

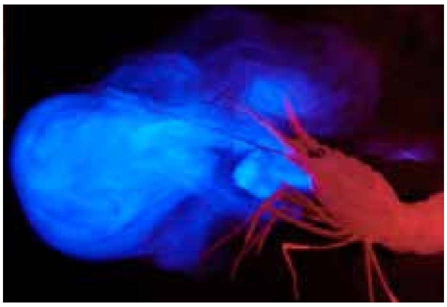
In this way, the students began in the same pre-scientific state as Pliny and, through laboratory work and discussion, gained modern scientific knowledge on each of the topics. The process motivated even the most unenthusiastic students.

Other activities in the project include synthesising indigo (Farusi, 2012), recreating ancient perfumes (Farusi, 2011), preparing glass tesserae with boric acid and preparing iron-gall ink (Farusi, 2007). The whole project was presented at the international Science on Stage festival[w3] in Copenhagen, Denmark, in 2011.

Image courtesy of NOAA



The bioluminescence of a jellyfish



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

Furtado S (2009) Painting life green: GFP. *Science in School* **12**: 19-23. www.scienceinschool.org/2009/issue12/gfp

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

Web references

w1 A simple tool to convert a wavelength in nanometres to an RGB or hexadecimal colour is available on the Academo website, a free collection of educational resources. See: http://academo.org/demos/wavelength-to-colour-relationship

w2 An accessible account of the 2008 Nobel Prize for Chemistry awarded to Osamu Shimomura, Martin Chalfie and Roger Y Tsien is available on the Nobel Prize website. See: www.nobelprize.org or use the direct link: http://tinyurl.com/p869fec

w3 Science on Stage is a network of local, national and international events for teachers, initially launched in 1999 by EIROforum, the publisher of *Science in School*. At each national event, a delegation of teachers is selected to represent their country at the Science on Stage international teaching festival. During the festival, about 350 primary- and secondary-school teachers from 25 countries will share their most innovative teaching ideas in workshops, on-stage performances and the teaching fair.

The next international festival will be held on 29 June–2 July 2017, in Debrecen, Hungary. Participants will be chosen through competitive national events in 25 countries. To find out more information about the application process, contact your national steering committee. See: www.science-on-stage.eu

Resources

Two accessible articles about (bio)luminescence:

Douglas P, Garley M (2010) Chemistry and light. *Science in School* **14**: 63-68. www.scienceinschool.org/2010/issue14/chemlight

Judson O (2015) Luminous life. *National Geographic*. www.nationalgeographic.com or use the direct link: http://tinyurl.com/qg7xzh5

A charming and informative animation about bioluminescence. See: www.youtu.be/oKjFVBVGad0

An atmospheric video with music celebrating the extraordinary beauty of ocean bioluminescence. See: www.youtu.be/uUbIWqiynBY

A short video demonstrating how to make luminol. www.youtu.be/IB_g2ddZZYk

A longer video showing how to make luminol. www.youtube.com/watch?v=58Ve69s0qD0

Gianluca Farusi teaches chemistry at the technical school (*Istituto Tecnico Industriale*) Galileo Galilei in Avenza-Carrara, Italy. Since 2004, he has also lectured in stoichiometry at the University of Pisa, Italy, for the degree programme in medicinal chemistry and technology. In addition, he is the regional tutor for the Italian ministerial project '*Insegnare Scienze Sperimentali*' ('teaching experimental sciences') and the regional REACH (registration, evaluation, authorisation and restriction of chemicals) tutor for secondary schools. Gianluca has been teaching for 20 years and nothing gratifies him more than the delight on his students' faces when they grasp a difficult chemical concept.

Susan Watt is a freelance science writer and editor. She studied natural sciences at the University of Cambridge, UK, and has worked for several UK publishers and scientific organisations. Her special interests are philosophy of science and science education.

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Sunspots on a rotating Sun

Explore simple harmonic motion with real astronomical images.

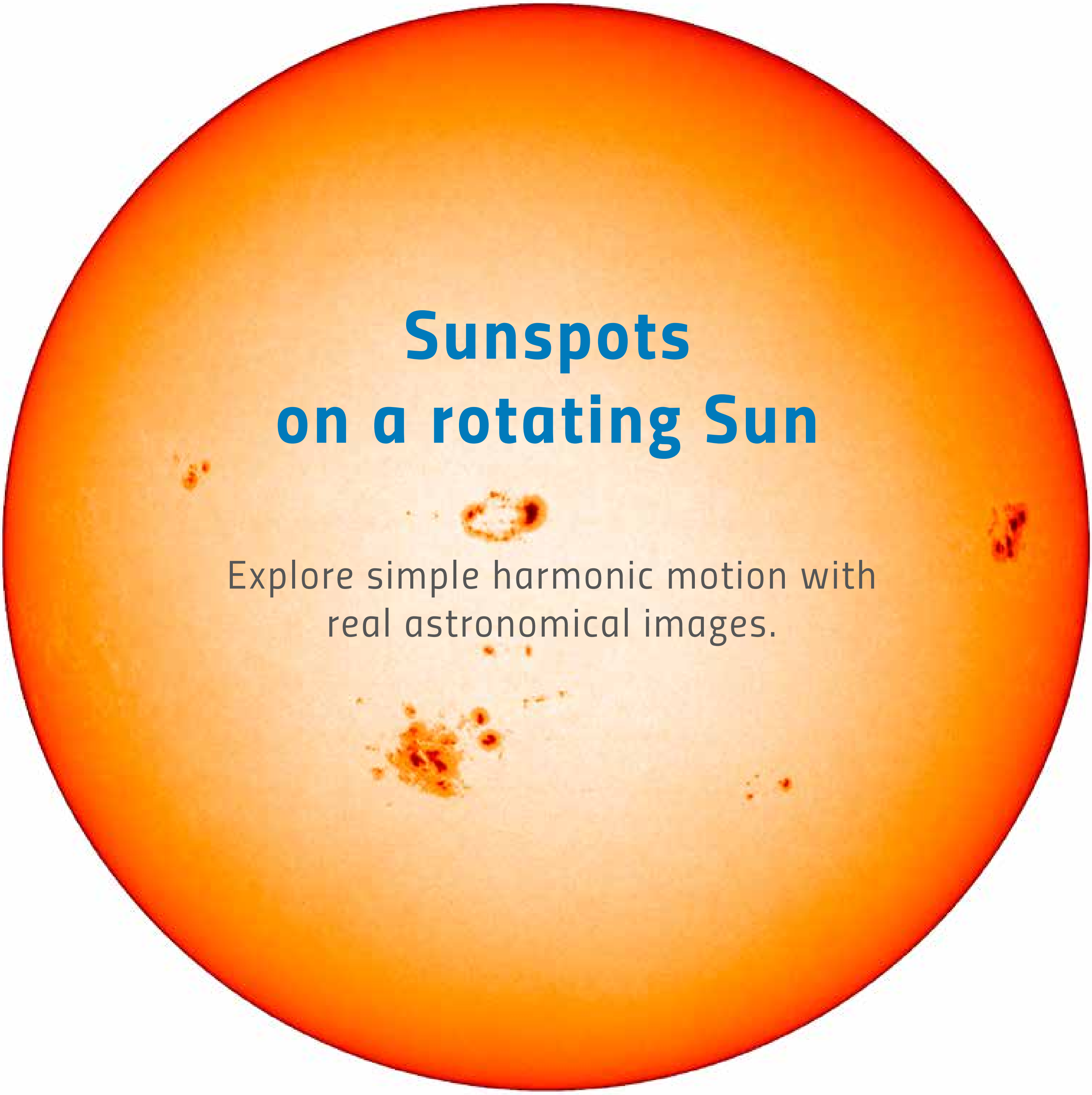

Image courtesy of SOHO (ESA and NASA)

By Carla Isabel Ribeiro

In this journal a few years ago, I described using Jupiter's moons to explore simple harmonic motion and mentioned that I would like to extend the project internationally (Ribeiro, 2012). This came to pass, but using a different astronomical phenomenon – sunspots. In 2013 and 2014, students from France, Greece, Italy, Poland, Portugal, Romania and Spain participated in an eTwinning project[w1] to determine the Sun's rotational period using sunspots. They designed their own experiments, prepared reports and worked with real data from the Solar and Heliospheric Observatory (SOHO) database maintained by NASA[w2].

Based on their work, this activity explains how to use equations relating to simple harmonic motion and sunspot images with a class of students aged 16-19. The main activity lasts approximately one hour but there are also extension ideas for a multi-lesson project, and you could even set up a network of classes similar to ours.

Sunspots and simple harmonic motion

Sunspots are temporary dark spots on the surface of the Sun. If we assume that they have no motion, we can use them to track the Sun's rotation.

Image courtesy of Nicola Graf

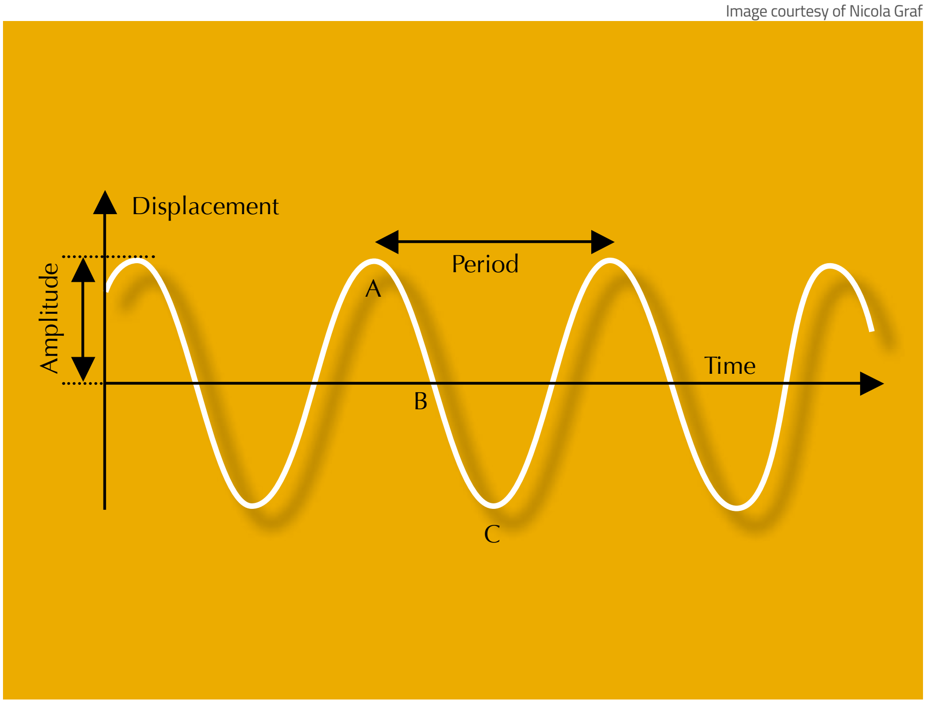

Image courtesy of the author Carla Isabel Ribeiro

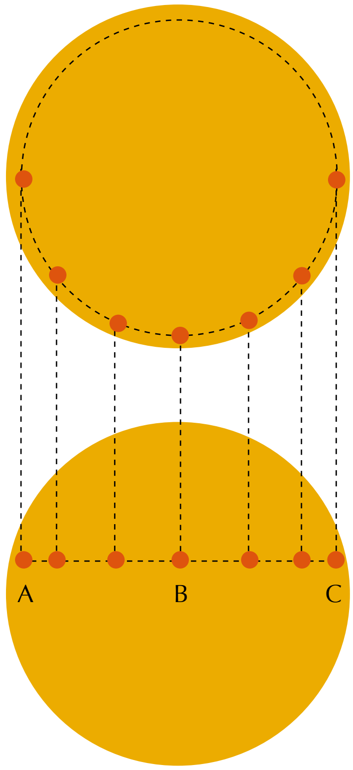

Figure 1: The movement of a sunspot as seen from above the orbital plane and from Earth (parallel to the orbital plane).

As seen from Earth, a sunspot shows simple harmonic motion. Simple harmonic motion (SHM) is the term used to describe regular periodic motions such as the swinging of a pendulum or the oscillations of an object attached to a spring.

For this experiment you can use images of sunspots taken by SOHO (Solar Heliospheric Observatory), a space-based observatory that investigates the Sun from its deep core, through its atmosphere and the domain of the solar wind.

Materials

- Several images of the same sunspot taken at different times, obtained from SOHO. During our project we used images taken one day apart.
- Ruler
- Pencil
- Graph paper
- Calculator

Procedure

1. If you are running this experiment as part of a larger project, you could begin as we did by asking your students to research the Sun and sunspots: what they are, and perhaps their link to Earth's climate and aurorae.

   The Sun, like all stars, is a globe of hot plasma – mainly ionised hydrogen undergoing fusion. This fusion releases energy in the middle of the Sun that is released as electromagnetic radiation by the atmosphere. As a result, the Sun glows.

   Sunspots occur when concentrations of the Sun's magnetic field inhibit the convection of the charged plasma. This lower convection reduces the surface temperature. Temperatures in the dark centres of sunspots drop to about 3700 K (compared with 5700 K for the rest of the Sun's surface) and so the surface appears much darker.
2. To determine the Sun's rotational period using images of a sunspot from the SOHO database, each group should measure the displacement (x) – the distance of their sunspot from the central axis of the Sun – at a succession of times (t) with a ruler.
3. The groups should record their data in a table and note the maximum possible displacement (the distance from the rotational axis to the outside edge of the Sun's image at the latitude of the sunspot).

   SHM can be interpreted as a projection onto one axis of an object that is moving with a uniform circular motion (UCM). In other words an object moving in a circle in the horizontal plane viewed from the side (equivalent to projection onto the x axis) will show the same to-and-fro motion as an oscillating

Image courtesy of Nikos Kyriazopulos

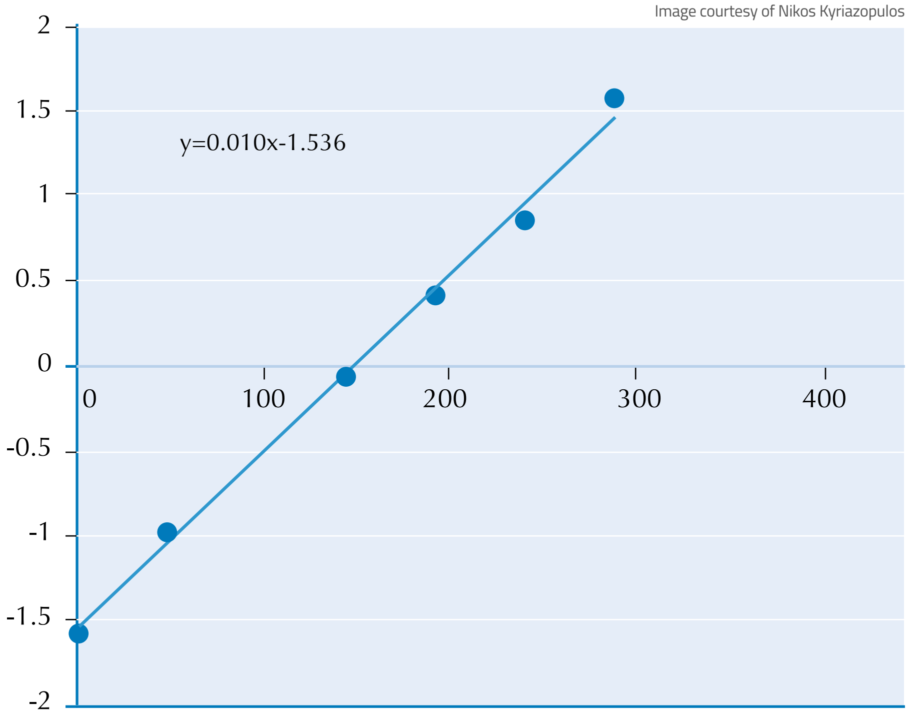

Figure 2: Results presented by the Greek students, plotting arcsin(x/A) on the y axis and the time in hours on the x axis which gave a rotational period of 26 days

object attached to a spring. Only when viewing the motion from above would we see the movement as circular. Plotting a graph of this motion (distance from the central point against time) produces the characteristic form of a sine wave (figure 1).

This is what should be apparent when measuring the horizontal displacement of the sunspots; they appear to move faster near the rotational axis at the centre of the Sun and slower as they approach the outer edges, as if they were attached to a spring. The relationship between the two motions (SHM and UCM) is represented by the equation:

$$x = A\sin(\omega\, t + \varphi) \qquad (1)$$

Where x and A are the displacement and the maximum displacement on the linear trajectory of the sunspot as seen from Earth, respectively. The physical quantities ω and φ are the angular frequency and the phase constant of the circular motion when seen from the solar pole, respectively. Because angular frequency $\omega = 2\pi / T$, where T is the orbital period, equation 1 can be rewritten as:

$$x = A\sin[(2\pi / T)\, t + \varphi] \qquad (2)$$

$$\arcsin(x / A) = (2\pi / T)t + \varphi \qquad (3)$$

4. The students should calculate arcsin(x/A) for all of their measured values of x and then plot a graph of arcsin(x/A) against t (figure 2).
5. They should then draw a line of best fit for the data.
6. Measuring the gradient of the line will give the rotational period of the Sun. In the example above (figure 2), the gradient is 0.01 radians per hour and so $T = 2\pi/w = 628.3$ hours = 26 days.

Extending the activity

If you wish to extend this activity, each student can repeat the experiment using images of a sunspot of their choice. This time, they should also measure the sunspot's latitude, allowing them to compare the Sun's rotation at different latitudes by comparing their results with those of other students.

Measuring the rotation at different latitudes should show that the Sun has a differential rotation: because it is not solid, the rotational period near the

REVIEW

✓ Astronomy
✓ Physics
✓ Maths
✓ Ages 16+

As with the stars of the night sky, too few young people today have seen sunspots – although they are fascinating and have played a role in the development of the science of astronomy. (If you'd like to see them for yourself rather than using the pictures here, view the Sun through well darkened glass or by projection through a pinhole. Take care: looking directly at the Sun can cause eye damage. Note, though, that sometimes there are few spots for months or even years.)

If you measure the horizontal position of a given sunspot as the days pass, you will have a fraction of a cycle of simple harmonic motion. In the article, this information is used to work out the Sun's period of rotation with a surprising result.

Eric Deeson, UK

The Italian, Greek, Spanish and Romanian students, respectively

Image courtesy of Franca Sormani, Nikos Kyriazopulos, Cristian Bordeianu and Marta Estrada Ibars

poles (about 34 days) is more than at the equator (about 25 days). Discuss why this might be with your students.

Can you think of how to improve this project or would you like to set up a similar European network with other schools? We encourage you to comment on the online version of this article at www.scienceinschool.org/2016/issue35/sunspots.

Reference

Ribeiro C (2012) Galileo and the moons of Jupiter: exploring the night sky of 1610. *Science in School* **25**: 41–47. www.scienceinschool.org/2012/issue25/galileo

Web references

w1 The eTwinning portal is run and managed by European Schoolnet and is a virtual meeting point for the exchange of information between schools. For more information, see: www.etwinning.net

w2 You can download real-time data from the Solar and Heliospheric Observatory (SOHO). SOHO is a project of international cooperation between the European Space Agency and the US National Aeronautics and Space Administration: http://sohodata.nascom.nasa.gov/cgi-bin/data_query

w3 The different methods used by the students during the project are described by the students themselves on the project's MagazineFactory site: http://magazinefactory.edu.fi/magazines/Sunspots/index.php

Resources

In our project the participants used different methods to measure the displacement of the sunspots, from simply using a ruler or drawing a grid onto the images of the Sun to using image processing software, and these are described on the project website[w3].

Wikimedia Commons hosts several sunspot videos including one of sunspots forming: http://tinyurl.com/zm4xssh and one showing the rotation of the sun with sunspots: http://tinyurl.com/hgpn2r7

The Alienworlds website from the University of South Wales has an animation that explains the Sun and sunspots. http://alienworlds.southwales.ac.uk/sunStructure.html#/photosphere

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Earth and Moon from space

Image courtesy of NASA

Geometry can take you to the Moon

Measure the distance from Earth to the Moon using high-school geometry and an international network of schools and observatories.

By Davide Cenadelli, Albino Carbognani, Andrea Bernagozzi and Cristina Olivotto

Imagine stretching your arm out and looking at your thumb, first with one eye, then with the other. The apparent shift of your thumb with respect to the background is called parallax. The same principle applies if two different schools 'look' at the Moon: they will see it slightly shifted with respect to the stars in the background.

In this activity, schools in different continents pair up so students aged 16-19 can compare their observation of the Moon across distances and calculate Earth's distance to it (figure 1). Equipped with only a good camera and a good knowledge of geometry, the observation takes approximately 1 hour and the calculation 3 hours (establishing the partnership might take a little longer…).

Defining the right conditions

The overall observation plan for the activity is detailed in figure 1, where M is the Moon, depicted as a point because its size is very small compared to the distance calculated (approximately 1/100th).

As in many scientific endeavours, planning is key. In this case, in addition to defining the right conditions to make the observations, the teacher needs to determine what margin of error is acceptable: this is important so the pupils are not disappointed if they don't find the exact distance. Below we list a number of important points to highlight when discussing the activity with the class, but also when setting up the partnership with another school.

Figure 1 shows how two observers (A and B) will see the Moon, M, as being in two slightly different positions in the sky. While in practice the two observation points, A and B, M, and the centre of Earth, C, do not lie on the same plane, to simplify the calculations so that we can use planar trigonometry alone we assume that they do.

For that approximation to be as exact as possible, the two observation points need to be at the same longitude, and the Moon should be at its highest point (in culmination)[w1] at the moment of the observation. This ideal situation is very difficult to obtain but we recommend that you stay as close to it as possible and that you are aware of the errors implied by sizeable deviations from such conditions.

Moreover, if the Moon's angle with the celestial equator (declination)[w1] is equal to the average of the latitudes of A and B, ABM forms an isosceles triangle and this further simplifies the calculations.

Having the right sky in the background

You will also need at least two bright stars[w1] (or planets) in the background to find the two apparent positions of the Moon, M_A and M_B.

Geometrical assumptions

Then we will consider that the two straight lines AM_A and BM_A are almost parallel, as are AM_B and BM_B. This would mean that the angles $\alpha \approx \alpha'$ (figure 1). While not strictly true, this assumption is acceptable, as the pairs of lines converge far from both Earth and the Moon. Of course, this appears to be very far from true in figure 1, because it is not drawn to scale.

If we measure the angle α and the distance AB – known as the baseline – plus another angle in the triangle ABM, we can calculate all the other distances. Otherwise, we can make the triangle ABM become isosceles, and knowledge of α and AB is sufficient to calculate all the distances.

A key point is that the baseline must be long enough, when compared to the distance we want to find, to prevent the parallax from becoming vanishingly small. For the Moon, a distance between the partner schools of around 1000 km is enough, but the larger it is, the better.

But there will still be errors…

Despite all the care that will go into choosing the best conditions, the measurements will not be perfect. The main sources of error are:

a) Imprecision in spotting the shift of the Moon in the two images, mainly because of overexposure of the Moon's disk;

b) A, B, C and M not lying exactly in a plane;

c) Distortions due to camera lenses;

d) Observation conditions;

e) Atmospheric refraction;

f) Time synchronisation.

Errors due to d) and e) are not very important: our measurement is based upon large angles and so is not affected greatly by an imprecision of a few arcseconds.

Time synchronisation (f) is not very important either because the Moon travels the equivalent of its own diameter in one hour, so an imperfect synchronisation of a few seconds (or even minutes) is not relevant.

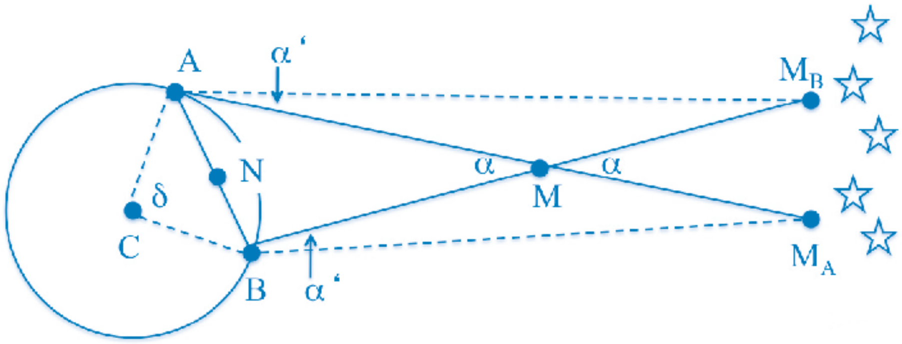

Image courtesy of the authors

Figure 1: A and B are two positions on Earth (two schools for example) as seen from above the pole; N is the middle between A and B; M is the Moon; M_A and M_B are the places where the Moon appears to be in the sky, as viewed from A and B, respectively; α is the parallax angle

REVIEW

✓ Physics
✓ Maths
✓ Astrophysics
✓ Geography
✓ Computer science
✓ Ages 14-16

This article describes a nice way to bring together mathematics with other science subjects, such as physics. It shows how to calculate the distance to the Moon or even Mars by using your own data from camera images and from your partner institution (e.g. the parallax network). Using pure mathematics – or pure applied mathematics, since you are solving a real problem – you will get good results.

Because of its short but efficient introduction, this article can be used either by science or by mathematics teachers.

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

Culmination angle of a celestial body

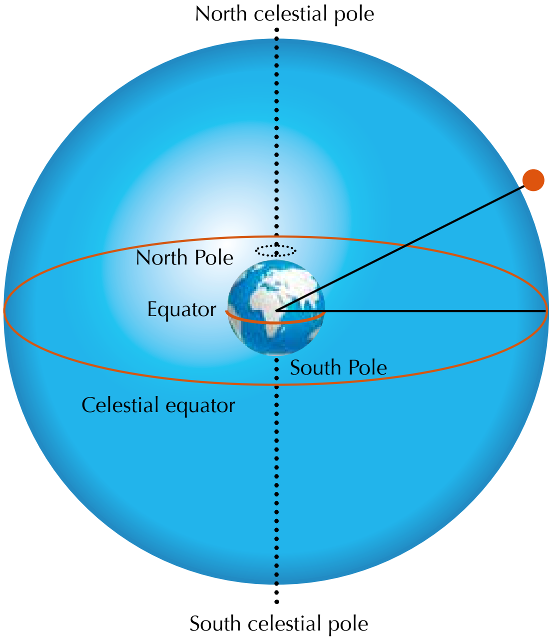

Image courtesy of Nicola Graf

Distortions due to camera lenses (c) can be reduced if a small angle of view is used, like the one provided by a telephoto lens. A normal camera lens introduces a larger, but still acceptable, error. In our case, that angle was not so small and we estimate it generated an imprecision of approximately 1-2%.

Errors due to a) and b) are the most important and can account for an imprecision of 5-10% each. Together, they account for an overall error of about 10-20%. To reduce a) we must choose a long parallax baseline so that the shift of the Moon is as large as possible; to reduce b) we must properly choose places and moments for observations so that A, B, C and M lie in the same plane. If both conditions hold (for us, the first condition did but the second didn't), the error can be reduced to a few percent.

Material

The only specific material necessary is a good camera to take photos of the Moon and the sky. A telephoto lens with a focal length of around 100–200 mm is the best choice, but a normal lens will also work if the bright stars or planets in the background are not very close to the Moon.

Background

The parallax network

We set up a network of schools, observatories and educators across the planet to undertake this measurement. It is made up of the following members:

- Mario Koch, teacher at the Friedrich-Schiller-Gymnasium in Weimar, Germany
- Noorali Jiwaji, physics lecturer at the Open University of Tanzania in Dar es Salaam, Tanzania
- Frank Oßwald, teacher at the Goethegymnasium in Weissenfels, Germany
- Matthias Penselin, teacher at Albert Schweitzer Gymnasium Crailsheim and at the House of Astronomy in Heidelberg, Germany
- Alexander GM Pietrow, Iosto Fodde and Jelle Mes, students from Leiden Observatory and members of the observing committee of the Leidsch Astronomisch Dispuut 'F. Kaiser', Leiden, Netherlands
- Elena Servida, teacher at Liceo Vittorio Veneto in Milan, Italy
- Brian Sheen, Roseland Observatory, St Austell, UK

With this network, or their own, teachers can propose dates to carry out lunar observations to work out the distance from Earth to the Moon.

The long distances between the schools in our network provide a sufficiently long baseline (distance AB) to make it possible to measure Earth's distance from Mars in May 2016 (Cenadelli et al, 2009; Penselin et al, 2014). At that time, Earth will be situated between the Sun and Mars, and Mars will be almost at its closest possible distance to Earth, an ideal position for such observations.

If you would like to contact any part of this international network to perform measurements, please contact Davide Cenadelli at davide.cenadelli@unimi.it

Figure 2: Superimposition of the two images taken on 2 February 2015 at 20.02 UT, simultaneously by an observer in Cape Town and at OAVdA

Procedure

1. Use the parallax network (see box) to find a school or observatory that is on a similar longitude to your school.
2. Note the latitude and longitude of the two partners (λ = latitude, l = longitude). Here, we use observations taken in Cape Town, South Africa, and at the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA), Italy:

   OAVdA, Italy: (λ_I 45.78° N, l_I 7.48° E)
   Cape Town, South Africa: (λ_S 33.93° S, l_S 18.42° E)
3. Agree the exact dates and times for the Moon observations (it is better to plan for several dates, in case the weather is bad). The two observers above agreed to make a simultaneous observation on 2 February 2015 at 20.02 UT. That evening there were two bright reference bodies, Jupiter and Procyon (α CMi), in the sky not far from the Moon, which could serve as reference points against which to measure the position of the Moon.

   The best circumstances are when bright background planets or stars, such as Jupiter and Procyon, are visible in the Moon's proximity, and ideally as close as possible to it so that a telephoto lens with a small field of view can be used. This helps to avoid the large perspective distortion effects typical of wide-field lenses.
4. On the chosen date, all participants with clear skies should take several images of the Moon with a camera, following the predefined time schedule. The images need to show as clearly as possible the Moon and the two bright reference bodies. They should be captured with different exposure times, in order to choose the best compromise between a not overwhemingly bright Moon and yet visible background stars.
5. Superimpose the images from two different observers into a single image, as in figure 2.
   - Measure the distance from Jupiter to Procyon on one image, and rescale the other image to match that distance so that both images are on the same scale;
   - Superimpose the images and mark the position of the Moon as seen from both schools on the same image;
   - Measure the shift of the centre of the Moon.
6. Calculate the parallax baseline, AB, as shown in figure 1.

   The angle, δ, between the two observers A and B can be calculated as follows (Roy & Clarcke (1977):

$$\begin{aligned}\cos\delta &= \sin\lambda_I \sin\lambda_S + \cos\lambda_I \cos\lambda_S \cos(l_I - l_S) \\ &= -\sin(45.78°)\sin(33.93°) + \cos(45.78°)\cos(33.93°)\cos(10.94°) \\ &= 0.1681\end{aligned}$$

$$\text{Thus } \delta = 80.32° \qquad (1)$$

Image courtesy of NASA

The Moon and Earth as seen from the International Space Station

Image courtesy of the authors

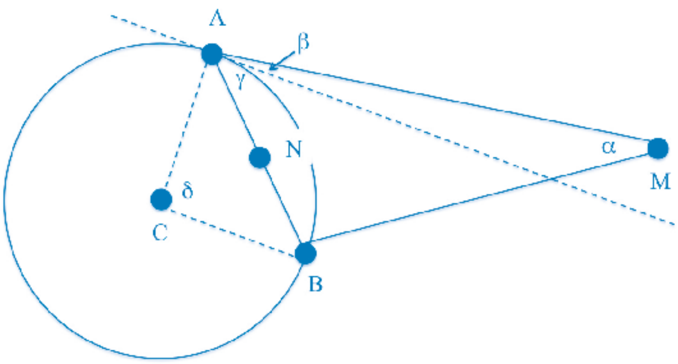

Figure 3: Close-up of the section of figure 1 showing the space between Earth and the Moon, and the angles β and γ

If we assume that Earth is perfectly spherical and its radius is 6367 km, the baseline AB is given by:

$$\begin{aligned} AB &= 2BN \\ &= 2(CB * \sin(\delta/2)) \\ &= 2 \times 6367\ \text{km} \times \sin(80.32°/2) \\ &= 8212\ \text{km} \qquad (2) \end{aligned}$$

7. Calculate the parallax angle, α.

   By simply using a ruler, we can estimate that the shift of the Moon that we observed (figure 2) is about 2.4 lunar diameters. As seen from Earth, the lunar diameter subtends an angle of 0.5°; that is, if we draw two lines from the eye of an observer to the extremes of the lunar diameter, the angle between the lines is 0.5°.

   Therefore if one lunar diameter corresponds to 0.5° and the apparent shift of the Moon we observed is 2.4 lunar diameters, then:

   $\alpha = 2.4 * 0.5 = 1.2°$

8. Calculate the distance between the Moon and the centre of the Earth, CM.
   We will calculate CM in two cases. In both cases we assume that A, B, M and C lie in the same plane.

Case 1: ABM is an isosceles triangle

In this case, the angles BAM and ABM are equal, and:

$$\begin{aligned} CM &= CN + NM \\ &= CA\cos\frac{\delta}{2} + \left(\frac{\left(\frac{AB}{2}\right)}{\tan\left(\frac{\alpha}{2}\right)}\right) \\ &= 4\,866\ \text{km} + 392\,080\ \text{km} \\ &= 396\,900\ \text{km} \qquad (3) \end{aligned}$$

The known distance at the time of measurement[w1] was 397 900 km, so we obtained a value that is underestimated by a mere 0.3%. Because of the approximations we used, this accuracy was partly a matter of luck.

Case 2: ABM is not an isosceles triangle

If we drop the assumption that AMB is an isosceles triangle, we need to know the value of another angle, such as BAM. BAM is equal to the sum of β, i.e. the altitude of the Moon above the horizon from A, and γ (see figure 3). β can be measured with proper equipment or, in its absence, can be taken to be almost equal to the altitude[w1] of one of the reference stars or planets we used to measure the shift of the Moon. For Procyon, we had $\beta = 39.3°$.

We can calculate γ using the value for δ that we calculated earlier and the geometry rule that says:
$\gamma = \delta/2$.

It follows that BAM = $\beta + \gamma = 79.5°$.

Finally, if we apply the law of sines to triangle ANM, we have:

$$\frac{\mathrm{NM}}{\sin 79.5°} = \frac{\mathrm{AN}}{\sin\frac{\alpha}{2}}$$

$$\rightarrow \mathrm{NM} = \mathrm{AN}\,\frac{\sin 79.5°}{\sin 0.6°} \approx 385\,536 \text{ km} \quad (4)$$

and hence:

$$\mathrm{CM} \approx \mathrm{CN} + \mathrm{NM}$$

$$= \mathrm{CA}\cos\frac{\alpha}{2} + \mathrm{NM}$$

$$= 4\,866\text{km} + 385\,536 \text{ km} \approx 390\,400 \text{ km} \quad (5)$$

Even without the approximation, this result is still realistic and only 1.9% less than the known value.

Acknowledgments

The authors wish to warmly thank all participants in our network, as well as the students who participated in the ESO Camp 2014 who performed a similar measurement.

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Roy AE, Clarcke D (1977) *Astronomy: Principles and Practice*. Bristol, UK: Adam Hilger. ISBN: 0852743467

Web references

w1 To find the values needed to perform the calculations described in the article, you can use the sky simulator Stellarium, a free open-source planetarium for your computer. See: www.stellarium.org

Resources

The method used in this article is also described in many astronomy textbooks. For example, see:

Karttunen H et al (2007) *Fundamental Astronomy* 5th edition. Berlin, Germany: Springer. ISBN: 9783540341437

Didactic material related to Penselin et al (2014), which is directly usable in the classroom, can be found here (in German only): www.wissenschaft-schulen.de/alias/material/parallaxe-und-entfernung-des-asteroiden-apophis/1311287

Davide Cenadelli graduated in physics and then earned his PhD at the University of Milan, Italy. His interests span stellar astrophysics, spectroscopy, and the history and philosophy of science. Davide is currently part of a research group involved in the quest for exoplanets around red dwarfs in the galactic neighbourhood at the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA) in Italy.

Cristina Olivotto graduated in physics at the University of Milan and received her PhD in the history of physics. After graduation, she began working in the field of science communication and education at the Astronomical Museum of Milan and as a lyceum teacher of physics and mathematics. Cristina worked at the European Space Agency for four years before founding Sterrenlab in 2011.

Albino Carbognani graduated in physics and then received his PhD in plasma physics at the University of Rome. Now an astronomer at OAVdA, he is responsible for the scientific research on astrometry and photometry of near-Earth asteroids. Albino is a member of the network Gaia-FUN-SSO coordinated by the Astronomical Observatory of Paris.

Andrea Bernagozzi graduated in physics at the University of Milan and then gained his masters in science communication at SISSA, the International School for Advanced Studies in Trieste, Italy. He is now a researcher at OAVdA, where he works mostly in the field of technology transfer. Andrea is a member of the UNICAMearth Working Group, established by the Geology Division of the School of Science and Technology, University of Camerino, Italy, for the development of new approaches to teaching and learning earth sciences.

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'Eggsperiments' for Easter

This Easter, have some intriguing science fun with eggs. You'll never look at them the same way again!

Image courtesy of Nicola Graf

By David Featonby and Susan Watt

Traditionally, Easter is the season of eggs – whether chocolate, painted or special in some other way. Along with the fun of egg hunts and creating (or buying) decorative eggs, we can use eggs to learn some science – as these five light-hearted activities show.

Most of the experiments described here are suitable for almost all ages and can usually be done in a few minutes with simple, easy-to-find materials – including quite a few eggs.

A normal hen's egg consists of three main parts: shell, white (or albumen) and yolk. However, if you can get some really fresh eggs, you may see when you crack them open that the white itself has two distinct parts: a firm inner layer and a runnier outer layer. Between the white and the shell there is another structure: a thin but quite strong membrane. In the activities below, we'll be looking at how this anatomy of eggs affects their properties.

The shell of an egg laid by a healthy, outdoor hen is surprisingly strong; battery-raised hens often lay eggs with thinner shells. Although a sharp tap can break the shell, the shell's hard material and its rounded, regular shape mean it is remarkably good at withstanding a heavy weight or force (such as the mother hen). There are several experiments you can do to demonstrate this strength – including, if you dare, actually walking on eggs.

Squeezing eggs

Students can try this simple experiment themselves to feel the surprising amount of force that eggs can withstand.

Materials

- Good-quality eggs, one per group of students. (Free-range eggs are best.)
- Cling film

Procedure

1. Wrap each egg in cling film, as a precaution in case it cracks.
2. Ask the students to remove any rings from their fingers.
3. Ask the students to take an egg in one hand and squeeze it as tightly as possible (figure 1). They should keep fingernails away from the egg.
4. It should be almost impossible, or at least very difficult, for anyone to break an egg, even squeezing very tightly.

Image courtesy of David Featonby

Figure 1: Holding an egg and increasing the pressure to try and crack the shell

What is happening? An 'eggsplanation'

The shell is made of a thin, brittle material – so why doesn't it break? The answer is the egg's domed shape, which – like a dome or arch in architecture – distributes the applied force to the over the whole structure, decreasing the pressure on any one part and so reducing the chance of breakage. This shape also ensures that the force acts only to compress the shell, rather than to stretch it or push it sideways. Because the eggshell is a hard material, it is very strong when compressed and so doesn't break.

In fact, the shape of an egg at the pointed end may be ideal for load-bearing. Engineers know that the arch shape that distributes weight best is the catenary. This mathematical curve has a shape similar to an egg at the pointed end, which is why eggshells will support even more weight when force is applied to the ends of the egg (as in the next activity), rather than around the middle.

Walking on eggs

It's even more impressive to walk on eggs – although it's riskier too!

Materials

- At least two boxes of a dozen good-quality eggs

Procedure

1. Check that the eggs are not cracked.
2. Put the boxes of eggs on the floor, placing two boxes next to each other so that you can stand with a foot on each box.
3. If you have more than two boxes, pair up the extra boxes and form a line for walking along. Consider placing the boxes near a wall to help the walker keep their balance.
4. Remove your shoes.
5. Gently step onto the boxes of eggs, one foot per box, spreading the pressure evenly as you stand (figure 2).

REVIEW

✓ Physics

✓ Pressure

✓ Motion

✓ Ages 4-19

It might seem unbelievable that you cannot break eggs by squeezing them or even walking on them. However, these and other strange facts can be demonstrated with the fun activities described in this article, which will make your students want to start 'eggsperimenting' and testing the laws of physics. The instructions are easy to follow and with some minor precautions (such as plastic sheets and paper towels), the activities shouldn't be too messy. An ideal way to learn traditional concepts of physics in a novel, fun and interesting way.

Catherine Cutajar, St Martin's College Sixth Form, Malta

Image courtesy of David Featonby

Image courtesy of David Featonby

Image courtesy of David Featonby

Figure 2: Walking on eggs

6. If you have extra boxes, gently walk along the eggs in the same way.

What is happening? An 'eggsplanation'

Because the eggs are in their boxes, they are kept upright. The walker's weight presses on the domed ends of the eggs instead of their sides, enabling them to withstand the maximum force. The weight is also shared between all the eggs you are standing on, thus minimising the pressure on each egg.

The same principle of weight distribution means that it is also possible to lie on a 'bed' of eggs (figure 3). To do this, you'll need about ten dozen eggs. Here, the weight is distributed over a large area, in a similar way to a bed of nails.

Egg spinning

From the outside, raw and hard-boiled eggs look just the same, but there is an easy way of telling them apart without breaking them open. This activity shows how to do this, either as a teacher demonstration or a class activity.

Materials

For the teacher or each group of students: one hard-boiled and one raw egg. The eggs in each pair should be closely matched in size and shape (weigh them to check the masses) and be at the same temperature.

Image courtesy of David Featonby

Image courtesy of David Featonby

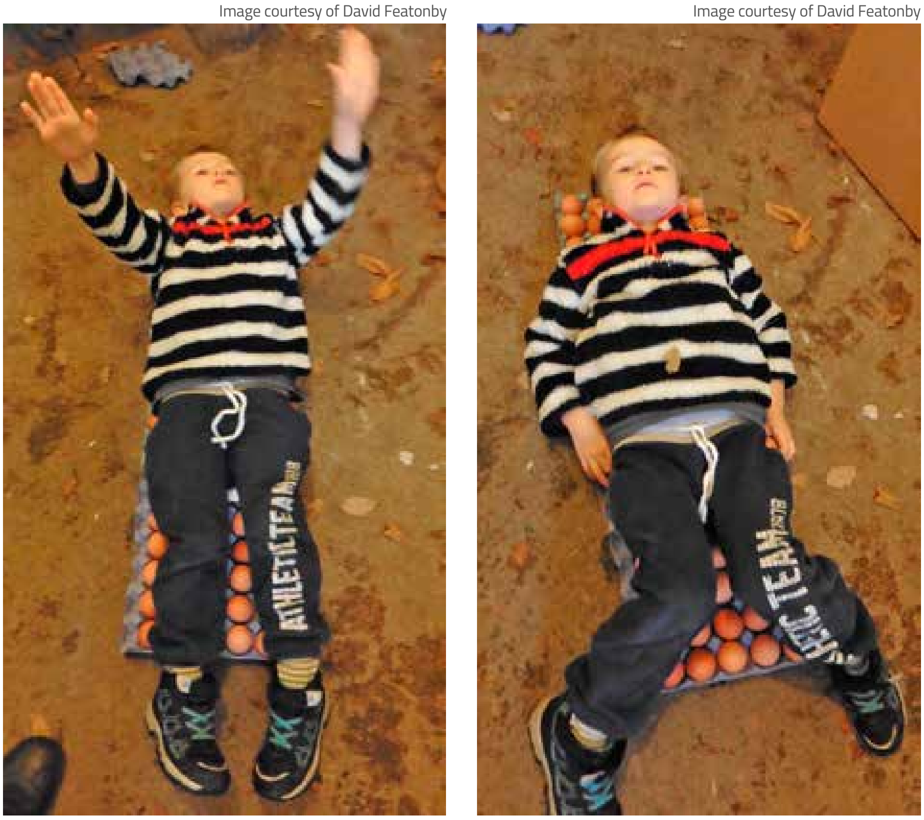

Figure 3: Enjoying a rest on a bed of eggs

Procedure

1. Ask the students to guess which egg is which (perhaps adding a mark to one egg to avoid confusion).
2. Take one egg and set it spinning quite fast on a hard surface.
3. Quickly stop it with a light touch, then quickly let go again. See whether it starts spinning again at all, or stays stopped. Try this a few times.
4. Do the same with the other egg.
5. You can tell which is the raw egg as this one will restart spinning slightly after being stopped.

What is happening? An 'eggsplanation'

Whereas the inside of the hard-boiled egg is solid, the raw egg is liquid inside. When the raw egg is set spinning and then stopped, the liquid inside it continues to move, which makes the egg start spinning again. But when a hard-boiled egg is spun and stopped, the solid interior cannot continue to move, so the egg will remain stationary.

More scientifically, we can understand this in terms of forces in a viscous (thick) liquid. When the raw egg is stopped by touching the shell momentarily, the liquid inside continues to move, producing forces across the liquid. If the egg is quickly released, these forces can then act on the shell to make the egg move again. With the hard-boiled egg, there is no viscous liquid to store the force, so stopping the spinning (which needs a little more force than with the raw egg) brings it to a complete standstill.

Extension

Ask your students to test which egg is more difficult to get spinning in the first place. Can they explain their answer, based on the principles described above? (They should find that the raw eggs are harder to start spinning for the same reasons that they are harder to stop.)

Bouncing eggs

Did you know that as well as being remarkably strong, eggs can also bounce? First, however, we need to remove the shell.

Materials

- A raw egg
- Vinegar (colourless vinegar is best)

Procedure

1. Place the egg in the vinegar overnight.
2. The following morning, the shell will have softened. Very carefully peel off the softened shell so that just the inner membrane remains. Be careful not to tear the membrane.
3. Rinse the egg so that no bits of shell remain on the membrane.
4. Now try dropping the egg from a few centimetres onto a smooth, hard surface. It should bounce! Take care though – too high a drop and the egg will burst.

What is happening? An 'eggsplanation'

Vinegar contains ethanoic (acetic) acid. This reacts with the eggshell, which is made of calcium carbonate:

$$2CH_3COOH + CaCO_3 \rightarrow H_2O + CO_2 + Ca(CH_3COO)_2$$

Ethanoic acid + calcium carbonate → carbon dioxide and calcium ethanoate

The resulting calcium ethanoate is soluble in water, so the shell begins to dissolve; if you leave it in vinegar for long enough, it will dissolve completely.

Why doesn't the egg burst when it lands? The answer lies with the membrane, which is surprisingly strong and a little bit stretchy. This elasticity allows the egg to spread out as it hits a hard surface, which means it decelerates more slowly than a rigid egg in its shell would. Because the deceleration is reduced, so too is the force that is exerted on the egg (Newton's second law of motion).

Egg 'suction'

A hard-boiled egg that has been very carefully shelled can be used to demonstrate atmospheric pressure.

Materials

- One hard-boiled egg
- Glass bottle with a neck a little smaller than the egg's width
- Matches

Procedure

1. Peel the hard-boiled egg very carefully so that the membrane is completely removed but there are no tears at all in the egg white.
2. Strike a match, wait for the flame to grow, then drop it into the bottle. Quickly do the same with a second match, then immediately seal the bottle with the egg while the matches are still burning.

   Within seconds, you should see the egg appearing to be sucked right into the bottle (figures 4-6).

What is happening? An 'eggsplanation'

As the matches burn, they use up oxygen from the air within the bottle, forming soot. A solid (soot) takes up less space than a gas (oxygen), so the pressure within the sealed bottle

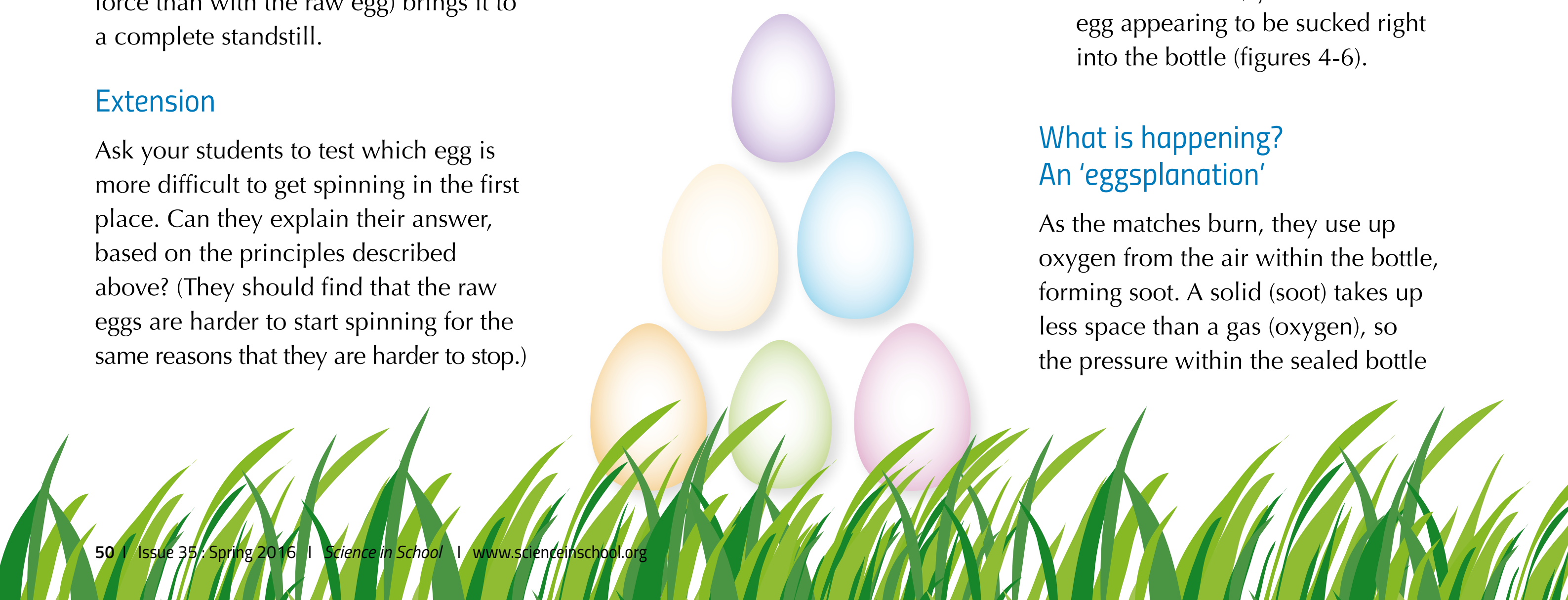

Image courtesy of David Featonby

Figure 4: Hard-boiled egg without shell on the bottle

Image courtesy of David Featonby

Figure 5: Hard-boiled egg being 'sucked' into the bottle

Image courtesy of David Featonby

Figure 6: Hard-boiled egg intact inside the bottle

decreases. As a result, the egg appears to be sucked into the bottle; in fact, it is the surrounding air pressure outside that forces the egg into the bottle.

A further consideration is that the burning matches heat the air around them, which you might expect to increase the pressure within the bottle. Clearly the reduction in pressure caused by the removal of oxygen outweighs the increase in pressure caused by the heat.

Extension

Repeat the experiment without the egg, but instead covering the mouth of the bottle with cling film as soon as the matches are dropped in. As the pressure in the bottle decreases, the cling film is drawn into the bottle, forming a concave surface.

Alternatively, this demonstration can be performed by (carefully!) pouring boiling water into the bottle before sealing it with the egg. As the steam condenses and the pressure inside the bottle is reduced, the egg is slowly drawn into the bottle. This can take several minutes.

Your ideas?

Do you do use eggs to do experiments in science lessons? Were these suggestions helpful? Why not leave a comment on the online version of this article, describing how you used these ideas and what other experiments you have tried? Did they work well? What could have been improved?

Resources

A video showing more about the egg squeezing and egg walking experiments. See: www.youtube.com/watch?v=Xckhg7Ns8so

A video showing more about the egg bouncing experiment. See: https://www.youtube.com/watch?v=3Iv9eLO0scA

More details and videos demonstrating the experiments in this article. See: www.science-sparks.com/2013/02/16/10-egg-science-experiments

Some more intriguing egg experiments with science explanations. See: www.livescience.com/44419-egg-science-experiments.htm and www.buzzfeed.com/kasiagalazka/things-you-can-do-with-eggs-besides-coloring-them#.cc8YRYYKq

David Featonby 'retired' from school physics teaching after 35 years in the classroom, and until 2011 was a teacher network co-ordinator for the UK's Institute of Physics. He has represented the UK at Science on Stage and now works voluntarily with the international Science on Stage (Europe) committee as UK representative and member of its European executive board. David is the author of various hands-on articles in *Science in School* and *Physics Education* and has led workshops at many conferences throughout the UK and Europe. He is particularly interested in showing the physics in everyday things to the public, whatever their age.

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Handwarmer science

Image courtesy of Nicola Graf

Help your students explore an exothermic reaction using the real-world example of a self-heating patch.

By Manfred Eusterholz, Andreas Böhm, Andy Bindl and Gregor von Borstel

Self-heating patches that can be worn on the skin for hours are becoming increasingly popular as a method of pain relief, and the same technology can also keep your hands warm on cold days. But how do these patches heat up? This activity allows your students can investigate this in a lesson.

Start by introducing your students to a hypothetical scenario in which they work for a scientific magazine. A letter to the editor arrives and it is your students' job to answer it.

Dear Madam,

I often suffer from painful shoulders and neck because of my job, so I'm thinking of trying self-heating patches that I can wear during the day to reduce the pain. I am curious as to how exactly they work and if they are reusable.

The information on the packaging claims that they are simply activated by air. Is this true? Are they harmless or could they cause any problems or side effects?

Thank you in advance for your help.

Susanne Musterfrau, Cologne

The challenge

Explain to your students that their task is to examine the functionality of the self-heating patches and provide an answer to the letter writer's question. They should:

1. Write down questions that they need to answer in order to explain how the self-heating products work.
   For example, they could consider the term 'air-activated'. Could just one of the main components of air activate the self-heating patches?
2. Use the materials provided to find answers to their questions, and document their process.
   The experiment described below can be used to test the reaction in small volumes.
3. Write a brief reply to the letter writer, in which they explain the functionality of the self-heating patches in a way that readers with some knowledge of chemistry will understand.

Image courtesy of Gregor von Borstel

Introducing the activity

Materials

Each group of students will need:

- Self-heating patch or body-warmer pack
- Kitchen roll or fillable teabags
- Spatula
- Oxygen
- Nitrogen
- Two 50 ml syringes
- Stoppers for the syringes
- Three-way valve
- Length of foam pipe insulation
- Temperature sensor or thermometer
- Scissors

Procedure

1. Open the patch or pack and remove two spatulas full of the filling, wrapping it in a paper towel or putting it in the teabag.
2. Remove the plunger from one of the syringes and place this wrapped material in the body of the syringe. Replace the plunger.
3. Seal the tip of the syringe.
4. Place a temperature sensor on the side of the syringe and wrap both the syringe and the sensor in pipe insulation.
5. Observe the set-up for a few minutes. Does the temperature change?

All images courtesy of Gregor von Borstel

Putting the material in a syringe

Adding a gas with another syringe

Watching what happens to the plunger

Measuring the temperature at the start of the reaction

Measuring the temperature during the reaction

Image courtesy of Gregor von Borstel

After the reaction you can see the red of rust.

6. What happens to the plunger of the syringe?
7. Unseal the syringe and depress the plunger fully.
8. Fill a second syringe with nitrogen.
9. Connect the two syringes using the three-way valve and depress the plunger of the second syringe to transfer the nitrogen to the first syringe.
10. Observe the set-up for a few minutes. Does the temperature in the first syringe change? What happens to the plunger of the first syringe?
11. Repeat steps 8–10 with oxygen instead of nitrogen.

About what happens

You will have noticed that the material from the self-heating patch releases heat when exposed to air and even more heat when exposed to pure oxygen. As the gas is used up in the reaction, the pressure in the syringe is reduced and the plunger moves down inside the syringe. The material doesn't react with nitrogen, so there is no heat or movement of the plunger. This is because the heat pack works by the oxidation of iron:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

This is an exothermic reaction: it releases heat. If you examine the contents of the syringe at the end of the experiment, you will see that they include flecks of red (rust).

What about the carbon and salt that are also present? Rusting is a redox reaction, with the iron being oxidised to ferric ions:

$$4Fe \rightarrow 4Fe^{3+} + 12e^-$$

and the oxygen being reduced:

$$12e^- + 3O_2 \rightarrow 6O^{2-}.$$

The salt and the carbon are not used up but act as electrolytes, helping the electrons to flow between the elements.

Further discussion

The syringes can be used to measure exactly how much oxygen is consumed in the reaction, and you could use this information to work out the rate of reaction. Perhaps you could discuss with your students other ways to increase this rate and other exothermic reactions that could be used to make a warming pad.

References

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Rau M (2011) The heat is on: heating food and drinks with chemical energy. *Science in School* **18**: 46 -51.
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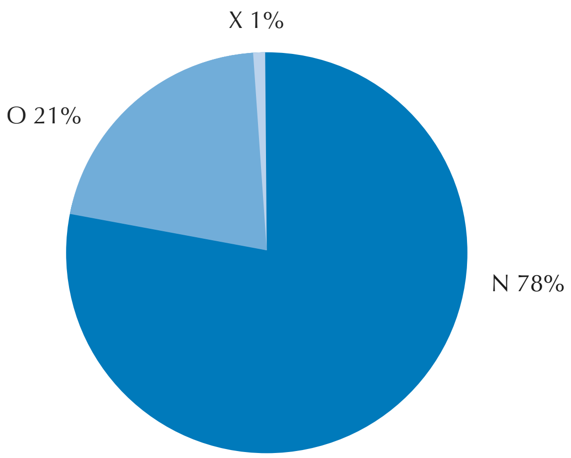
Web reference

w1 Learn more about *Lebensnaher Chemieunterricht* and find more of their activities. See: www.lncu.de



Air is mostly nitrogen (N) and oxygen (O)

Image courtesy of Nicola Graf

Manfred Eusterholz, Andreas Böhm, Gregor von Borstel and Andy Bindl are all German chemistry teachers who work together as part of *Lebensnaher Chemieunterricht*[w1] (real-life chemistry education; Rau, 2011). In 2015, they travelled to London, UK, for the Science on Stage Europe festival, where they won a European Science Teacher Award for their work (Howes, 2015).

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