Autumn 2013 Issue 27

SCIENCE in SCHOOL

The European journal for science teachers

In this issue:

Evolving threats: investigating new zoonotic infections

Also:

Peering into the **darkness:** modelling **black holes** in primary school

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Editorial

Once upon a time, scholars tended to wear long robes, live in monasteries and focus on botany. Some of these medieval scientists recorded their extensive knowledge of medicinal plants; today, researchers are using these manuscripts to inspire and develop modern medicines (page 38).

Although efficient in some cases, these early treatments could not combat the rampant epidemics of the time, such as the plague, which constantly re-emerged because humans and animals lived in such close proximity. Unfortunately, history repeats itself, and we are once again struggling with the threat of zoonoses: animal diseases that cross to humans (page 12).

Modern genetics, too, owes a debt to monastic botany, and more specifically to Gregor Mendel, whose laws of heredity underlie the theory of evolution and are still taught in biology classes. To explain – literally – the nuts and bolts of evolution, why not use everyday materials to construct your own phylogenetic trees in the classroom (page 26)?

Plants clearly provide inspiration in many scientific fields. Did you know, for example, that iodine was originally discovered in seaweed? Although at the time, the chemists involved were actually trying to make gunpowder (page 45).

More violent and infinitely more destructive than the firing of a gun are volcanic eruptions. To better understand volcanoes, an international team of scientists are using tiny particles – muons – to see inside (page 6).

On an even bigger, hotter and more destructive scale, the supernova explosion of a dying star can result in a black hole – sucking into it all surrounding matter. Black holes may be difficult to grasp conceptually, but they can be easily demonstrated in the classroom using simple equipment (page 32).

From medieval herbal remedies to monitoring volcanoes with cosmic particles: this issue should make your heart beat fast with excitement. So why not take the opportunity to simulate this with a gruesome, hands-on activity to investigate how the heart pumps (page 18)?

Isabelle Kling
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editor@scienceinschool.org
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To read the whole issue, see: **www.scienceinschool.org/2013/issue27**

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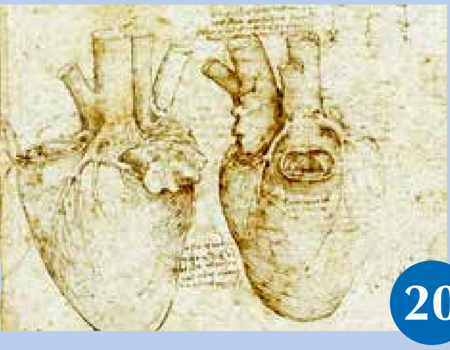

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Image courtesy of the European Space Agency, NASA and Felix Mirabel (the French Atomic Energy Commission & the Institute for Astronomy and Space Physics / Conicet of Argentina)

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A range of scales: from fusing a nucleus to studying a dwarf planet

EFDA-JET: Making a deliberate error for ITER

Forthcoming experiments at the Joint European Torus (JET), currently the world's largest fusion energy experiment, will take a surprising twist, with some internal components being deliberately melted. The reason? In preparation for ITER, JET's tenfold-larger successor, scientists will need to know what effect such melting would have on experiments.

ITER is under construction in the south of France. It will create the first ever long-duration burning fusion plasma, which will inflict a heat load on the vessel that is equivalent to the temperature on the surface of the Sun. Astonishingly, ITER's design engineers predict that tungsten tiles can withstand this condition during normal operation. However bursts of turbulence similar to solar flares may momentarily heat the tungsten above its melting point (3422 °C). To simulate this, a tile in JET has been deliberately misaligned to create transient melts. These will be superficial only and will not endanger the 700 tonne JET vessel, but the effect on the plasma – if any – will be vital information for the ITER design team.

To learn more about the fusion research at JET and ITER, see:

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

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

Dooley P (2013) A thermometer that goes to 200 million degrees. *Science in School* **26**: 44-49. www.scienceinschool.org/2013/issue26/fusion

Find out more about fusion in the Universe in the *Science in School* series of fusion articles. See: www.scienceinschool.org/fusion

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

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

Image courtesy of EFDA

EMBL: What an 'X'perience!

Are you struggling to store all your movies on regular DVDs? A new method published by researchers at the European Bioinformatics Institute (EBI, part of the European Molecular Biology Laboratory, EMBL) makes it possible to store 100 million hours of high-definition videos in a cup of… DNA!

The team, led by Nick Goldman and Ewan Birney, designed a method to synthesise information into DNA, duplicate it, and read it back. Stored under the right conditions, DNA can last tens of thousands of years, as shown by studies of woolly mammoth remains. DNA is also very small and dense, and its code is universal: all qualities that could make it a very appealing technology for storing the enormous amounts of data generated in research facilities.

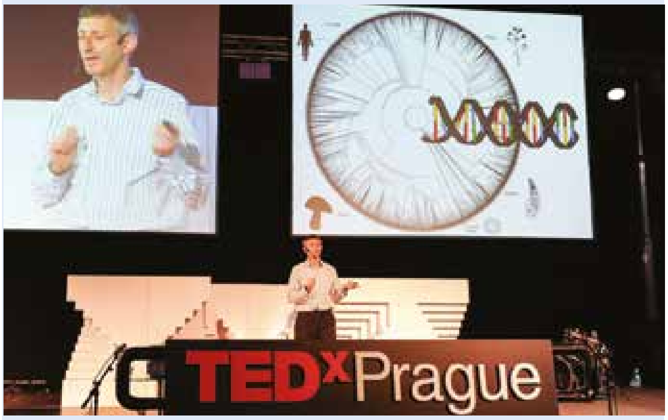


Image courtesy of Ondrej Vitousek

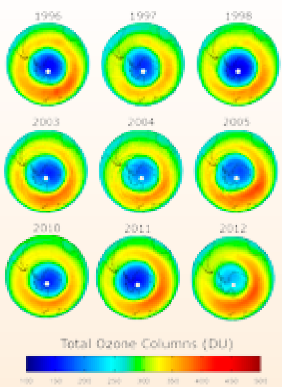
Nick Goldman introduced his team's findings to a fascinated audience at a recent TEDx event in Prague, Czech Republic. The experience proved to be a high point in the popularisation of research on DNA storage.

To learn more, watch Nick Goldman's talk on Youtube (http://youtu.be/a4PiGWNsIEU) or read the press release on the EMBL website (www.embl.org or use the direct link: http://tinyurl.com/olkpefy).

EMBL is Europe's leading laboratory for basic research in molecular biology, with its headquarters in Heidelberg, Germany. The European Bioinformatics Institute is part of EMBL and is based in Cambridge, UK. 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 inter-governmental scientific research organisations (EIROs). This article reviews some of the latest news from the EIROs.



Ozone levels over the Antarctic from 1996 to 2012. Blue indicates low levels of ozone and shows the hole in the ozone layer.

Image courtesy of BIRA / IASB

ESA:

Is the ozone layer recovering?

Since the 1980s, the emission of chlorofluorocarbon (CFC) gases has caused a hole to form in the protective ozone layer of the atmosphere. Weather conditions make the low levels of ozone particularly noticeable over the Antarctic in spring (September to November).

The European weather satellite Metop is monitoring the hole in the ozone layer, and the European Space Agency (ESA) Climate Change Initiative collects many measurements to track the changes over time.

Since the reduction in CFC emissions in the 1990s, the hole has begun to shrink. The newest data from Metop show that the hole in the ozone layer over Antarctica in 2012 was the smallest it has been in a decade. CFC gases remain in the atmosphere for a very long time, but these promising results demonstrate that the ozone layer has begun to recover.

To learn more about the chemistry behind the hole in the ozone layer, see:

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

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 European weather satellite Metop keeps an eye on the ozone layer in the atmosphere.

Image courtesy of ESA / AOES Medialab

ESO:

Dwarf planet Makemake lacks atmosphere: distant frigid world reveals its secrets

Image courtesy of ESO / L Calçada / Nick Risinger (skysurvey.org)

Astronomers used three telescopes at facilities of the European Southern Observatory (ESO) in Chile to observe the dwarf planet Makemake as it drifted in front of a distant star and blocked its light. The new observations have allowed them to check whether Makemake is surrounded by an atmosphere. This chilly world has an orbit lying in the outer Solar System and was expected to have an atmosphere like Pluto, but this has now been shown not to be the case. The scientists also measured Makemake's density for the first time. The new results were published in the journal *Nature*.

This artist's impression shows the surface of the distant dwarf planet Makemake. It is about two thirds of the size of Pluto, and travels around the Sun in a distant path that lies beyond that of Pluto, but closer to the Sun than Eris, the most massive known dwarf planet in the Solar System.

For more information, see the press release on the ESO website (www.eso.org or use the direct link: http://tinyurl.com/q5pjqmt) or refer to the original research paper:

Ortiz JL et al (2012) Albedo and atmospheric constraints of dwarf planet Makemake from a stellar occultation. *Nature* **491**: 566–569. doi: 10.1038/nature11597

Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2013/issue27/eiroforum#resources), or subscribe to *Nature* today: www.nature.com/subscribe

To learn about the discovery of Eris, the most massive known dwarf planet in the Solar System, see:

Hayes E (2011) How I killed Pluto: Mike Brown. *Science in School* **21**: 6-11. www.scienceinschool.org/2011/issue21/pluto

ESO is by far the world's most productive ground-based astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. ESO is the European partner in the ALMA project, which is a collaboration between Europe, North America and East Asia, in co-operation with the Republic of 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 and ILL: Crystallography? What is that?

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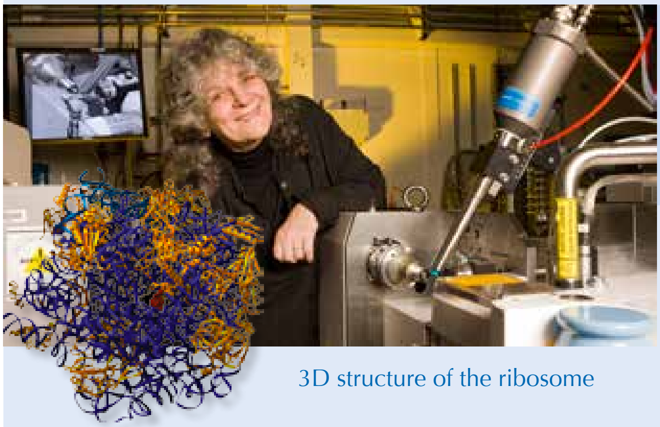

Image courtesy of M Pelletier and C Bruneau

Image courtesy of ESRF

3D structure of the ribosome

Ada Yonath, 2009 Nobel Prize Winner in Chemistry, while carrying out an experiment at the ESRF to decipher the structure of the ribosome. To celebrate 100 years of crystallography, she was invited to Grenoble in March 2013 to give a lecture to the general public entitled "Is there a limit to life expectancy? Wishes, predictions and reality".

Obviously, crystallography is the study of crystals, but it is also much more than that. Crystallography is a powerful technique that allows us to explore all sorts of material and even biological samples. It is a way to look at atoms and molecules and to understand how the world around us is ruled by these tiny bits of matter.

Modern crystallography started about one hundred years ago, when Max von Laue discovered that X-rays were diffracted by crystals. Soon after, William Lawrence Bragg, helped by his father, found that the X-ray diffraction patterns could reveal the intimate structure of matter. Laue and the Braggs received Nobel Prizes only two years after their discoveries, in 1914 and 1915, respectively. To celebrate this tremendous breakthrough, 2014 has been declared the International Year of Crystallography by the United Nations.

Today, crystallography is more active than ever thanks to the development of large-scale facilities such as very powerful X-ray sources, called synchrotrons, and neutron sources, which can both be compared to super-microscopes for the investigation of matter. In Grenoble, France, two world-class facilities are leading neutron and X-ray research: the Institut Laue Langevin (ILL) and the European Synchrotron Radiation Facility (ESRF). Every year, they welcome thousands of researchers from all over the world to perform crystallographic experiments.

ESRF and ILL started celebrating 100 years of crystallography in 2012 by co-organising various events. Much more is expected in 2013 and 2014: an exhibition, 3D digital animations and interactive educational material will be produced in various languages, together with many partners from across the world. We will keep you informed!

Learn more about the history of crystallography (currently only in French). See www.echosciences-grenoble.fr/sites/100-ans-de-cristallographie or use the shorter link: http://tinyurl.com/ou3flm5

On the Nobel Prize website, find out more about the work of Max von Laue (www.nobelprize.org or use the direct link: http://tinyurl.com/nnddkuu) and the Braggs (www.nobelprize.org or use the direct link: http://tinyurl.com/qcg5swy).

To find out more about crystallography, see also:

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

Haddow M (2012) The new definition of crystals – or how to win a Nobel Prize. *Science in School* **24**: 59-63. www.scienceinschool.org/2012/issue24/crystals

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

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

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

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

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

A large stand at the Fête de la Science in Grenoble celebrated 100 years of crystallography in October 2012.

Image courtesy of Serge Claisse, ILL

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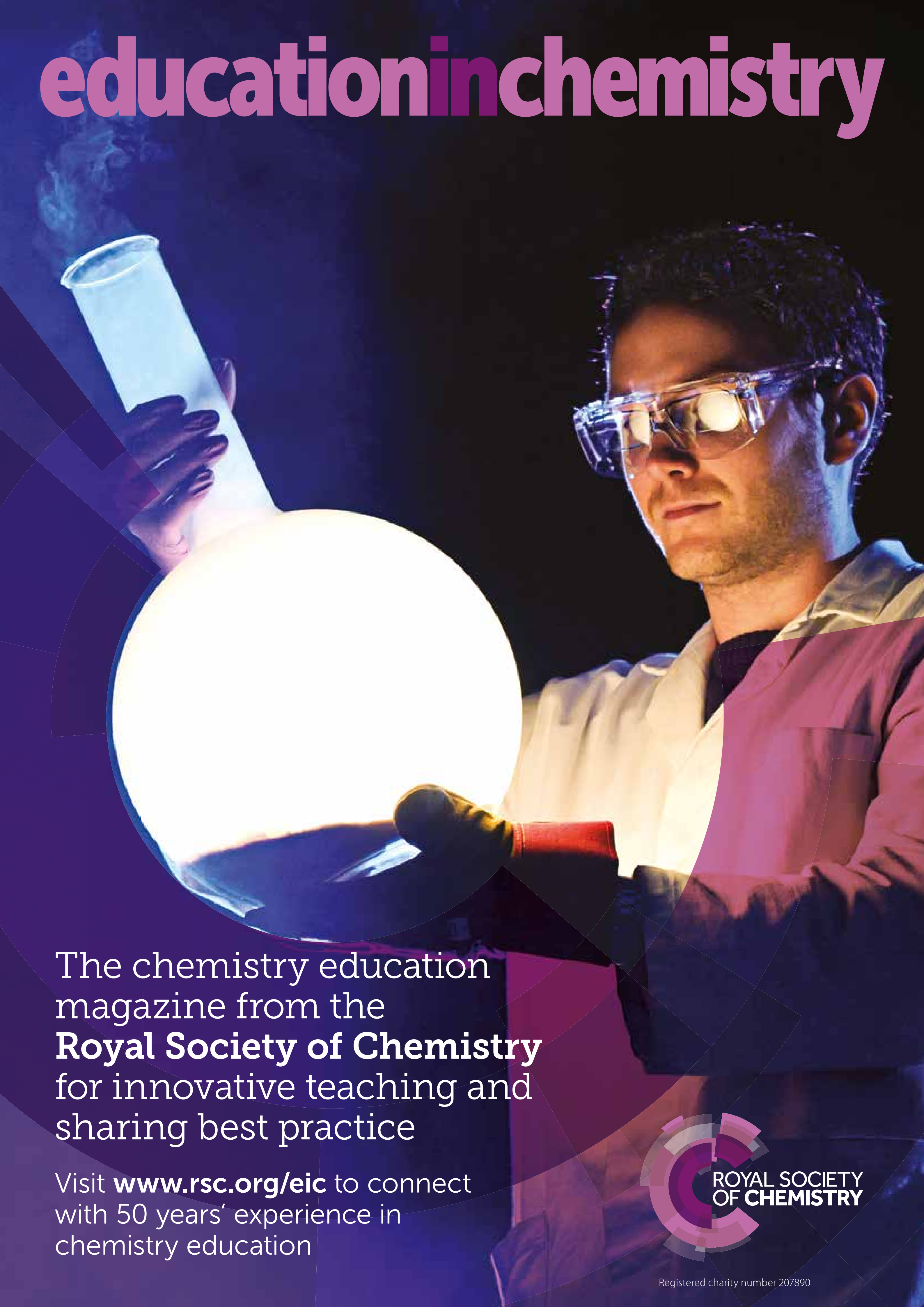
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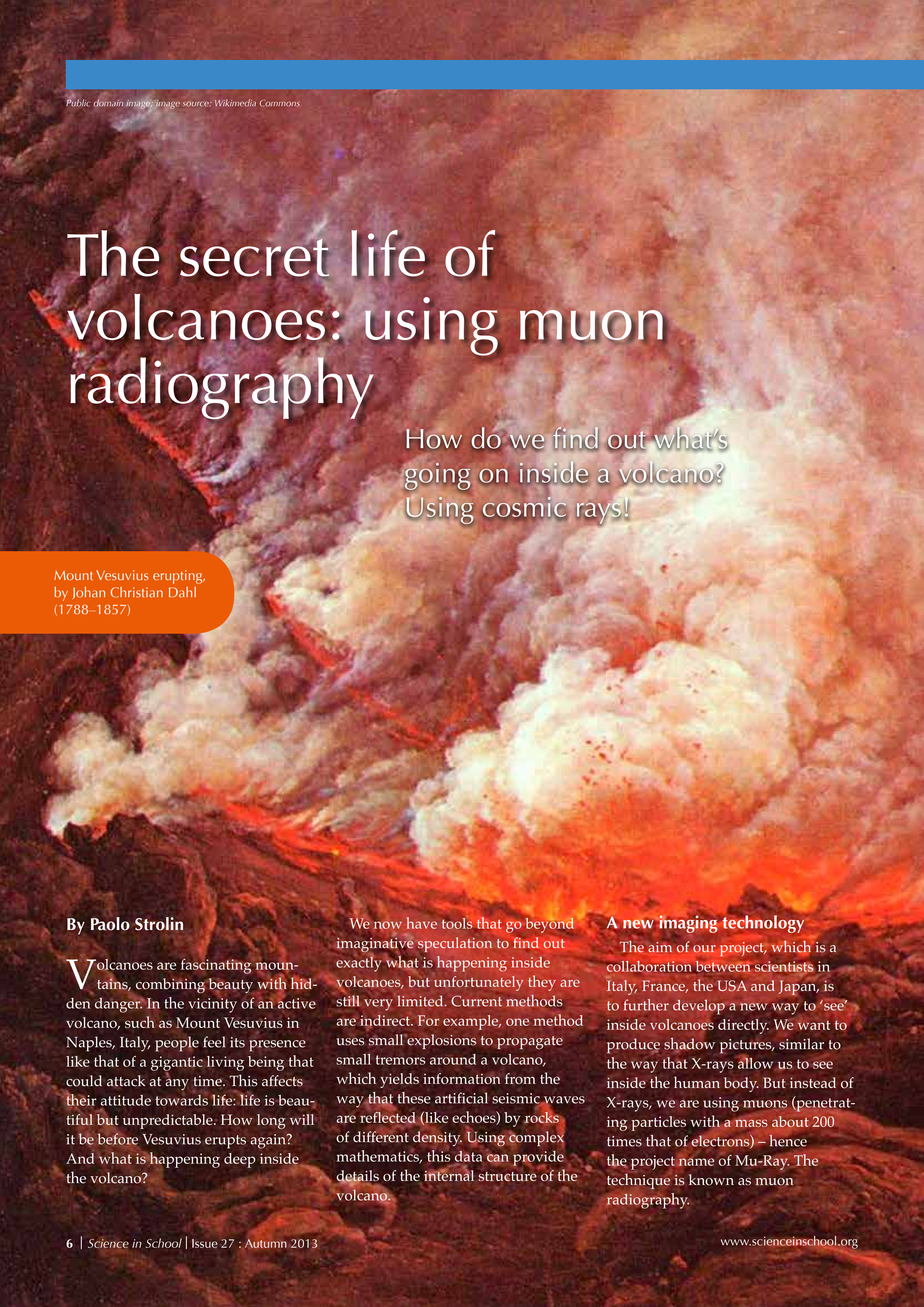

Mount Vesuvius erupting, by Johan Christian Dahl (1788–1857)

The secret life of volcanoes: using muon radiography

How do we find out what's going on inside a volcano? Using cosmic rays!

By Paolo Strolin

Volcanoes are fascinating mountains, combining beauty with hidden danger. In the vicinity of an active volcano, such as Mount Vesuvius in Naples, Italy, people feel its presence like that of a gigantic living being that could attack at any time. This affects their attitude towards life: life is beautiful but unpredictable. How long will it be before Vesuvius erupts again? And what is happening deep inside the volcano?

We now have tools that go beyond imaginative speculation to find out exactly what is happening inside volcanoes, but unfortunately they are still very limited. Current methods are indirect. For example, one method uses small explosions to propagate small tremors around a volcano, which yields information from the way that these artificial seismic waves are reflected (like echoes) by rocks of different density. Using complex mathematics, this data can provide details of the internal structure of the volcano.

A new imaging technology

The aim of our project, which is a collaboration between scientists in Italy, France, the USA and Japan, is to further develop a new way to 'see' inside volcanoes directly. We want to produce shadow pictures, similar to the way that X-rays allow us to see inside the human body. But instead of X-rays, we are using muons (penetrating particles with a mass about 200 times that of electrons) – hence the project name of Mu-Ray. The technique is known as muon radiography.

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Towering over the Italian town of Naples, Vesuvius erupted dramatically in 1872. Photograph by Giorgio Sommer (1834-1914).

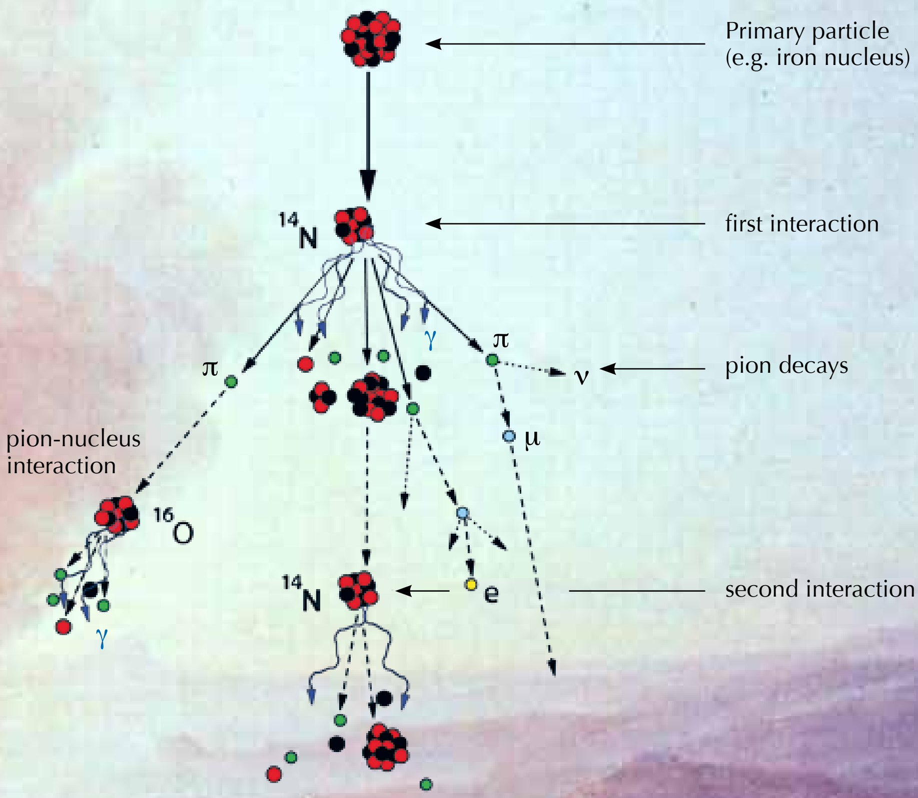
Public domain image; image source: Wikimedia Commons

The interior of Vesuvius according to Athanasius Kircher (1602-1680), from his work Mundus Subterraneous

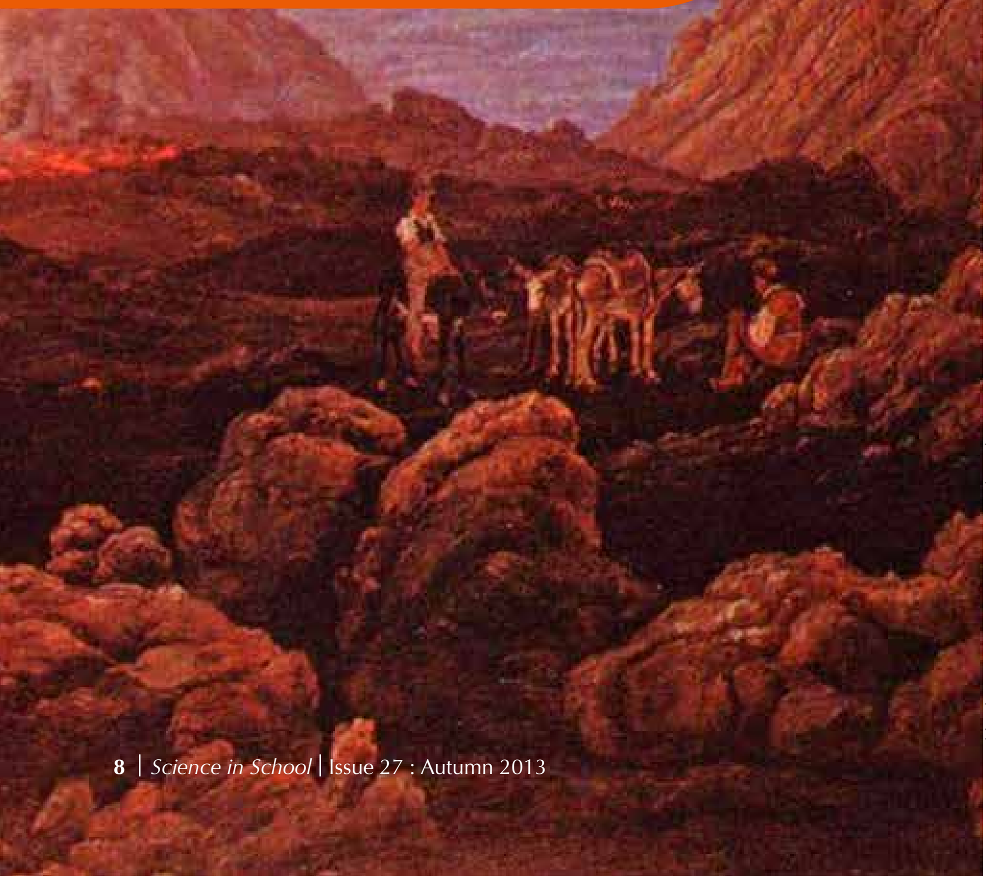
Muons are produced, along with other particles, when cosmic rays (high-energy particles originating in outer space) interact with atomic nuclei in Earth's atmosphere to produce 'showers' of secondary particles. The muons inherit the high energy of the parent cosmic rays, which enables them to penetrate and pass through the rock of the volcano and to be detected on the other side of the mountain. Because denser materials absorb more muons (just as dense materials such as bone absorb more X-rays), this provides a basis for producing shadow images of the volcano's interior.

Muon radiography was first used in 1971 – not for volcanoes, but for investigating the interior of the pyramid of Chefren at Giza, Egypt. The Nobel-prize winning physicist Louis Alvarez placed a muon detector inside the pyramid to pick up changes in muon flux (rate of muon flow) that could indicate the presence of a hidden burial chamber. However, none was found.

In 2007, Hiroyuki Tanaka and collaborators from the University of Tokyo were the first to apply this technique to volcanoes. They carried out radiography of the top part of the Asama volcano in Honshu, Japan, *Image courtesy of the Max Planck Institute for Astronomy*



The shower of particles produced when a cosmic ray, a primary particle accelerated by mysterious mechanisms in the distant Cosmos, reaches us and interacts with an atomic nucleus in Earth's atmosphere. Muons are indicated by the symbol μ; other particles shown are photons (γ), pions (π), neutrinos (ν) and energy (e).



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which revealed a region with rock of low density under the bottom of the crater. The presence of low-density regions can be used in computer simulations that predict how possible eruptions could develop, indicating the most dangerous areas around the volcano. Their observations showed that muon radiography could indeed produce useful images of the internal structure of volcanoes.

The really important advantages of muon radiography of volcanoes are two-fold. First, whereas current indirect methods can provide information to a spatial resolution of some 100 m, muon radiography can be up to ten times more specific, mapping internal structures to a resolution of some 10 m. Second, muon radiography offers the possibility of continuous monitoring, thus potentially revealing the evolution of structures over time. The time resolution depends on the thickness of the rock traversed by the muons: the thicker it is, the fainter the muon flux and the longer it takes to accumulate enough muons for a picture. The time needed can thus be weeks, months or years.

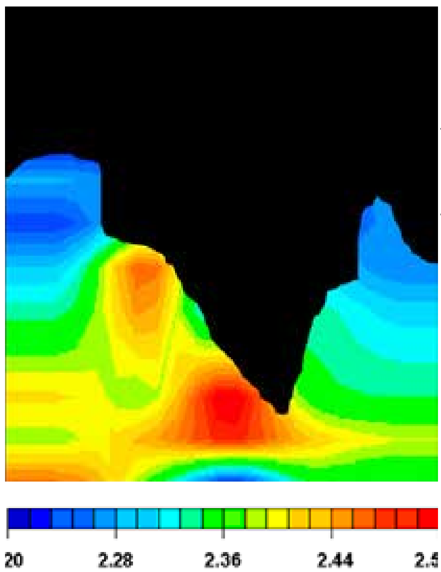
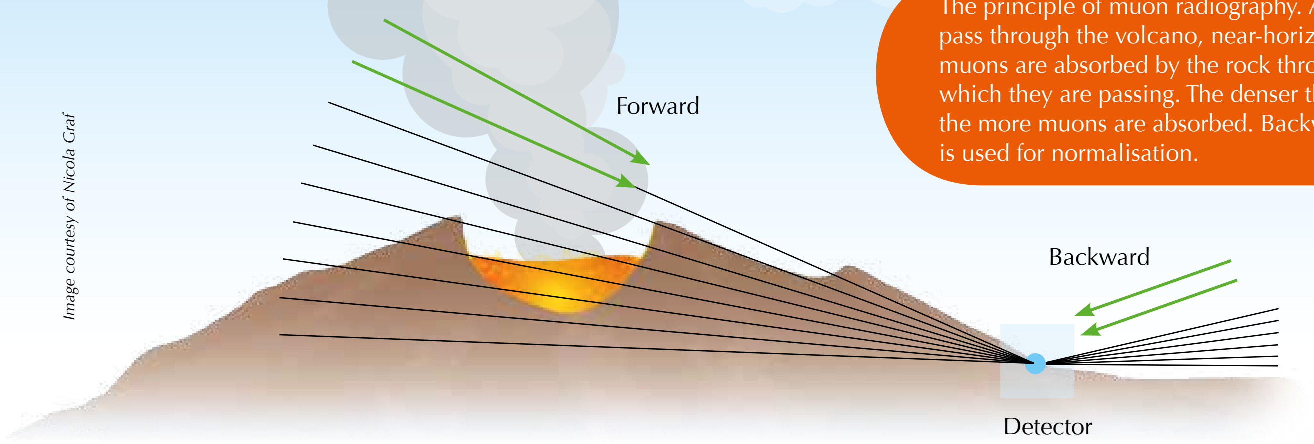


Image courtesy of H T M Tanaka

Image obtained from muon radiography of Japan's Asama volcano. The different rock densities are shown on a colour scale, and the internal shape of the volcano can be clearly seen.



The principle of muon radiography. As they pass through the volcano, near-horizontal muons are absorbed by the rock through which they are passing. The denser the rock, the more muons are absorbed. Backward flux is used for normalisation.

Muon radiography is now being used for volcanoes around the world: in the Lesser Antilles, at the Puy de Dôme in Central France, and in our very challenging work on Vesuvius with the Mu-Ray project. The images are produced using detectors called muon telescopes, which use technology developed in particle physics and play the role of the X-ray film in conventional radiography. The telescopes detect near-horizontal muons emerging from the volcano's edifice, having passed right through it. By reconstructing the path of each single muon through the volcano, the apparatus reveals the amount of muon absorption in each direction. Denser rocks absorb more muons, so a map of muon fluxes gives a negative image of the rock densities inside the volcano. Such images cannot help to predict when an eruption might occur, but – combined with other observations – can help to foresee how one could happen.

Imaging Vesuvius

So, what about Vesuvius? This volcano is a special challenge, not only because it represents the highest volcanic risk in Europe, but also because of the mountain's unusual structure. Vesuvius is in fact situated within the remnants of a much larger volcano, Mount Somma. Moreover, inside the summit of Vesuvius is a crater that is 500 m wide and 300 m deep: this means that, to look below the bottom of the crater, muons have to penetrate deep into the mountain, through almost two kilometres of rock, to reach the detector on the opposite side of the volcano. Only muons of very high energy travelling in a near-horizontal direction are able to pass through all this rock, so their flux at the detector is very low, making imaging extremely difficult. This explains why the project – and the development of muon radiography – is extremely challenging.

To look inside Vesuvius, therefore, we need to develop a new type of muon telescope. To detect enough particles of such low flux to produce an image, this apparatus must cover a much larger area than previous muon telescopes. Substantial improvements are also needed to distinguish the experimentally important particles from background muons – which we plan to do by measuring each muon's time of flight through the telescope to confirm that it really has the right direction to have passed through the volcano.

A prototype telescope with a detector area of just 1 m^2, compared to 10 m^2 or more to be covered by the final telescope array, has been recording data at Vesuvius since Spring 2013. The data is currently being analysed.

The detectors consist of plastic scintillator strips – a technology borrowed from particle physics. These strips can be used to cover large areas and provide long exposure times, and they are robust enough to withstand volcanic conditions. Of practical importance too are the telescope's low energy consumption, enabling it to be powered by a solar panel, and its portability, so that it can be used in different locations. Depending on funding and the experience gained with the prototype, we hope as the next step to construct two telescope arrays, each with total areas of 4 m^2, to record data for one year or more.

Image courtesy of Paolo Strolin

The Mu-Ray muon telescope prototype at Vesuvius.

Public domain image; image source: Wikimedia Commons

In its most famous eruption, in 79 AD, Mount Vesuvius destroyed the Roman town of Pompeii. *The Last Days of Pompeii* by Karl Briullov (1799–1852)

New frontiers

Meanwhile, particle physicists and volcanologists continue to work together in muon radiography. As well as providing a powerful tool for the study of geological structures, this expanding field also has potential industrial applications, such as seeing inside nuclear reactors or determining the remaining thickness of the wall of an iron furnace, which can then be replaced at the right time.

Alongside these possibilities, there is another developing technology that promises imaging on an even larger scale: neutrino radiography. With their extraordinary penetration power, neutrinos produced by cosmic rays and passing through Earth itself could at some future date provide information about the density of the core of our own planet.

Acknowledgments

The Mu-Ray project is funded by the Istituto Nazionale di Fisica Nucleare (Italian national institute for nuclear physics) and the Istituto Nazionale di Geofisica e Vulcanologia (Italian national institute for geophysics and volcanology), with contributions by the Italian Ministry of Education and Research (MIUR-PRIN), Fermilab (USA) and IN2P3-Orsay (France) and support from the *Provincia di Napoli* (province of Naples) and the *Istituto Fondazione Banco di Napoli* (foundation of the bank of Naples).

The author would like to gratefully acknowledge the contributions to this new field of research by HKM Tanaka and A Taketa (ERI-Tokyo); K Niwa and T Nakano (Nagoya); D Gibert and J Marteau (DIAPHANE collaboration); C Carloganu (TOMUVOL collaboration); F Ambrosino, G Castellini, R D'Alessandro, G Iacobucci, M Martini, M Orazi and G Saracino (Mu-Ray collaboration).

Web reference

w1 – Learn more about the Scienza e Scuola (science and school) project. See: http://scienzaescuola.fisica.unina.it

Resources

To learn more about the Mu-Ray project, see the project website. http://mu-ray.fisica.unina.it

Details can also be found in:

Poppi F (2011) Muons reveal the interior of volcanoes. *CERN Bulletin* **50:2**

For more technical details about the Mu-Ray project, see:

Anastasio A et al. (2013) The Mu-Ray experiment: An application of SiPM technology to the understanding of volcanic phenomena. *Nuclear Instruments & Methods in Physics Research A: Accelerators, Spectrometers, Detectors and Associated Equipment* **718**: 134-137. doi: 10.1016/j.nima.2012.08.065

Ambrosi G et al. (2011) The Mu-Ray project: Volcano radiography with cosmic-ray muons. *Nuclear Instruments & Methods in Physics Research A* **628(1)**: 120-123. doi: 10.1016/j.nima.2010.06.299

Beauducel et al. (2008) Muon radiography of volcanoes and the challenge at Mt. Vesuvius.

The article can be downloaded from the Mu-Ray project website (click on 'Read the complete proposal'). See: http://mu-ray.fisica.unina.it

The website of the European Space Agency (ESA) offers multimedia background information about cosmic rays. See: http://esamultimedia.esa.int/multimedia/edu/Cosmic_Rays.swf or use the shorter link: http://tinyurl.com/m6ap2c3

ESA's Eduspace website offers school-level information about volcanoes, including how they are monitored. See: http://www.esa.int/SPECIALS/Eduspace_Disasters_EN/SEM3WAMSNNG_0.html or use the shorter link: http://tinyurl.com/k6ep7tb

To mimic in the classroom how volcanoes are traditionally investigated, by monitoring the characteristic way seismic waves travel through rocks of different density, see:

Bazanos P (2012) Building a seismograph from scrap. *Science in School* **23**: 25-32. www.scienceinschool.org/2012/issue23/earthquakes

With its most famous eruption, in 79 AD, Mount Vesuvius destroyed the Roman town of Pompeii. To learn how modern scientific analyses are casting light on the ancient town, see:

Capellas M (2007) Recovering Pompeii. *Science in School* **6**: 14-19. www.scienceinschool.org/2007/issue6/pompeii

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Paolo Strolin is an emeritus professor at the University of Naples Federico II, Italy. His main scientific background is particle physics, in particular neutrino physics. His interest in education has led him to be involved in the Scienza e Scuola (science and school) project, which links school teachers, school students and professional researchers to encourage and nourish young people's interest in and knowledge of science[w1].

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Earth science

Physics

Image courtesy of NASA

Photo of the Cleveland Volcano, Aleutian Islands, taken from the International Space Station on 23 May 2006. The volcano emitted a plume of ash but did not erupt.

Evolving threats: investigating new zoonotic infections

In the African forest, Fabian Leendertz and his team look for new infectious agents that can be transmitted from animals to humans. Could one of them cause the next pandemic?

By Julia Heymann

Our modern lifestyle, in which we can travel around the globe in a matter of days, has made it easier for infectious diseases to spread. Pathogens that have recently been transmitted from animals to humans can be particularly dangerous because they are new to our immune system. Fabian Leendertz at the Robert Koch Institute[w1] in Berlin, Germany, studies previously unknown infectious microbes in Africa, hoping to prevent the outbreak of new zoonoses.

The word *zoonosis*, derived from the Greek words *zoon* (creature) and *nosos* (disease), describes an infectious disease that can be transmitted between animals and humans. Two established examples are rabies and bubonic plague, both of which can be deadly for humans. Whereas an *epidemic* affects a certain population, a *pandemic* is an infection spanning multiple continents or even the whole world. Significantly, all recent pandemic outbreaks have been caused by animal pathogens that have recently evolved to broaden their host spectrum. Human immunodeficiency virus (HIV) originated in chimpanzees or gorillas, the 2003 outbreak of severe acute respiratory syndrome (SARS) was caused by an avian coronavirus, and the 2009 swine flu pandemic came from – well, you can guess.

How did these infections become such a serious and global danger? "The majority of human pathogens came from elsewhere in the animal kingdom," Fabian explains, so that alone is not the explanation. However, "Today, it is far easier for a pathogen to spread between countries. What would have been a small incident in the past can now quickly become a worldwide outbreak." Our increased mobility is not the only reason for this:

Image courtesy of Scott Bauer, US Department of Agriculture / Wikimedia Commons

REVIEW

- Biology
- Evolution
- Health
- Ecosystems
- Climate change
- Ages 14-18

This comprehensive and simply written article about research into zoonotic infections can be used in biology lessons to address the topics of evolution, health, ecosystems or climate change. Suitable comprehension and extension questions include:

1. Why are zootonic infectious so dangerous?
2. How may environmental changes cause more zootonic infections in the near future?
3. What could governments do to prevent new pandemics?
4. What tests allow scientists to determine if an individual has been infected by a zoonosis?
5. How should authorities manage an emergency of a pandemic caused by zoonosis?

This article could also be used to stimulate discussions about the history of infectious diseases; the interactions of organisms with their environment; and recent food security scandals. Starting with the known zoonoses mentioned in the article, it could be used to discuss the economic, social and political consequences of recent pandemics.

Panagiotis Stasinakis, 4th Lyceum of Zografou, Greece

Plane landing over Simpson Bay

Image courtesy of Steven Conry; image source: Flickr

"As human residential areas grow and humans enter more and more remote territories, we encounter new pathogens. Changing the local ecosystem eliminates some species and benefits others, some of which could bring zoonotic microbes with them."

Ebola virus, for example, was passed from apes to humans, presumably by the consumption of 'bush meat': wild animals such as fruit bats or monkeys that are hunted for food. Often, they are butchered without gloves. If those animals have an infection, it can easily spread to the people hunting, butchering or eating them. In parts of Africa, wild animals are an important food source, and rapid population growth has stimulated the bush meat trade. Fabian's research focuses on this method of disease transmission.

At bush markets, live wild animals can be bought as food. This is one way in which zoonotic infections can spread.

Image courtesy of Fabian Leendertz

Monitoring our relatives' health

The primates include not only humans, but also lemurs, monkeys and our closest relatives: the great apes, such as chimpanzees and gorillas. Any virus or bacterium that infects our primate relatives could also be dangerous to us. To identify new infectious agents that jump the species barrier, therefore, the German researchers teamed up with behavioural scientists in Ivory Coast, West Africa, to study the great apes. They collaborate as part of the Great Ape Health Monitoring Unit[w2], an institute that provides space to researchers from around the world who want to obtain samples from wild apes. Whenever one of the apes that they are studying becomes ill or dies, the team collects blood, faeces and urine samples to send to Fabian and his group in Berlin. If the ape dies, it is autopsied onsite by one of the veterinarians.

Public domain image / Wikimedia Commons

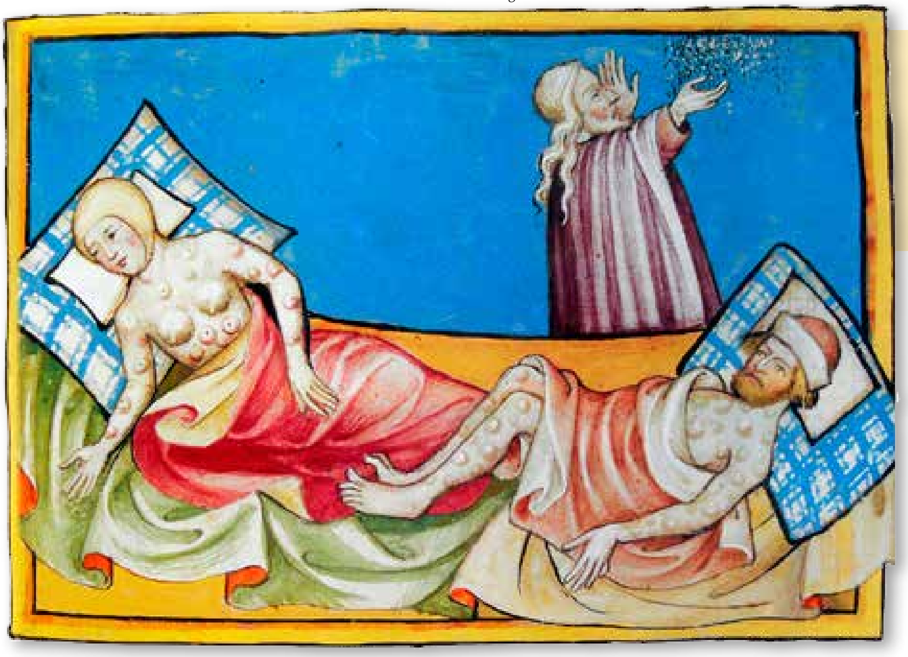


Illustration from the Toggenburg Bible (Switzerland) of 1411. The disease is widely believed to be the plague, the 'Black Death'. However the location of the bumps or blisters is also consistent with smallpox.

Image courtesy of Fabian Leendertz

In the field, researchers wear biohazard suits when extracting samples, to protect them from dangerous micro-organisms.

Identifying the responsible pathogen

When the samples arrive in Fabian's lab in Berlin, he and his co-workers try to find out which pathogen is behind the outbreak – and if it is already known. Several laboratory tests can expose the identity of the microbe, by revealing its genome sequence or characteristic surface molecules.

One such technique, the polymerase chain reaction (PCR), multiplies DNA sequences and makes them easier to identify. Fabian then searches for regions that are unique to certain micro-organisms. If one of those specific sequences is present in the sample, the pathogen can be identified as belonging to a certain bacterial or viral family. By testing different types of sample – blood, faeces or urine – the scientists can search for specific types of disease, for example those caused by respiratory, intestinal or systemic pathogens.

If the pathogen is an unknown micro-organism, "we try to culture it and isolate the whole genome for sequencing. Then we present the newly discovered microbe to the scientific world," Fabian explains.

Can it infect us?

Does the newly discovered microbe infect only apes or can it be transmitted to humans? If people can be infected, will they become ill? Could they pass the disease on to other humans? To answer these questions, the German scientists travel to Africa and take samples from people living close to where the virus was found; these people are not necessarily ill, but could have antibodies in their blood that indicate a past infection. The scientists also work with local doctors who send samples to Germany.

If the microbe is found in human samples, it could have been acquired either directly from apes or indirectly from another host. To determine whether it might cause an epidemic or even a pandemic, the researchers try to find out if it can be passed from one person to another. This is a difficult task, involving interviewing lots of villagers. Have they had close contact with apes or with ill people? Where and when? Using this data, the researchers hope eventually to

Image courtesy of Fabian Leendertz

In parts of rural Africa, people and monkeys may live in close contact, increasing the probability of infecting each other.

Image courtesy of Fabian Leendertz

Blood samples are taken from locals to check if they have been infected with the pathogen.

Public domain image / Wikimedia Commons

The plague was detected in rats at the Port of New Orleans in 1914, prompting a major rat eradication effort. These three men are examining rats for the disease.

Public domain image / Wikimedia Commons

During the bubonic plague of 1900–1902 in Brisbane, Australia, rats – the worst carriers of the dreaded disease – were destroyed in their thousands.

identify the source and the means of transmission of the newly discovered pathogen.

If the pathogen proves to be dangerous, the health authorities are notified and take charge of emergency measures. Sick people are quarantined, doctors and nurses are called to the outbreak zone, and bush markets and public transport may be shut down temporarily. The researchers themselves also need to be careful. “We carry a mobile miniature lab with which we can instantly test for the most dangerous species, like Ebola virus,” explains Fabian. Until it is clear what microbes they are dealing with, they protect themselves with biohazard suits.

Image courtesy of Jans Canon / Wikimedia Commons

A wild rat

The outlook

The research strategy has proved successful: in recent years, the group discovered why wild chimpanzees had started dying of anthrax (Leendertz et al., 2004). Fabian and his colleagues found that a previously harmless soil bacterium (*Bacillus cereus*) had acquired – from a related pathogenic bacterium (*Bacillus anthracis*) – the genetic information to produce the dangerous anthrax toxin. The bacterial strain that evolved from this genetic transfer (*Bacillus cereus anthracis*) can live in the soil and is highly virulent, thus posing a lethal threat to chimpanzees. The next step will now be to test whether this specific strain is found in the local human population and, if so, how humans can be protected, for example, by vaccination.

Reference

Leendertz FH et al. (2004) Anthrax kills wild chimpanzees in a tropical rainforest. *Nature* **430**: 451-452. doi: 10.1038/nature02722

Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2013/issue27/zoonosis#resources), or subscribe to *Nature* today: www.nature.com/subscribe

Web resources

w1 – Website of the Robert Koch Institute, the German centre for disease control: www.rki.de

w2 – Website of the Great Ape Health Monitoring Unit: www.eva.mpg.de/primat/GAHMU

Resources

To learn about the ecology of bird flu, another zoonotic infection, see:

Niekoop L, Rienks F (2006) The ecologist’s view of bird flu. *Science in School* **3**: 24-30. www.scienceinschool.org/2006/issue3/birdflu

The University of Minnesota has created ‘Outbreak at Watersedge’, an

Public domain image / Wikimedia Commons

The 1918 Spanish influenza ward at Camp Funston, Kansas, USA, showing the many patients ill with the flu

Distribution of protection masks in Mexico City during the 2009 flu pandemic

Image courtesy of kalitemarketing.com

online game in which you track the source of an outbreak of illness. See: www.mclph.umn.edu/watersedge

In the online game Pandemic II, you are a virus, parasite or bacterium with the goal of infecting and killing everyone on the planet. See: www.crazymonkeygames.com/Pandemic-2.html

In a TEDed video, Mark Honigsbaum describes the history of pandemics and how that knowledge can help to halt future outbreaks. See: http://ed.ted.com/lessons/how-pandemics-spread

To learn more about a very different hazard of human–wildlife interactions, see:

Notman N (2012) Cracking down on wildlife trafficking. *Science in School* **24**: 6-11. www.scienceinschool.org/2012/issue24/juliana

If you enjoyed this article, you may like to browse the other biology-related articles in *Science in School*. See: www.scienceinschool.org/biology

Image courtesy of Jebulon / Wikimedia Commons

The top of the plague column ("Pestsäule") in Vienna, Austria. Plague columns were built after plague epidemics in Christian cities to thank the Virgin Mary (or sometimes the Holy Trinity) for preserving the city and the survivors.

Julia Heymann studied biology and did her PhD on infectious bacteria at the Max Planck Institute for Infection Biology in Berlin, Germany, before doing a post-doc at the Robert Koch Institute in Berlin. She also holds a degree in journalism and is currently working as a writer for *Spektrum der Wissenschaft*.

To learn how to use this code, see page 53.

Image courtesy Turnervisual / iStockphoto

Science teachers: using education research to make a difference

As a teacher of science, technology, engineering or mathematics (STEM), you are in a perfect position to encourage more students to take up STEM studies and careers. But what are the best ways to inspire students and achieve this goal? Research projects in science education can really help, but finding your way through all the results can be a challenge.

Teachers are in a perfect position to encourage more students to take up STEM studies and careers.

The DESIRE project (Disseminating Educational Science, Innovation and Research in Europe) was set up to tackle the problem of making educational research more accessible to teachers[w1]. From 2011 to 2013, a range of STEM professionals – including science teachers, science communicators and policymakers – were consulted to identify the main challenges that science teachers face in accessing new ideas from STEM educational research, and the best ways to make research available to help develop innovative teaching.

Go online

The most efficient way to access new information is through online communities, websites and blogs. Some online portals are a central point to access information on a wide range of resources: these include eTwinning[w2], Scientix[w3], inGenious[w4] and the Learning Resource Exchange platform[w5]. Being active in topic-based online communities is a great way to create and share ideas with other STEM professionals from universities and the private sector, as well as teaching. Moodle[w6] and Edmodo[w7] are recognised by many teachers as ideal social media as they are controlled, secure online areas. Pearltrees[w8] helps to save links and explanations, and Diigo[w9] enables resource sharing.

Attend events

Conferences and other face-to-face events are good opportunities to meet the innovators of new teaching practices, and also to network with other teachers. Attending a training course can have a long-lasting impact on your teaching and help you to become more confident about using new approaches in class. You can share out opportunities to attend events between yourself and your colleagues, so that you all have a chance to be inspired. On your return, make the most of the knowledge you have gained by discussing it with your colleagues.

Participate

Even if there is limited time and money available to you to attend events in person, you can still participate in European and national STEM education projects, for example through European Schoolnet[w10] or other national and international bodies active in formal and informal STEM education. Involvement in such activities will enable you to benefit

How can teachers best use STEM educational research to inspire their students?

from the experience of the professionals leading these initiatives, and to share your own knowledge. By doing this, you will in turn enhance the way STEM education resources are developed and communicated in a way that takes your needs and constraints into account.

Inspire

You can inspire colleagues to participate in STEM education projects and use the results of research by showing them the advantages – namely, that it will reinforce their STEM teaching skills and keep their knowledge up to date. Perhaps share success stories from your own experience, or create a small exhibition or event with your students to display the new insights they have obtained through using alternative methods. Involving your head teacher is key, as this will help to motivate your colleagues and provide professional recognition for your efforts.

Although lack of time is a major challenge for all teachers, remember that most new methods and tools are designed to make teaching more efficient. Once you are familiar with them, they can save you time and effort in teaching your STEM curriculum. So think about the long-term vision you have for your classes.

Image courtesy of Shutterstock

Acknowledgements

DESIRE is one of many projects offered to science teachers by European Schoolnet, a network of 30 ministries of education in Europe. Other major platforms are Scientix[w3] and Ingenious[w4].

The DESIRE project has been funded with the support of the Lifelong Learning programme of the European Union. It is carried out by European Schoolnet together with INDIRE (*Agenzia Nazionale per lo Sviluppo dell'Autonomia Scolastica*), Universitat Autònoma de Barcelona, Danish Science Communication (*Dansk Naturvidenskabsformidling*) and Ecsite (the European network of science centres and museums). This article reflects the views only of the authors, and the European Commission cannot be held responsible for any use that may be made of the information contained herein.

Image courtesy of European Schoolnet

Web references

w1 – The DESIRE project and its results. See: http://desire.eun.org

w2 – eTwinning, a learning community that promotes school collaboration and teachers' professional development. See: http://etwinning.net

w3 – Scientix, the community for science education in Europe, which aims to facilitate sharing of know-how and best practices. See: www.scientix.eu

w4 – inGenious, which has resources to encourage interest in science education and careers among young Europeans. See: www.ingenious-science.eu

w5 – Learning Resource Exchange for schools, which provides educational content from many different countries. See: http://lreforschools.eun.org

w6 – Moodle, a virtual learning environment and social community for teachers. See: https://moodle.org

w7 – Edmodo, a social learning platform for teachers, students, and parents. See: www.edmodo.com/about

w8 – Pearltrees, a tool that acts as an extension of internet browsers to reference favourite web pages. See: www.pearltrees.com

w9 – Diigo, a research tool and knowledge-sharing community . See: www.diigo.com

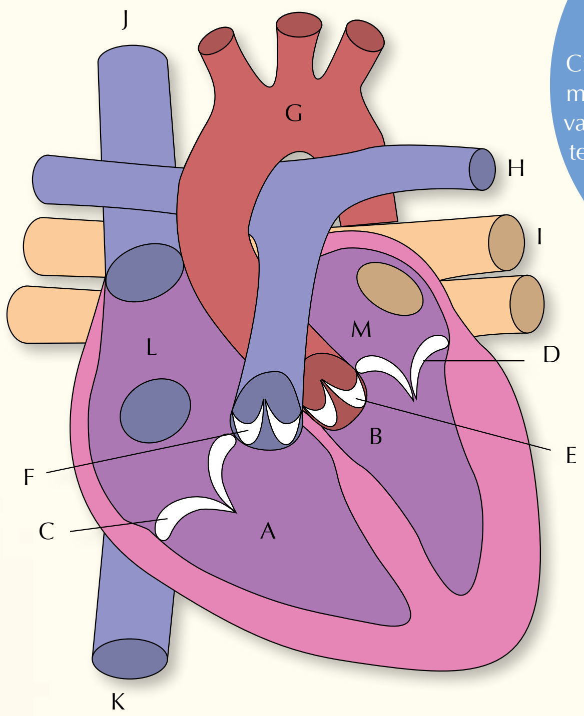
w10 – European Schoolnet, where you can subscribe to newsletters for opportunities to participate in education projects. See: www.eun.org

How can STEM educational research be effectively used in teaching?

To learn how to use this code, see page 53.

From the bottom of our hearts: a hands-on demonstration of the mammalian heartbeat

Using nothing but a pig's heart, a knife and a supply of water, you and your students can investigate how the heart pumps.



A typical diagram of the heart, showing the structures involved but explaining very little about the function. A: Right ventricle; B: left ventricle; C: tricuspid valve (atrioventricular); D: mitral valve (atrioventricular), E: aortic valve (arterial); F: pulmonary valve (arterial); G: aorta; H: pulmonary artery; I: pulmonary vein; J: superior vena cava; K: inferior vena cava; L: right atrium; M: left atrium

Image courtesy of Edmond Hui

REVIEW

- Biology
- History of science
- Mathematics
- Cardiovascular system
- Ages 11-19

The article shows how important curiosity can be: in this case, the desire to better understand the physiology of the mammalian heart led to the discovery of a simple but effective strategy to study how blood is pumped.

Although novel, the strategy is so simple that it could be used with students of almost any age. With younger students (ages 11-14), the teacher should demonstrate the activity; older students (ages 15-19) should be able to work autonomously in groups.

The authors also suggest some further investigations, which would extend the educational value of the activity and create interdisciplinary opportunities involving mathematics. Furthermore, the historical information in the introduction would be an excellent starting point for discussions with older students about the history of science and the relationship between science and technology.

Betina Lopez, Portugal

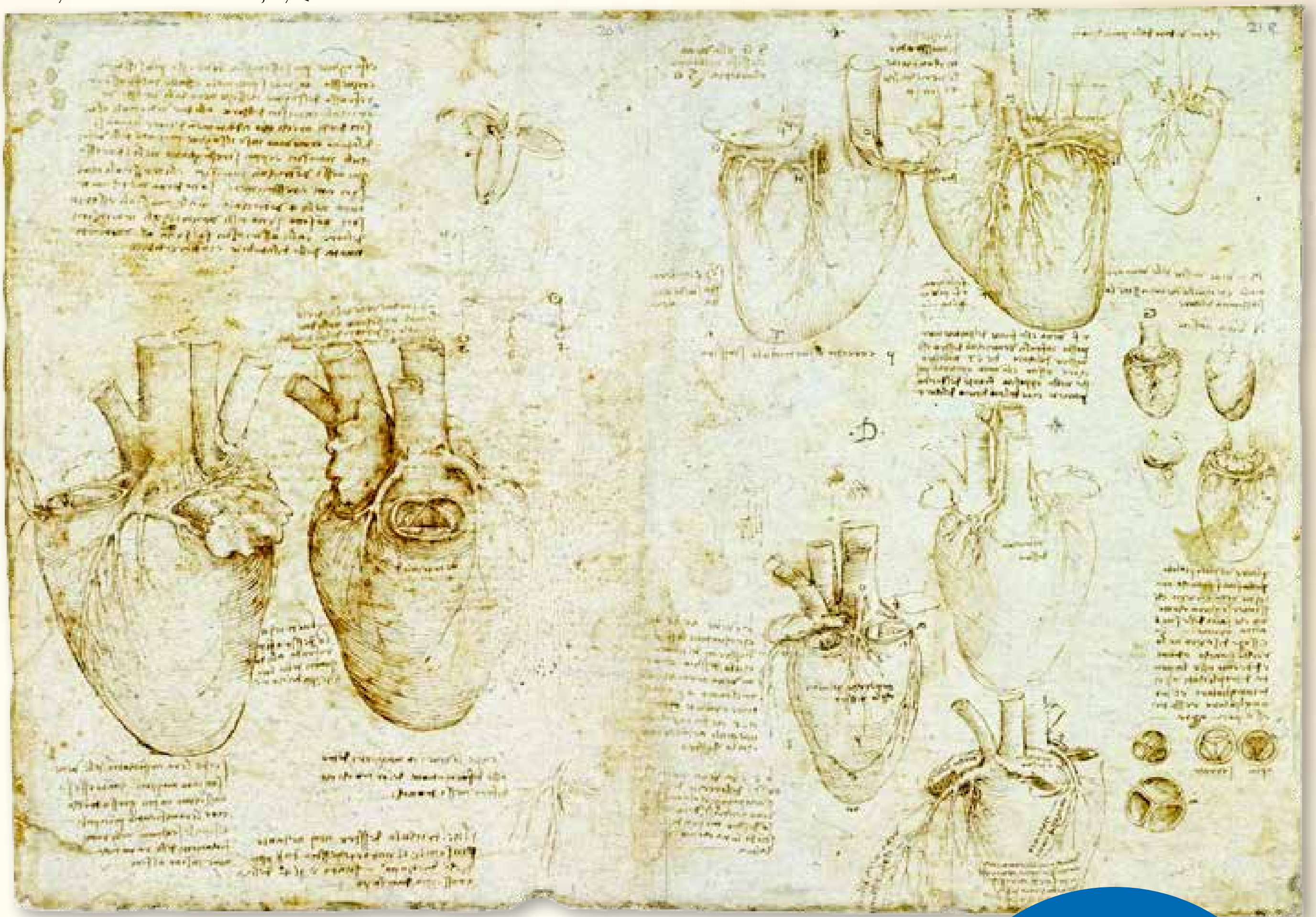


Figure 1: The heart and coronary vessels by Leonardo da Vinci. Da Vinci's drawings and notes record both his remarkable powers of observation and his inability to reconcile what he saw with the traditional understanding of the heart at the time. Blood circulation was not discovered for another hundred years.

By Edmond Hui and Archie Taplin

Leonardo da Vinci was one of the first people to look carefully at the heart and describe what it did. His drawings of the heart and its valves are masterpieces of scientific art (figure 1), and he made remarkable observations about the way that blood flows through the vessels and chambers and activates the arterial valves.

Nevertheless, da Vinci never fully understood how the heart pumps, because he was unaware of the circulation of blood in the body. He could see the arteries and veins, but not the capillaries that connected them. He was also hampered by the prevailing view at the time: that the heart moved blood to transport heat from the liver to the muscles, and that the function of the lungs was to cool the blood.

So to da Vinci, the heart appeared to pump blood into vessels that branched into ever-smaller vessels – essentially dead ends. And where did the blood flowing into the heart come from? Without knowing this, he could not reconcile the large volumes that the heart could clearly pump with the fact that there was apparently nowhere for the pumped blood to go.

Today, the circulation of blood is well understood, but only a small proportion of people have actually witnessed the pumping action of the mammalian heart. Hearts are cryptic organs, hidden inside living animals; exposing the heart usually causes the animal to die. Even in open-heart surgery, the valves and the flow of blood are obscured by the opaque heart tissues. Modern medical imaging systems can produce spectacular displays of the heart in action, but these images are difficult for laypeople to interpret and impossible to create in schools. The biomechanical functioning of the heart is thus so obscure that in popular culture the organ is primarily thought of as a metaphor for emotion.

School biology lessons document the dual circuit of the vascular system and name the parts of the heart, but do not really explain *how* the blood is propelled, or *why* the heart is arranged

Royal Collection Trust / © Her Majesty Queen Elizabeth II 2013

as it is. Try searching the Internet for demonstrations of the heart and you will find thousands of diagrams and other teaching resources. However, we found none that actually showed the pumping action of a real mammalian heart.

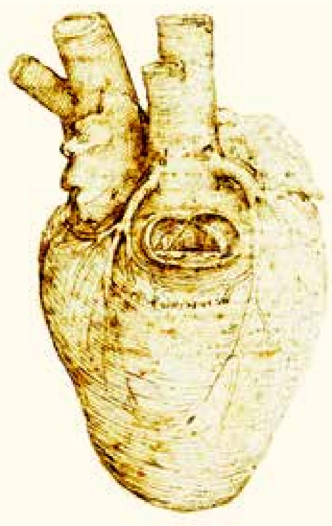
Investigating the mammalian heart for ourselves

We wanted to discover for ourselves how the mammalian heart actually pumps. We started with the idea that we should be able to make the heart pump by squeezing it manually, much like a simple plastic hand pump.

We obtained an undamaged pig's heart and tried manually compressing it under water. We also tried pumping it while attempting to run water into the atria from the tap; this was difficult as the atria were flaccid and had multiple openings. Neither approach seemed to work – no water was expelled from either the pulmonary artery or aorta.

After this failure, we re-examined both the heart and our initial understanding of its function, and began to dissect it. First, we completely removed both atria, which resemble floppy bags with holes in them. The remainder, literally the bottom of the heart, consists of a pair of open ventricles with the aorta and pulmonary artery rising between them. The system is visually and mechanically very simple – clearly just a pair of pumps. At first sight, there were no signs of the atrioventricular valves: they were hanging down like curtains, close to the walls of the ventricles.

To identify which ventricle was connected to which artery, we ran water into one of the ventricles from the tap. To our surprise, the atrioventricular valve immediately closed inwards towards the stream of water (figure 4 on page 21). As da Vinci had described for the arterial valves, it was not pressure, contraction or compression that activated the atrioventricular valves, but the actual movement of the liquid.



We found that by manually compressing the heart while water was flowing into the ventricles, we could close the atrioventricular valve completely and produce a dramatic spurt of water from the artery.

We realised that in our earlier attempt, the atria had been blocking the flow of water into the ventricles. Now, however, we had an unobstructed flow and were able to manually reproduce the pumping action of the heart. We could see not only how the contraction (or manual compression) of the ventricles moves the liquid, but also the precise action of the valves – something very seldom seen by anyone but a heart surgeon.

Initially, we had imagined that the atrioventricular valves had robust, hinged or elastic flaps (cusps) that responded to pressure differences. How wrong we were! Instead, the cusps are membranous and flaccid, like parachutes attached to the ventricular walls – billowing out when the flow of liquid inflates them, and prevented from turning inside out by 'heart-strings' (chordae tendineae) that work like parachute cords.

When the blood moves from the ventricle into the artery, another valve (the arterial valve) stops the high-pressure blood from leaking back into the ventricle. By trimming the aorta and pulmonary artery closer to the ventricles, we were able to observe these valves opening and closing as well.

On a personal level, we have been amazed. To sort through the internal organs of a pig, remove the heart and then discover all this intricate detail for ourselves has been a scientific adventure. We were also struck by the realisation that we had not properly understood the available resources, and that what had seemed to be a complex and obscure subject was in fact fully accessible to school-age students.

Demonstrating a beating heart in the classroom

We believe that this demonstration of the heart pumping mechanism is novel, yet it is easy to repeat in any school laboratory. After the activity, the students should have understood the functional anatomy of the heart, directly observed the motion and function of the four heart valves, and grasped the importance of flow to the motion of the valves.

The pumping mechanism alone can be demonstrated in just a few minutes. However, a full demonstration – with student participation and a discussion of the heart's connections to surrounding organs and the circulatory system – can productively occupy two hours.

The activity is suitable for any age of secondary-school students (11+).

Materials

For each group, you will need:

- A pig or sheep heart

  The heart fully attached to the liver and lungs is known in the UK as a 'full pluck', and can be requested from a good butcher or local abattoir. Alternatively, you can use pre-packed hearts from the supermarket. In this case, make sure you buy some spares, as they have normally been trimmed by cutting across the atria. The aorta and pulmonary artery may also have been cut very short but if the ventricles are undamaged, the demonstration will work.
- A sharp knife or scalpel
- Running water.

Procedure

Preparing a full pluck

1. Remove the pericardium and separate the heart from the lungs by cutting the pulmonary artery and vein as far from the heart as possible (figure 2). The vena cavae and aorta will already have been cut when the organs were removed from the body cavity.

Figure 2: Finding the arteries. The pulmonary artery and aorta can be manually isolated from surrounding tissues, ready to be cut.

Image courtesy of Ed Hui

2. Identify the light coloured and elastic-walled aorta and pulmonary artery; the dark vena cavae and the pulmonary vein; and the atria. Remove the atria, trimming their walls close to the tops of the ventricles (figure 3). Be careful not to damage the aorta and pulmonary artery, which rise from the centre of the heart. The heart is now ready for use.

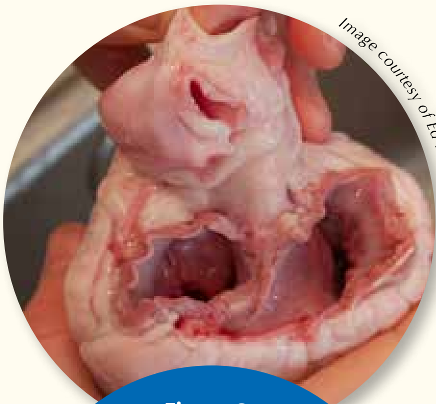


Image courtesy of Ed Hui

Figure 3: The atria have been removed and the atrial walls trimmed down to the tops of the ventricles. The two holes are the openings into the ventricles. The heart is held in the correct orientation for the demonstration, with the forefinger of the right hand ready to compress the right ventricle.

Preparing a supermarket heart

1. Trim any vestiges of the atria down to the ventricular wall.

Performing the demonstration

Identify the left and right ventricles; the demonstration works better on the thinner-walled right ventricle. Turn on the tap so that a smooth, continuous stream of water is flowing. Hold the heart so that the stream enters the centre of the opening of the right ventricle. The tricuspid valve should close inwards to touch the incoming stream of water (figure 4).

Figure 4: As the stream of water enters the right ventricle, the tricuspid valve closes inwards.

Image courtesy of Ed Hui

A) The stream of water is flowing into the centre of the right ventricle. The tricuspid valve has closed inwards against the incoming stream. The left hand is supporting the aorta.

Image courtesy of Ed Hui

B) Once the water flow has stopped, the closed tricuspid valve is visible. Note that the mitral valve in the left ventricle remains open because the water has only been run into the right ventricle. The actual demonstration should be performed with the heart held under a continuous stream of water.

If you now compress the heart, the valve will close completely and water should be expelled from the pulmonary artery (figure 5). Squeeze rhythmically to mimic the action of a beating heart[w1]. If you trim the aorta and pulmonary artery close enough to the heart, you should be able to see the arterial valves (figure 6).

Image courtesy of Ed Hui

Figure 6: By trimming the aorta and pulmonary artery close enough to the heart, you should be able to see the arterial valves.

Figure 5: When the right ventricle is compressed with the right hand, a stream of water is expelled from the pulmonary artery. This stream can be seen flying over the knuckles of the right hand towards the camera.

Image courtesy of Ed Hui

Image courtesy of Ed Hui

Further investigations

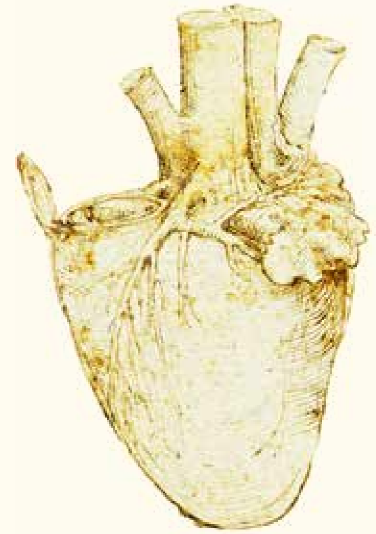
1. Attach surgical tubing to the outflow vessels, then measure the water pressures achieved when you compress the heart.
2. Challenge your students to prove that the heart is a pair of independently functioning pumps by dissecting away an entire ventricle. Using a second heart, repeat the exercise using the other ventricle. These isolated ventricles should function when manually compressed.
3. In live animals, the two ventricles contract simultaneously, propelling blood first through one ventricle and eventually through the other. Despite their markedly different morphology, therefore, over time, the two ventricles must average precisely the same volume of blood per beat. How is this equilibrium achieved? Given their observation that the thinner-walled right ventricle is easier to compress manually than the left ventricle, the students should consider the implications for cardiopulmonary resuscitation, which is essentially this demonstration performed with the heart *in situ*.
4. This demonstration is only possible once the atria have been removed. Ask your students to research the function of the atria.

Figure 7: "I can do gory!" Archie Taplin holds a pig's heart, having just removed the pericardium. The liver can be seen at the top of the picture, the lungs are on the left, and the trachea extends to the tongue on the far left.

Image courtesy of Ed Hui

Acknowledgements

We are grateful to the TED organisation and Teddington School, without which neither of us would have made these observations. Laverstoke Park Farm supplied the full plucks with great care and attention. A number of heart experts generously answered our basic questions on heart anatomy and function, including Dr Andrew Ho (Evelina Children's Hospital, London); Professor David Firmin (Imperial College, London); Dr Gary Ruiz (King's College Hospital, London); Professor David Celermajer (University of Sydney); Dr Louise Robson (University of Sheffield) and Martin Clayton (The Royal Collection, Windsor Castle). Nonetheless, any errors and omissions in this paper are entirely our own.



Web references

w1 – A video of the demonstration is available on Youtube. See: http://youtu.be/5OuLTQlTEso

w2 – Archie Taplin's talk for the school's TEDxTeddington conference was the inspiration for the authors' investigation of the heart's anatomy and function. http://youtu.be/4tQR4H88zmE

w3 – In the 'Leonardo da Vinci: Anatomy' app for the Ipad, Martin Clayton, curator at Windsor Castle, tells the story behind Leonardo da Vinci's life-long ambition and reveals the mind of a scientist who was centuries ahead of his time. See: www.touchpress.com/titles/leonardo-da-vinci-anatomy

Resources

The following scientific papers about heart anatomy are remarkably accessible and were helpful in the preparation of this paper:

Ho SY (2002) Anatomy of the mitral valve. *Heart* **88(suppl. 4)**: iv5–iv10. doi: 10.1136/heart.88.suppl_4.iv5

Ho SY, Nihoyannopoulos P (2006) Anatomy, echocardiography, and normal right ventricular dimensions. *Heart* **92(suppl. 1)**: i2–13. doi: 10.1136/hrt.2005.077875

If you found this article useful, you might like to browse the other teaching activities in *Science in School*. See: www.scienceinschool.org/teaching

Dr Edmond Hui is a marine biologist by training and the network manager at Teddington School, as well as the organiser of the TEDxTeddington conference. Archie Taplin, aged 15, is a student at Teddington School.

The two undertook this demonstration because Archie was interested in developing a talk for TEDxTeddington on a zoological subject[w2]. When Ed pointed out the difficulty of creating a dramatic zoological presentation on stage ("It'll either involve live animals or it'll be gory…"), Archie replied "I can do gory!". This comment, coinciding with Ed's enjoyment of the 'Leonardo da Vinci: Anatomy' Ipad app[w3], was the inspiration to investigate the pumping heart.

To learn how to use this code, see page 53.

Image courtesy of Michael Apel / Wikimedia Commons

Juvenile male damselfly (*Calopteryx virgo*)

Phylogenetics of man-made objects: simulating evolution in the classroom

Image courtesy of kevincole / Wikimedia Commons

American avocet (*Recurvirostra americana*)

Evolutionary relationships can be tricky to explain. By using simple, everyday objects, your students can work them out for themselves.

By John Barker and Judith Philip

Birds, bats and insects all have wings; horses, millipedes and crocodiles all have legs. Many unrelated species can be grouped by physical similarities – that is one of the problems with studying morphological phenotype to determine evolutionary relationships. Convergent evolution can result in apparently similar structures. Although the end product may be the same (e.g. the presence of wings), the starting points can be very different. Some organisms that may appear similar and hence related are actually widely separated from each other in the evolutionary tree.

At a molecular level, DNA and protein studies can be used to produce a family tree by looking at the differences between homologous sequences: sequences that are thought to have evolved from a common ancestor. Kozlowski (2010) describes an excellent activity to demonstrate this in a classroom, but there is a sense of being removed from the study – the data required is simply downloaded and used. This article provides a complementary, more hand-on introduction to evolutionary studies, in which the students gather all the necessary data themselves before considering the underlying principles.

In this classroom activity, your students can use a wide range of objects to create an artificial phylogeny based on morphology. The family tree that they produce will be artificial in the sense that the objects used have not actually evolved from each other. However, the problems faced and the questions posed are similar to those addressed by palaeontologists using specimens of fossils, or by entomologists using specimens of dead insects in museum cabinets.

The activity, which takes approximately 30 minutes, is suitable for a wide range of students, from the age of about 15 up to postgraduate level.

It allows students to:

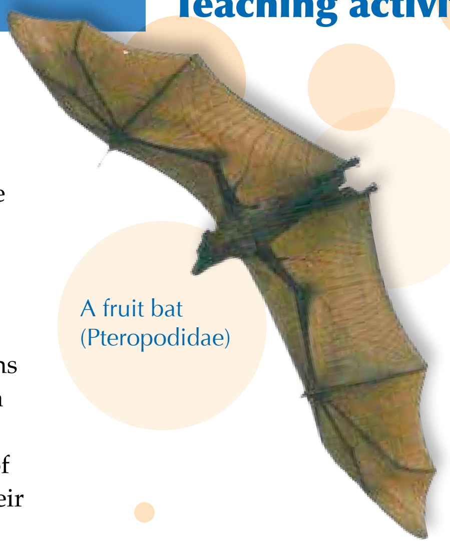
1. Use morphology to make an ‘evolutionary’ tree.
2. Link morphology to adaptations and consider the definition of a species.
3. Hypothesise the morphology of missing links and state how their hypothesis could be tested.
4. Consider the challenges and limitations of using evolutionary trees based on morphology and on DNA sequences.
5. Investigate for themselves the concepts of divergent, convergent and parallel evolution.
6. Present, discuss, defend and evaluate a proposed evolutionary tree.
7. Recognise the expertise required by scientists when making evolutionary trees.

REVIEW

- Biology
- Evolution
- Ages 14-19

Evolution is a tricky concept to understand. This article describes an unusual but simple classroom activity, using cheap and easily available materials to teach some of the most basic principles of evolution. More specifically, through the use of evolutionary trees, students can investigate the phenomena of divergence, convergence and parallel evolution. It’s also fun!

Michalis Hadjimarcou, Cyprus



A fruit bat (Pteropodidae)

Image courtesy of Peter van der Sluijs / Wikimedia Commons

Guiding principles

There are four guiding principles used to produce an evolutionary tree based on morphology:

1. Organisms that resemble each other in many ways are probably more closely related than are organisms that resemble each other only slightly. That is, the greater the similarity in structure (the more features in common), the closer the probable relationship between two forms.
2. Evolution is usually the result of a gradual accumulation of small changes in structure (and function) but occasionally there are larger changes.
3. In general, simpler forms give rise to more complex ones and smaller forms to larger ones, although there can be exceptions.
4. Evolutionary processes do not go into reverse, but specialised structures can be lost.

Activity: evolution in the classroom

One version of this activity uses metal objects such as nails, screws, staples, paperclips and drawing pins. The greater the number of objects used, the longer the activity will take.

As a guide, it will take the students around 15 minutes to sort out the evolutionary relationships and 10-15 minutes for feedback and discussion. The time required could be shortened by using fewer objects or using

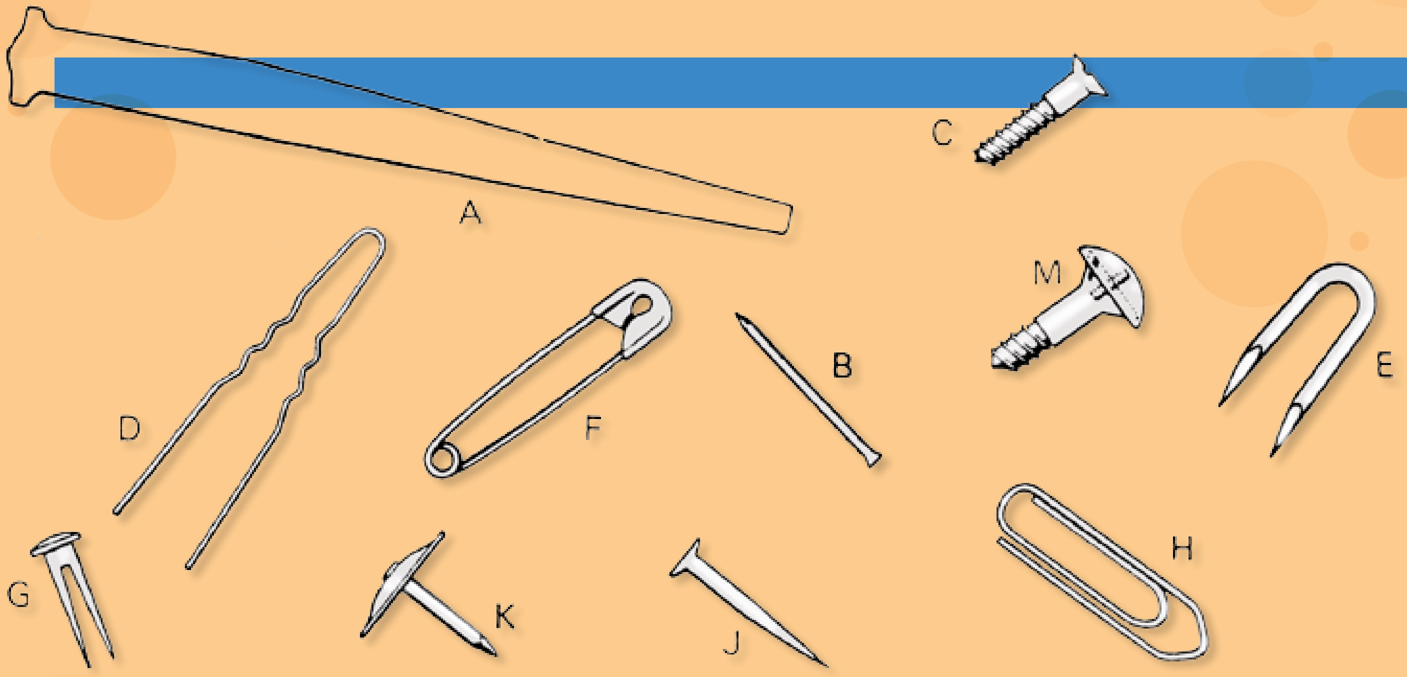


Image courtesy of John Barker

printouts instead of real objects – although it is more fun to handle real objects.

Materials

For each group, you will need one example each of some or all of the following metal objects (figure 1). Alternatively, you can use printouts of the objects (see the procedure, below).

- 75 mm tack [A]
- 20 mm nail [B]
- 20 mm screw [C]
- Hairpin (50 mm) [D]
- Staple (25 mm) [E]
- Safety pin (40 mm) [F]
- Split rivet (20 mm) [G]
- Paperclip (32 mm) [H]
- 25 mm tack [J]
- Upholstery pin (20 mm) [K]
- 13 mm nail [L]
- Mirror screw (20 mm) [M]
- Insulated staple (13 mm) [N]
- Round-headed paper fastener (20 mm) [O]
- Flat-headed paper fastener (20 mm) [P]
- Round-headed screw (25 mm) [Q]
- 50 mm nail [R]
- Drawing pin (6 mm) [S]
- Hook (20 mm) [T]
- Kirby grip [W]
- Bolt (65 mm) [Z]

Note, however, that it is not essential that the objects are exactly the size stated.

Procedure

1. Divide the class into groups.
2. Either:

   a) Hand out one of each of the objects shown in the figure to every group. Make sure each object has a letter.

   b) Download the pictures of the objects in figure 1 from the *Science in School* website[w1] and cut them out, keeping the letter with the picture. Use the printouts as though they were the actual objects.
3. Ask your students to arrange the objects to form a possible evolutionary series, using the four guiding principles. Encourage them to choose the smallest, simplest form as the probable common ancestor for the group and then try to arrange the others as branches of a tree derived from this ancestor.
4. Ask your students to record their trees using the letters associated with the objects.
5. Explain the concepts of divergent, convergent and parallel evolution. Then get your students to mark their trees to show possible divergence, convergence or parallel evolutionary developments.

Some solutions and discussion points

Some lines of evolution seem very obvious whereas other specimens will be quite difficult to place. Some may fit in several positions.

- The common ancestor is probably L — a small, simple form with a tiny head and simple shaft.
- L → B → R is an obvious line showing increase in size.
- L → J → A is a parallel line with a square shaft and larger head between Land J. L or B or J could have → C by an increase in complexity of head and shaft. (L or B seems the more likely ancestor because J has a square shaft.)
- C → Q → Z is a line showing an increase in size, increase in complexity of head, and finally a change in the shaft. Probably C → T through a change in head accompanied by slimming of the body.
- L → S → K is a line showing an increase in size and specialisation of the head. Probably S → P through an increase in size, but the material is different so it is possible that B or J → P, in which case there would be a convergence between P and S / K.
- Is G part of this evolutionary series? Either S or P could → G by a thickening and subsequent splitting

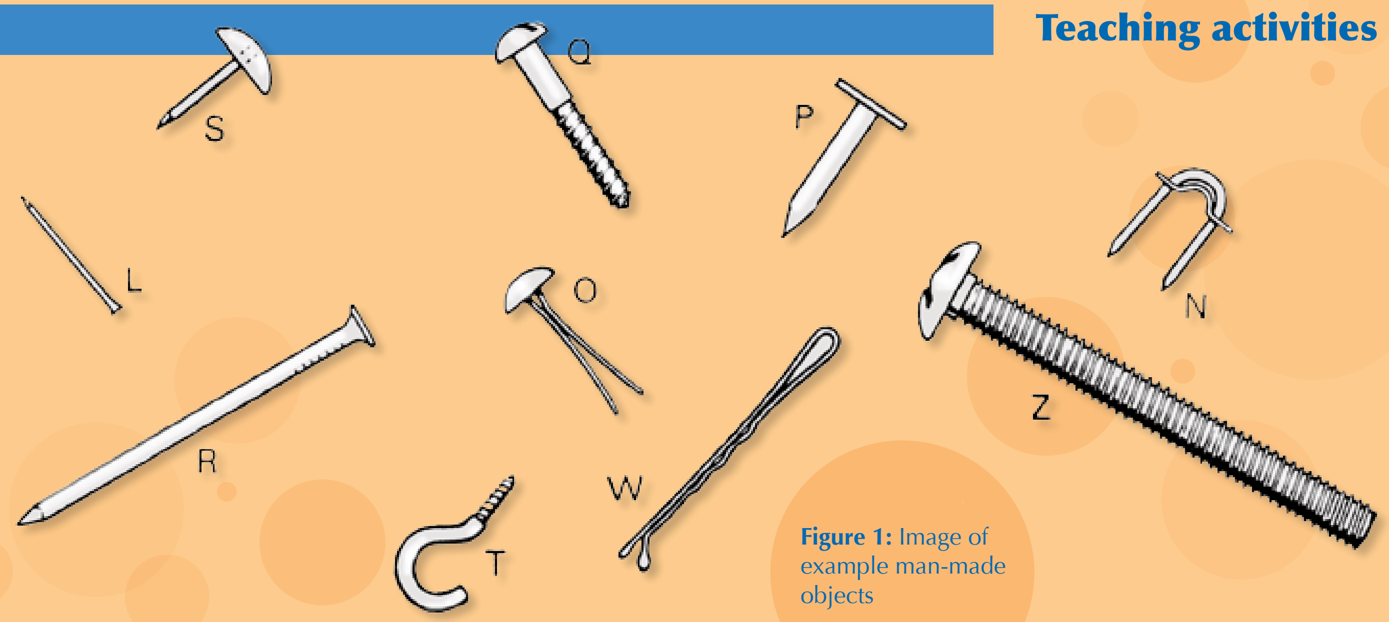


Figure 1: Image of example man-made objects

of the shaft. Probably G → O by a combination of elongation and slimming (a sort of eel-like series).

- M presents an interesting problem: of its two parts, one, the base component, is clearly very close to C in structure; the other part, the top component, shows similarities to Z but the head is smooth, not grooved. M also shows similarities to S but the shaft is threaded, not smooth. This is probably part of the radiation from C but it is clearly convergent to S. Do the two components represent two sexes (illustrating sexual dimorphism) or is M really a curious hybrid between descendants of C and S?

All the evolutionary series considered so far basically have a straight shaft and a single axis (exceptions are G and O where the shaft is double; T, which has a curved head, is another highly divergent type). We could say that all these forms are members of a single order – Orthos (from the Greek for 'straight') or some similar name. The rest of the objects are bent in various ways – Sinuos (from the Latin for 'curve') or some similar name. Of the curved objects, the simplest form is probably E so this is likely to be nearest to the common ancestor.

- Probably L → E by loss of its tiny head and bending of the shaft but it is just conceivable that T → E by loss of the screw thread and further bending of the head. It seems more likely that T is convergent to the series descended from E.
- E → N by addition of the plastic insulation.
- E → D by elongation and slimming of the two sides and appearance of waves.
- D → W by further asymmetrical specialisation of the two sides.
- H and F look as though they are related, with H → F by addition of material to form a head. H might be derived from E by slimming and bending, possibly with common ancestry with D; extra bends formed later, thus E → X (not represented in the collection – an as yet undiscovered fossil) → D → W and X → H → F.
- G and O have double shafts – could they be part of the Sinuos order? O could be derived from E by slimming and development of the centre into a sort of head, and then O could develop into G by strengthening and solidification. In this case, there would be strong convergence between G and S / P.

Within each 'order', there are several divergent lines. Series showing increases in size are common in the Orthos group; they also show variety in the development of the head and of the shaft, both independently and together. The Sinuos group shows variety in the bending of the two shafts; they generally lack heads – which may make it more probable that G and O are Orthos and not Sinuos.

Your students may have thought out quite a different series of evolutionary lines but as long as they can justify them using the four general principles, then each series is just as credible. If the objects were extant organisms, then there would be other possible lines of argument – such as studies of their molecular characteristics or of their embryology – which might support some hypotheses while discounting others and so indicate more precisely the probable evolutionary series.

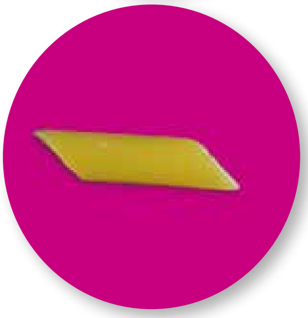
Variations

This type of activity can also be carried out with a range of other objects, for example biscuits or dried pasta. These materials can introduce another variable – that of colour. Do the colour differences represent camouflage, for example, or sexual dimorphism?

For a simple, 20-minute activity, a small group of objects can be used to represent the problems sometimes faced by palaeontologists. New specimens can be introduced as if they were recently discovered fossils. How can these new finds be accommodated in the tree?

Images courtesy of Isabelle Kling



Once your students have completed their trees, it is useful for them to assess each other's work. For example, they could ask:

1. Why have you put XX at the start of your tree?
2. Do you think YY evolved before ZZ?
3. Why (not)?
4. Do you think different coloured versions of the same shape are the same or different species?
5. Why (not)?

Have any groups of students produced identical trees? Can each group justify their reasons for choosing particular evolutionary pathways? This could lead to a discussion of why it is very difficult to generate an undisputed 'correct' tree. The students can then start to appreciate the depth and range of expertise that is required by an evolutionary biologist.

Next, tell your students that the pasta shapes (or biscuits) are made from a range of primary ingredients (wheat, rye and corn) and that if they were to look at the chemical composition of each shape, they would get a very different set of trees. The students normally make the link to DNA. For 15- to 16-year olds, it is sufficient to say that some species have similar DNA even though they look different. For older students (16+), convergent and divergent evolution can be discussed in more detail.

An extension activity for older students could be a discussion of the difficulties associated with extracting uncontaminated DNA from ancient samples (see, for example, Hayes, 2011).

A further extension activity could be to introduce the molecular phylogeny activity described in Kozlowski (2010).

Acknowledgement

The activity using metal objects was originally developed by the Open University's Science Course






Images courtesy of Isabelle Kling

Foundation Course Team for the S100 Course, Unit 21 'Unity and diversity', Study Guide. This version has been adapted from Barker (1984).

References

Barker JA (1984) Simulating evolution. *Journal of Biological Education* **18(1)**: 13–15

Hayes E (2011) An archaeologist of the genome: Svante Pääbo. *Science in School* **20**: 6-12. www.scienceinschool.org/2011/issue20/paabo

Kozlowski C (2010) Bioinformatics with pen and paper: building a phylogenetic tree. *Science in School* **17**: 28-33. www.scienceinschool.org/2010/issue17/bioinformatics

Web reference

w1 – Download pictures of the metal objects to use for the activity from the *Science in School* website. www.scienceinschool.org/2013/issue27/phylogenetics#resources

Resources

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

The website of the Natural History Museum in London, UK, offers excellent information about evolution. See: www.nhm.ac.uk/nature-online/evolution

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

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John Barker taught at a school in London, UK, for a decade and then moved into science teacher education, first at Borough Road College, London, and then at the Centre for Science Education, Chelsea College, London, during which time he was one of the team that produced Nuffield Advanced Biology. He is keenly interested in initial science teacher education courses and was director of the course at Chelsea College and, after their amalgamation, at King's College London, for more than ten years. He is now retired.

To learn how to use this code, see page 53.

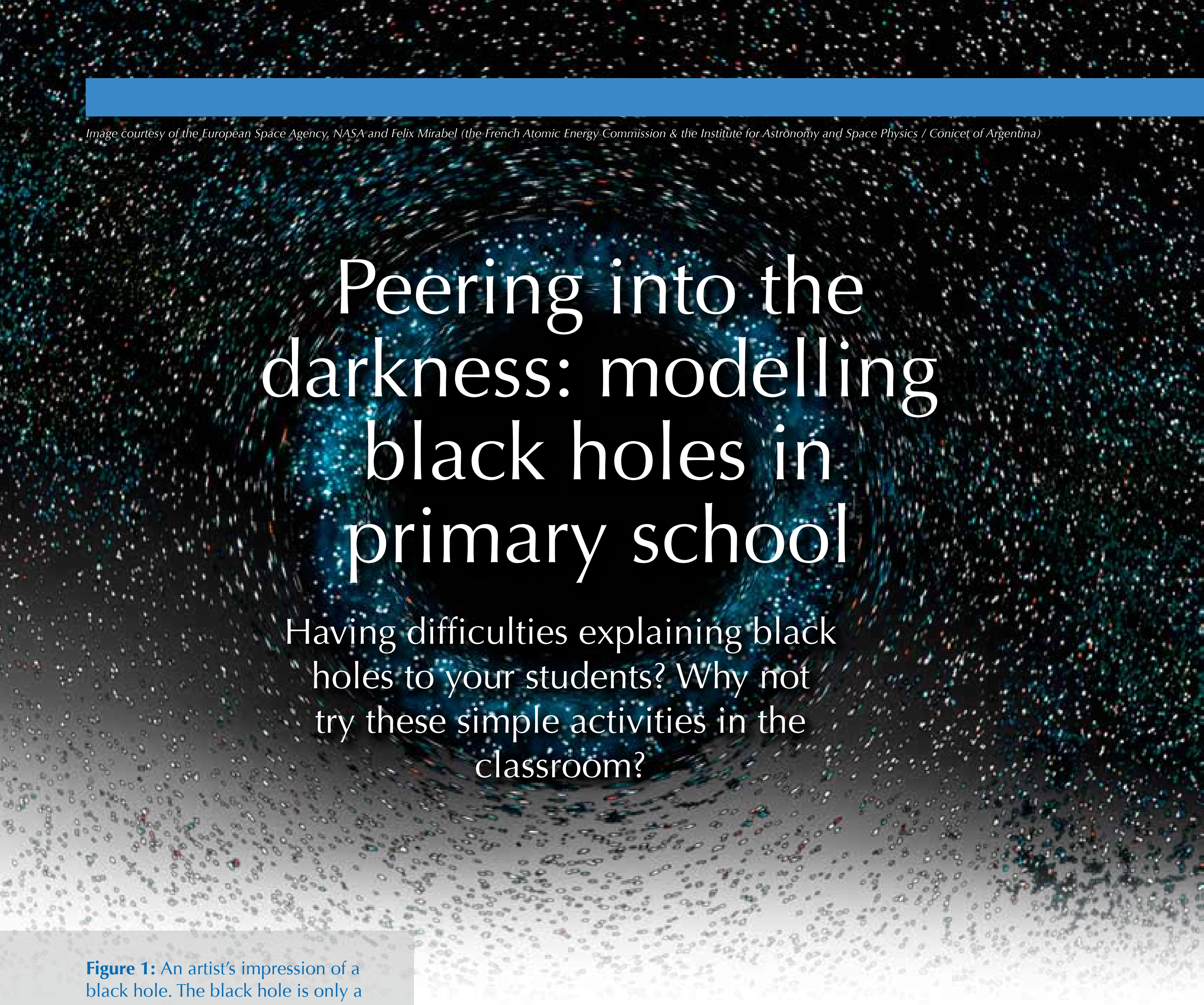


Image courtesy of the European Space Agency, NASA and Felix Mirabel (the French Atomic Energy Commission & the Institute for Astronomy and Space Physics / Conicet of Argentina)

Peering into the darkness: modelling black holes in primary school

Having difficulties explaining black holes to your students? Why not try these simple activities in the classroom?

Figure 1: An artist's impression of a black hole. The black hole is only a point in the very centre, but its gravity is so strong that the light from stars around it is unable to escape.

By Monica Turner

Many young people have heard of black holes and understand that if something falls into one, it cannot get out again – even light cannot escape. That is how a black hole gets its name: it is a point in space that does not emit any light (figure 1). This is not an easy concept to explain. In this article, therefore, I briefly introduce black holes and then describe two simple activities to help school students to visualise what is happening. Each activity should take about an hour; both are suitable for pupils aged 10-14 (although note that the reviewer suggests using the activities with students aged 10-19).

Black holes

Black holes form during the death of very massive stars (at least several times the mass of our Sun).

A star consists of a hot core surrounded by many layers of gas[w1]. In the core of the star, lighter elements such as hydrogen and helium are joined together by thermonuclear fusion to form heavier elements such as metals. The heat created in this process exerts an outward pressure, which counteracts the force of gravity pulling the gas towards the centre of the star and gives the star its large size. When the star runs out of fuel in its core, however, it is unable to support these heavy outer layers of gas. If the dying star is very massive, gravity will pull on the gas and cause the star to become smaller and smaller until its density reaches infinity at a single point, which is called a *singularity* (figure 2).

Close to the singularity, gravity is so strong that nothing can escape. The escape velocity would need to be higher than the speed of light – so not even light can escape, which is why the black hole is black. (It is not actually a hole, though: there is a lot in there, although we cannot see it.)

At a certain distance from the singularity, gravity is weak enough to allow light to escape, thus objects beyond this distance are visible. This

Image courtesy of Monica Turner

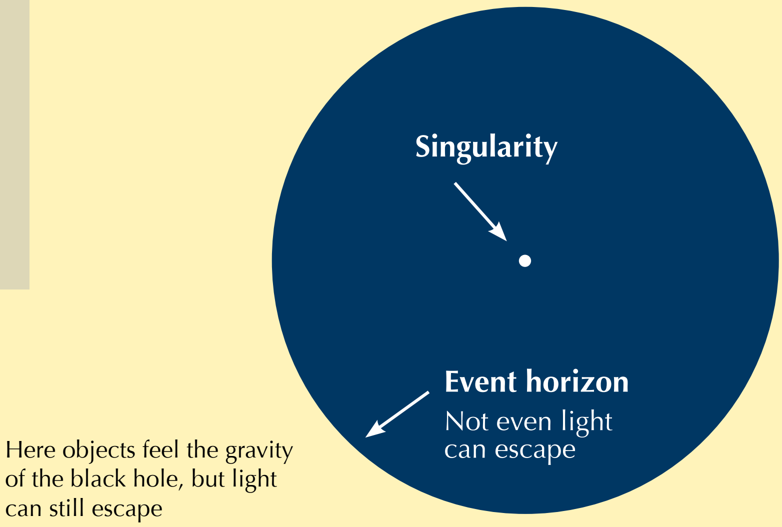


Figure 2: A black hole: the collapsed star or singularity; the event horizon, a region around the singularity where not even light can escape; and the region outside the event horizon, where objects can feel the gravity of the black hole without becoming trapped.

boundary is called the event horizon. Objects outside the event horizon still feel the black hole's gravity, and will be attracted towards it, but they can be seen and can potentially escape falling in. Once objects are sucked inside the event horizon, however, there is no return.

After the black hole forms, it can grow by absorbing mass from its surroundings, such as other stars and other black holes[w2]. If a black hole absorbs enough material, it can become a *supermassive black hole*, which means it has a mass of more than one million solar masses. It is believed that supermassive black holes exist in the centres of many galaxies, including the Milky Way.

Usually, astronomers observe objects in space by looking at the light; this, for instance, is how they study stars (for example, see Mignone & Barnes, 2011). However, since black holes do not emit any light, they cannot be observed in the usual way. Instead, astronomers have to observe the interaction of the black hole with other objects. One way to do this is to look at the motions of stars around the black hole, since their orbits will be altered by its presence[w3].

REVIEW

- Physics
- Astrophysics
- Solar systems
- Gas laws
- Gravity
- Relativity
- Ages 10-19*

In this article, the author briefly describes how black holes are formed in space and how they interact with what is known as 'space–time'. She then describes very simple but impressive experiments to demonstrate the formation of black holes and how they can influence the space around them.

Suitable comprehension questions after the activities include:

- Describe black holes.
- What allows stars to be stable? (Your students could discuss gravity and fusion.)
- What is a singularity?
- How does gravity influence massive objects? What about photons (light)?
- What are supermassive black holes?

Gerd Vogt, HLUW Yspertal, Austria

*Note that the author recommends the activities for pupils aged 10-14.

Physics

Image courtesy of ESO

An image of the galaxy NGC 3621, taken using the Very Large Telescope at the European Southern Observatory (ESO). This galaxy is believed to have an active supermassive black hole at its centre that is engulfing matter and producing radiation.

Activity 1: Modelling the formation of a black hole

This activity will demonstrate to students how a black hole is formed through the collapse of a massive star, once the core of the star is unable to support the weight of the outer layers of gas surrounding it. The time needed should be about one hour.

Materials

Each working group will need:

- A balloon
- A few sheets of aluminium foil, each approximately 30 cm square
- A pin for popping the balloon.

Method

1. Have the students inflate the balloon and tie it closed. They should then wrap the balloon in several layers of aluminium foil to create the model star.
2. Explain that the layers of foil represent the different gas layers of the star, and the balloon that gives them their shape is analogous to the hot burning core of the star. Inside the core, the heat created by thermonuclear fusion exerts a pressure on the gas layers of the star, which keeps them from collapsing.
3. Have the students simulate the effect of gravity by trying to lightly compress the balloon. The pressure of the core is such that the star cannot collapse from gravity.
4. When a star reaches the end of its life, it runs out of fuel in the core and is no longer able to hold up the gas layers. Have the students pop the balloon with the pin, which simulates this process.
5. Again, they should try to compress the balloon with their hands to mimic the effect of gravity. This time, they will be able to compress the foil into a small ball, which simulates the formation of a black hole. Note that the mass of the small ball is the same as that of the model star, but their sizes are quite different.

Discussion

- If a real star were the size of the balloon, then how big would the black hole really be? Is the crumpled ball too large or too small to represent a real black hole?
  Answer: The crumpled ball is much too large to represent a black hole. Even a real black hole, formed from a massive star, is smaller than the tip of a pencil.
- What would happen if you used more pieces of aluminium foil to make the gas layers in the star?

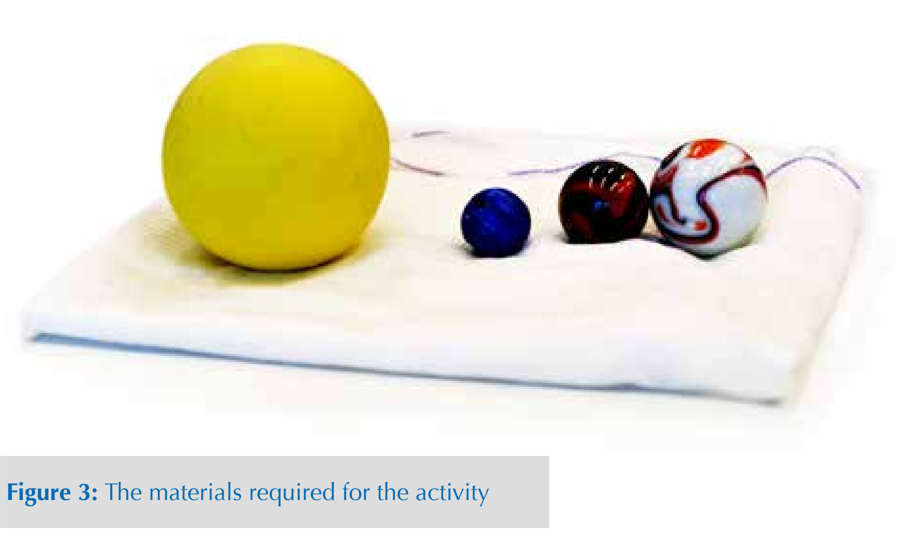


Image courtesy of Charlotte Provost and Monica Turner

Figure 3: The materials required for the activity

Figure 4: Step 4: placing the heavy ball in the centre causes the space-time fabric to curve.

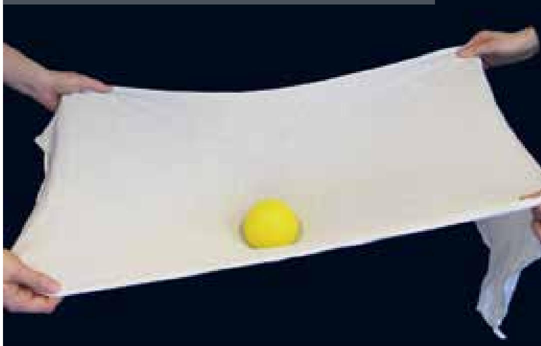


Figure 5: Step 5: roll a small marble along the fabric, and observe how its trajectory is altered.

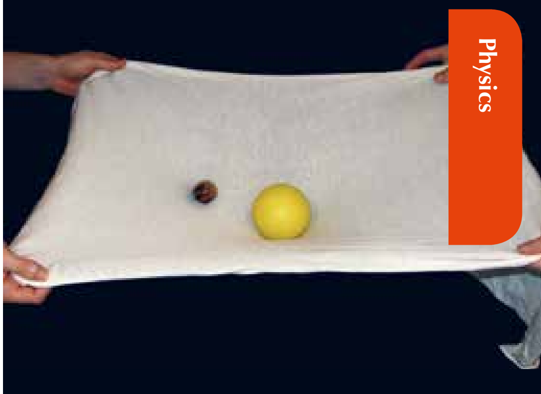
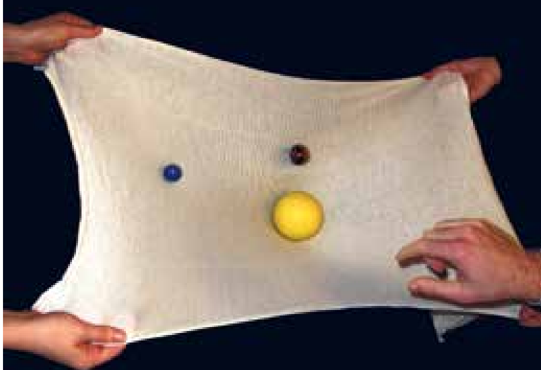


Figure 6: Using marbles of different weights.



Images courtesy of Charlotte Provost and Monica Turner

Would the star be more massive? What about the black hole? Building the star with more layers of gas (represented by the foil) would make the star more massive. It would also result in the formation of a more massive black hole, since there would be more material with which to form the black hole.

- The concept of density (mass per unit volume) could be introduced here. Which has a higher density, the star or the black hole? Although they have a different size, the star and black hole have the same mass, since they are made from the exact same amount of material. However, since the black hole is smaller, it has more material contained in less volume, and therefore has a higher density.

Activity 2: Modelling the action of a black hole

In this activity, students will build a model of a black hole to help them visualise how a black hole can 'bend' space–time and affect nearby objects. The activity should take about one hour.

Materials

Each working group will need (figure 3):

- A light elastic bandage used for muscular injuries (e.g. Tubifix, sold in chemists' shops), the largest ones available (used for the thorax)
- A small marble
- A very heavy ball (such as those used in games of boules, bocce or pétanque)
- A pair of sharp scissors.

Method

1. Cut a piece of elastic bandage about 40 cm long. If it is tubular, you will need to cut it open on one side.
2. Ask several students to stretch the bandage horizontally until it becomes taut, to represent two-dimensional space.
3. Place the marble on the bandage, and make it roll across the surface of the bandage. Its path should be a straight line, similar to that of a light ray travelling through space.
4. Place the heavy ball on the bandage, and you will see how it deforms the fabric of space. Space becomes curved around the heavy mass.
5. Make the marble roll close to the mass; its trajectory should be altered by the deformation of the bandage. This is similar to what happens to light passing close to a massive object that deforms the space surrounding it. Try varying the speed of the marble to see how its path changes.
6. The more concentrated the central mass (that is, the heavier the large ball), the more curved the bandage will be. This increases the depth of the 'gravitational well', from

Physics

Image courtesy of NASA

The Hubble telescope in orbit around Earth

which a marble would not be able to escape.

7. As the marble passes close to the large ball, it starts to revolve around the 'black hole' and eventually falls in. Once it is there, you can see how things may easily fall into a black hole but have difficulty getting out. This is what happens with black holes: their gravity deforms space in such a way that light or other objects fall in and cannot escape.

Discussion

- What happens when you decrease the speed of the marble? Why? When the speed of the marble is high enough, the marble has enough energy to escape the gravity of the black hole. However, if the speed of the marble is too low, the force of gravity from the black hole is too strong and the marble will not be able to escape.
- What happens when you use a heavier large ball? What about a heavier marble (figure 6)? Because more massive objects create a stronger gravitational force, in both cases you will need to throw the marble harder for it to escape the gravity of the black hole.
- How would you be able to tell if there is a black hole somewhere by observing the motions of the stars? If a black hole becomes massive enough, stars that pass nearby will become trapped in its gravitational field and begin to orbit the black hole, much as the planets in our Solar System orbit the Sun. By observing the motions of many stars, astronomers can look for stars that have orbits around the same central point. If they cannot see an object at this central point, this is evidence that a black hole could be present there.

Acknowledgements

Activity 1 was adapted from the 'Journey to a Black Hole' demonstration manual on the Inside Einstein's Universe website[w4]. That activity was in turn adapted from the 'Aluminum Foil, Balloons, and Black Holes' activity on NASA's Imagine the Universe website[w1].

Activity 2 is adapted from a resource in the UNAWE database by Ricardo Moreno from Exploring the Universe, UNAWE[w5] Espagna.

Reference

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

This article is part of a series of *Science in School* articles about how the electromagnetic spectrum is used in astronomy. See www.scienceinschool.org/em

Web references

w1 – NASA's Imagine the Universe website provides information for both teachers and students about the life cycles of stars. Search http://imagine.gsfc.nasa.gov (for 'life cycle of stars') or use the direct link: http://tinyurl.com/l4la9eh

To find the original of Activity 1, search for 'aluminum foil' or use the direct link: http://tinyurl.com/m4nldmn

w2 – The website of the European Space Agency offers an animation demonstrating what happens when an object gets too close to a black hole. See http://spaceinvideos.esa.int/Videos/2013/03/Black_hole_eats_a_super-Jupiter or use the shorter link: http://tinyurl.com/l8u3nfc

w3 – The ESO website offers a video showing real data of stars orbiting a black hole. See: www.eso.org/public/videos/eso0846a

w4 – Hosted by Harvard University, the Inside Einstein's Universe website offers a range of educational astronomy resources, including a downloadable demonstration manual and other materials about black holes. See: www.cfa.harvard.edu/seuforum/Einstein

w5 – UNAWE is an astronomy programme to educate and inspire young children around the world. See: www.unawe.org

Resources

The Hubblesite website from the Space Telescope Science Institute offers lots of information about black holes, as well as interactive, online activities and experiments. See: http://hubblesite.org/explore_astronomy/black_holes

The Ask an Astronomer website at Cornell University offers accessible answers, aimed at different levels (beginner, intermediate, advanced), to many questions about black holes. See: http://curious.astro.cornell.edu/blackholes.php

The Kids Astronomy website provides a simple reference for young children to learn about black holes. www.kidsastronomy.com/black_hole.htm

To find out what happens when a massive star explodes in a supernova, see:

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

To learn more about the fusion reactions that occur in stars, and how light elements are fused into heavier ones, see:

Boffin H, Pierce-Price D (2007) Fusion in the Universe: we are all stardust. *Science in School* **4**: 61-63. www.scienceinschool.org/2007/issue4/fusion

Rebusco P, Boffin H & Pierce-Price D (2007) Fusion in the Universe: where your jewellery comes from. *Science in School* **5**: 52-56. www.scienceinschool.org/2007/issue5/fusion

These two articles are part of a series of *Science in School* articles about fusion in the Universe. See: www.scienceinschool.org/fusion

To complement this simulation of a black hole, you may like to model eclipses or the aurorae (northern and southern lights) in the classroom.

Rosenberg M (2012) Creating eclipses in the classroom. *Science in School* **23**: 20-24. www.scienceinschool.org/2012/issue23/eclipses

Jeanjacquot P, Lilensten J (2013) Casting light on solar wind: simulating aurorae at school. *Science in School* **26**: 32-37. www.scienceinschool.org/2013/issue26/aurorae

Or why not browse all the teaching activities in *Science in School*? www.scienceinschool.org/teaching

You may also find the full collection of astronomy- and space-related *Science in School* articles helpful. See: www.scienceinschool.org/astronomy and www.scienceinschool.org/space

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Physics

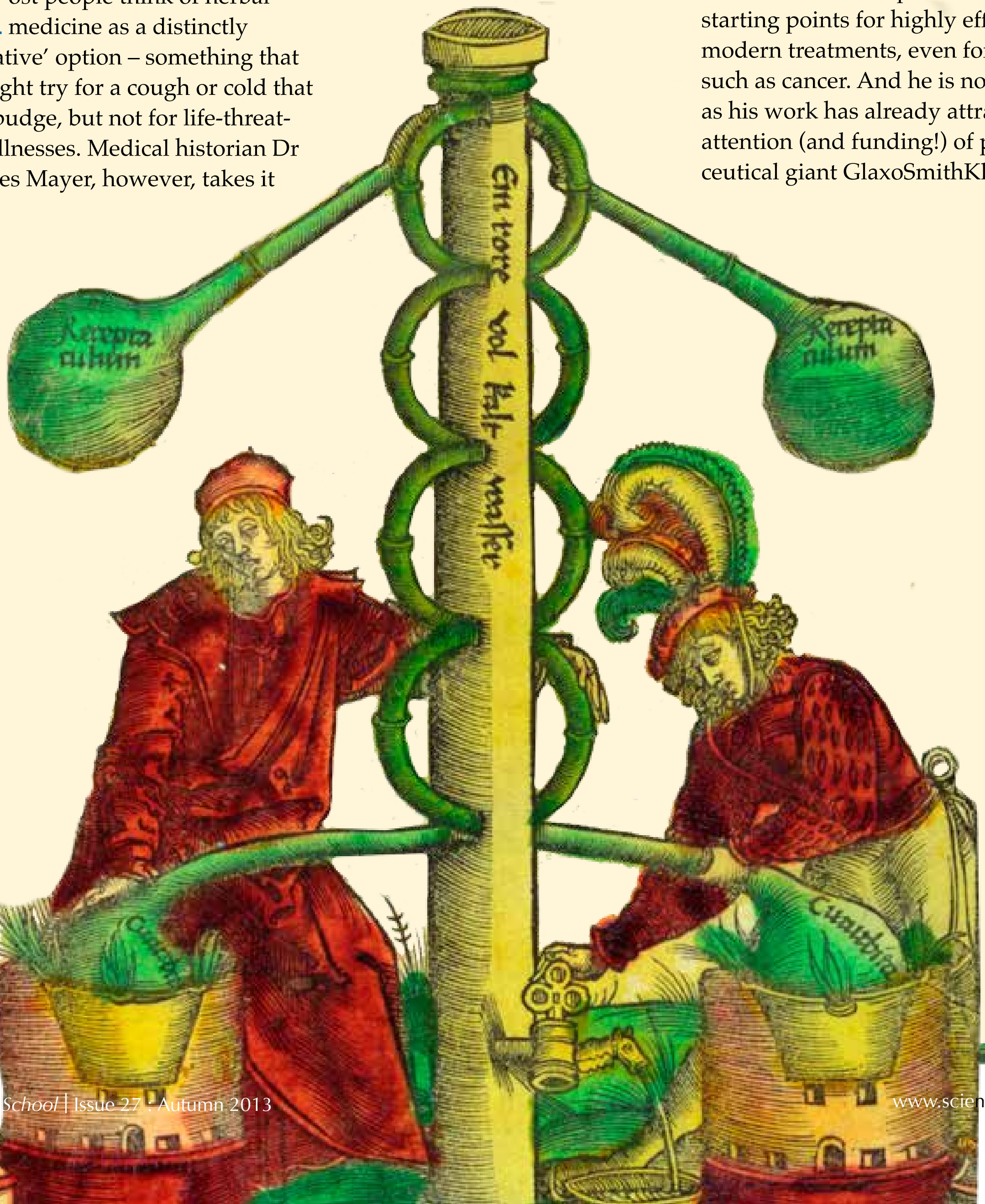
To learn how to use this code, see page 53.

Monastic medicine: medieval herbalism meets modern science

A group of German researchers is bringing to light the medicinal wisdom of the Middle Ages.

By Susan Watt and Eleanor Hayes

Most people think of herbal medicine as a distinctly ‘alternative’ option – something that you might try for a cough or cold that won’t budge, but not for life-threatening illnesses. Medical historian Dr Johannes Mayer, however, takes it all much more seriously: he believes that the herbal remedies described in medieval texts can provide excellent starting points for highly effective modern treatments, even for diseases such as cancer. And he is not alone, as his work has already attracted the attention (and funding!) of pharmaceutical giant GlaxoSmithKline.



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REVIEW

- **Biology**
- **Chemistry**
- **Medicine**
- **History**
- **Religious studies**
- **Ages 12+**

It is widely known that herbs are useful in everyday life in a number of different ways; this article describes one such application – how medieval monastic herbs can be used as a source of modern medicines. Of great interest is the obvious link between history, religious studies and science disciplines such as plant biology, chemistry and pharmacy. Equally interesting is the complex procedure involved in extracting useful information from medieval monastic manuscripts. Overall, the article shows beautifully how knowledge can be transferred across time and different civilisations.

The article is an excellent source of information for interdisciplinary lessons. Relevant topics could include:

- Natural ingredients for modern medicines
- Using old wisdom for new discoveries
- How knowledge is transferred across time and different civilisations.

Suitable comprehension questions include:

1. Why is it difficult to gather useful information about herbs that could be used to treat illnesses?
2. The pharmaceutical industry normally relies on the combined work of biologists, chemists, pharmacists and doctors to develop a new drug. In the case of the monastic medicines described in this article, researchers from a wider spectrum of disciplines are needed. Explain why this is the case.
3. Once useful medicinal herbs have been identified, why can it be difficult to source large amounts of the specific herbs or their active ingredients?

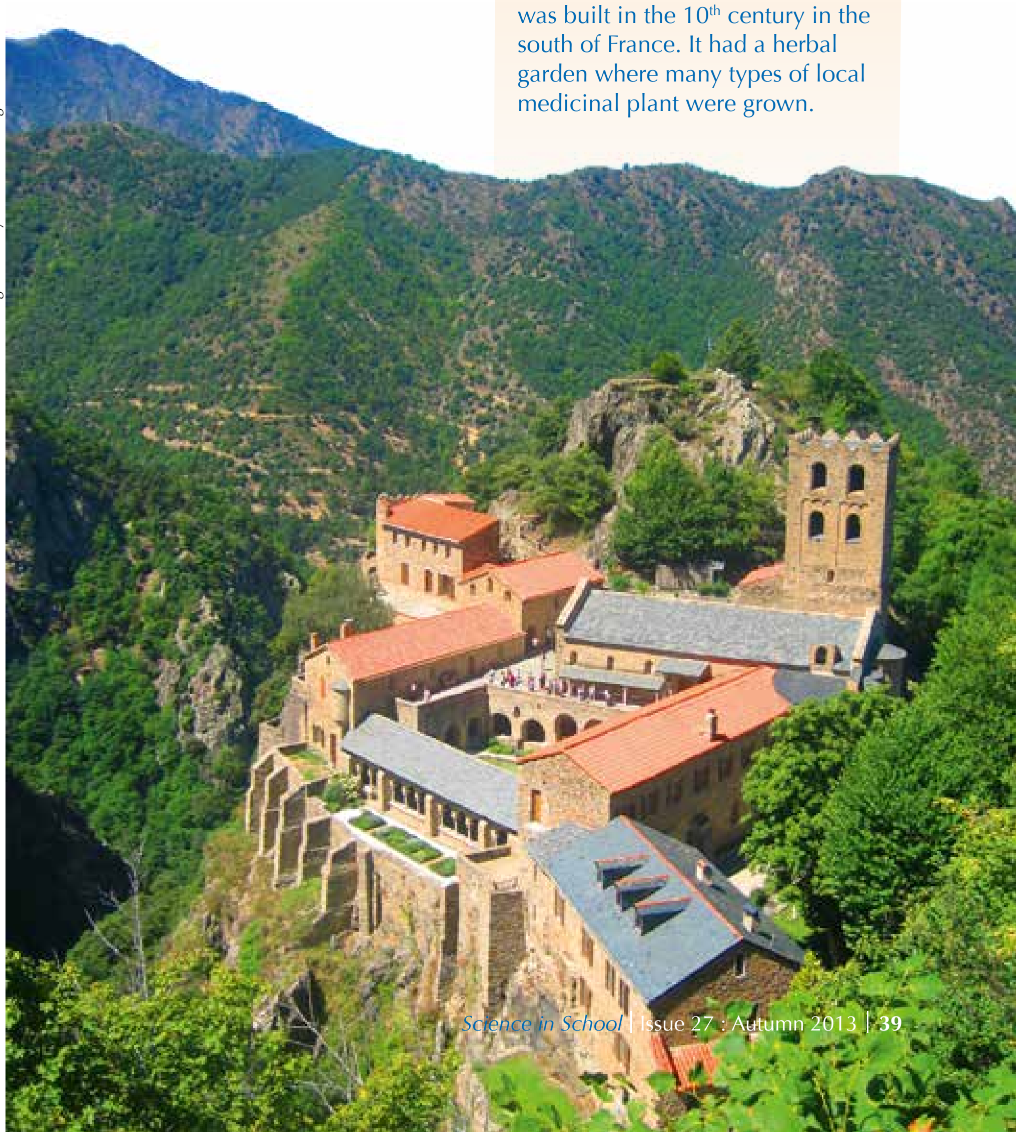
Michalis Hadjimarou, Cyprus

The focus for Dr Mayer's research group at the University of Würzburg, Germany, is monastic medicine (*Klostermedizin* in German). For the past 30 years, group members have been sifting through monastic manuscripts dating from the 8th century onwards, translating and publishing details of plant remedies and the ailments that they are intended to treat.

Their work moved from the historical towards the more scientific some 14 years ago, when the group received a visit from a manager at GlaxoSmithKline. When the visitor asked "What is monastic medicine? Is it praying or something?", Dr Mayer explained that in fact it meant elucidating the herbal treatments documented by monasteries and investigating their physiological effects.

That visit led to a research group being established at the university, with sponsorship from GlaxoSmithKline, to look for effective modern remedies derived from medieval monastic knowledge. So far the collaboration has led to the development of some products to treat the common cold,

Image courtesy of Isabelle Kling



The abbey of St-Martin-du-Canigou was built in the 10th century in the south of France. It had a herbal garden where many types of local medicinal plant were grown.

Images courtesy of Heike Will

Ten years ago, the Klostermedizin research group started a project together with Abtei to investigate the active ingredients and mechanisms by which hops *(Humulus lupulus)* and valerian *(Valeriana officinalis)* work as sedatives (see, for example, Schellenberg et al., 2004). They found that the lignans in hops function similarly to adenosine, an inhibitory neurotransmitter that promotes sleep. Hops work in a similar way to the hormone melatonin, which plays a role in the body clock.

Salvia officinalis, a type of sage, is mentioned in medieval manuscripts as being useful for improving memory. Recent research at the University of Newcastle, UK, has shown it to be effective in this role (it appears to help reduce the breakdown of the neurotransmitter acetylcholine), which makes it a candidate for the development of a treatment for dementia (Scholey et al., 2008). Drug development and clinical trials take time, however, so Dr Mayer expects it will be another ten years before a drug based on sage becomes available.

Image courtesy of Heike Will

sold under the appropriately named brand Abtei (German for 'abbey'). The group now has other links with pharmaceutical companies, as well as with Würzburg University Hospital.

The initial source of such fruitful results is the huge range of historical texts. "First we tried to research the plants that were documented in monasteries used in the early and higher Middle Ages, between the 8th and 12th centuries," says Dr Mayer. "But now we are researching the whole history of medicinal plants in Europe up to the modern day, looking for indications of what might be useful."

The research involves several steps: translating the texts (often from medieval Latin), identifying precisely which plant was used for which treatment – no easy task given the inconsistent and varied common names used for many plants – and then finding the active ingredients.

Some of these ingredients are then tested in laboratories at Würzburg University Hospital or at their partner pharmaceutical companies. For example, scientists in the ear, nose and throat department at the hospital are currently testing the effect of water- and alcohol-based extracts of *Osmunda regalis* (old world royal fern) and

Reliable remedies

Although many plants have been used traditionally in medicine, few have been investigated scientifically to find out whether they are indeed safe and effective remedies for the conditions they are said to treat. In addition to laboratory studies, such as those carried out by Dr Mayer's group, the clinical efficacy of a treatment also needs to be tested.

Scientists agree that the best way to find out the effect of a treatment is via a high-quality clinical trial, or RCT (randomised controlled trial). These include several precautions to make sure the trial results are free from bias:

- The treatment being studied is compared to one or more alternative *control* treatments, including a placebo (one that has no direct pharmacological effect, such as a sugar pill).
- Participants in the trial are randomly assigned to the different treatments.
- Neither the patients themselves, nor the people giving them the treatment, know which treatment each has been given; this is called *double-blinding*.
- The trial needs to have enough people taking part so that the results could not easily have occurred by chance (the more data there is, the less likely this is to happen).

While this all may seem very complicated, without these precautions the results could easily be due to factors other than the treatment itself, so they would not be reliable. Even when a high-quality study has been done, the results need to be examined alongside those from other such trials to see what the total evidence suggests. (To learn more about clinical trials, see Garner & Thomas, 2010, and Brown, 2011.)

Herbal treatments that are supported by good-quality evidence include these:

- Artichoke *(Cynara scolymus)* can aid digestive problems as it increases the flow of bile, which helps to digest fats. See *The Handbook of Clinically Tested Herbal Remedies*[w1] for evidence.
- Cranberry *(Vaccinium macrocarpon)* may help prevent urinary tract infections: drinking cranberry juice is thought to make bacteria less able to adhere to walls of the urinary tract. (However, a recent evidence review concluded cranberry is less effective than previously thought.) See the Cochrane Collaboration website[w2] for evidence.
- St. John's wort *(Hypericum perforatum)* is as effective in treating depression as some pharmaceutical antidepressants, but like them it can also have side effects. See *The Handbook of Clinically Tested Herbal Remedies*[w1] for evidence.

Artichokes can aid digestive problems.

Image courtesy of Richardfabi / Wikimedia

Cranberries may help prevent urinary tract infections.

Image courtesy of Liz West / Wikimedia

St. John's wort has been proven in clinical trials to be effective at treating depression.

Image courtesy of Heike Will

BACKGROUND

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Folio from a manuscript of the *De Materia Medica* by Dioscorides (ca. 40-90 AD), showing a physician preparing an elixir. From Iraq or Northern Mesopotamia, perhaps Baghdad.

Public domain image / Wikimedia Commons

Public domain image / Wikimedia Commons

Chelidonium majus (greater celandine) on cultures of ear cancer cells. Finally, a few promising leads have been passed on for development as potential new drugs, undergoing clinical trials and other testing to conform to legislative requirements. If the fern and celandine extracts prove effective, for example, the clinical trials will be carried out at the hospital.

This complex process is reflected in the multidisciplinary expertise of Dr Mayer's team, which comprises academics from a variety of backgrounds: historians of medicine and scholars of Latin and ancient Greek, plus chemists, biologists and pharmacists – all of whom are needed to fully understand the medieval recipes. There are also outside specialists that the group can call on – including a Cistercian monk who is a biologist.

Dr Mayer's own background is in history. "I first studied history, and then the history of medicine and that's how I found out that we didn't know what plants they really were using in the Middle Ages. So I started to make a database about historical plants used in Europe," he says.

Although most of the key texts are written in Latin, in many cases this is a translation from earlier texts written in Arabic, some of which also contain

Hildegard of Bingen (1098-1179) was an influential Benedictine abbess who wrote botanical and medicinal texts, as well as theological manuscripts and beautiful liturgical music. She is shown here, in a miniature from the *Rupertsberger Codex des Liber Scivias,* being inspired by God.

Folio from Hieronymus Brunschwig's *Liber de arte Distillandi de Compositis* (Strasbourg, 1512) showing two figures performing a distillation. Brunschwig's comprehensive book on distillation was one of the earliest texts devoted exclusively to chemical technology. This book expanded on his smaller, earlier work on distillation of herbal remedies to include a wide range of alchemical distillation techniques.

knowledge preserved from ancient Greek authors such as Aristotle. As Dr Mayer explains: "In the early Middle Ages there was not much literature here in Europe, and Pliny the Elder (23-79 AD) was the most important antique author for monastery medicine. Then in the 11th century, they started to translate Arabic texts into Latin, and so a lot of new plants came into European medicine." One example of this is *Alpinia officinarum*, a plant used to treat respiratory problems and also for relaxation. Although this plant is endemic to Europe, its medicinal use started only after the Arabic medicine texts arrived.

In time, the translation of Arabic texts came to overshadow the epoch of monastic medicine because it led to the foundation of many universities in the 13th century. So from this time onwards there were professional physicians, and monastic medicine became less important.

There was, however, a new period of monastic medicine in the 16th century, because many missionaries sent to the newly discovered lands in the Americas were monks. "The missionaries were interested in finding out what the native Americans did with the special plants in Central and South America. So they wrote books about the use of these plants, and sent the information back to Europe," says Dr Mayer.

Today, Dr Mayer's group collaborates not only with industry but also with working monasteries, advising on special plants to grow in the monastery gardens and on their uses in tea-style infusions and in lotions. They even run courses for the public at the local monastery in Oberzell – which brings in some useful additional funding for the group.

Dr Mayer has found that cultivating plants is not always the best way to obtain them, either because it's hard to get them to grow or because the ingredients obtained from wild plants are better than those from cultivated plants. "You must go out in the woods to find these plants, like *Arnica montana*; it's very difficult to cultivate the plants and to get enough flowers," he says. "But in the wild it grows well." Which is perhaps a fitting reminder of the fabulous complexity of nature, as evident today as it was to the people of the Middle Ages.

Class activity

Students can carry out their own research into herbal medicines that have been shown to be effective – or not. Perhaps ask them to investigate some commonly used herbal remedies (e.g. echinacea, evening primrose, gingko, ginseng, valerian) and to explain what the available information suggests and how reliable they think this is.

One of the best resources to find out about the efficacy of medicines of all kinds is the Cochrane Collaboration website[w2]. The Cochrane Collaboration produces reviews of clinical trials data to establish whether there is good evidence that a treatment is effective. The reviews can be accessed via the Cochrane website.

Another resource is *The Handbook of Clinically Tested Herbal Remedies*[w1] by Marilyn Barrett (2004), which can also be accessed online. The author has compiled evidence from trials of more than 30 commonly used herbal remedies, together with reviews of each trial and a rating of the quality of the evidence that each provides (graded I, II or III).

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w1 – A good compilation of evaluative information about herbal treatments is: Barratt M (2004) *The Handbook of Clinically Tested Herbal Remedies Volume 2*. USA: Haworth Press, Inc. ISBN: 0-7890-2724-0. This is available online, for example at: http://www.pharmacognosy.com/book.pdf

Images courtesy of WeiterWinkel / Flickr

Monasteries such as the Cistercian abbey of Maulbronn, in southern Germany, preserved and transmitted important knowledge about herbal medicine in the Middle Ages.

w2 – The Cochrane Collaboration produces reviews of clinical trials data, including trials of herbal medicines, which can be accessed via the Cochrane website. www.cochrane.org/cochrane-reviews

The most recent review of evidence for the effectiveness of cranberries in the prevention of urinary tract infections showed no significant benefit. http://summaries.cochrane.org/CD001321

Resources

The Science and Plants for Schools website offers a teaching resource about medicines and drugs from plants. Using a card-game format, the activity is suitable for teaching students aged 16+ about plant-derived pharmaceuticals, or it could be used to introduce younger students to poisons. See www.saps.org.uk or use the direct link: http://tinyurl.com/cnc4zw8

To learn more about Arabic science and medicine between the 7^{th} and 17^{th} centuries, see:

Khan Y (2006) 1000 years of missing science. *Science in School* **3**: 67-70. www.scienceinschool.org/2006/issue3/missing

To learn more about the work of Dr Mayer's research group, visit the Forschergruppe Klostermedizin website (in German): www.klostermedizin.de

If you found this article interesting, why not browse the other science topics in *Science in School*: www.scienceinschool.org/sciencetopics

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Susan Watt is a freelance science writer and editor. She studied natural sciences at the University of Cambridge, UK, and also holds degrees in philosophy and experimental psychology. She has worked for the Science Museum, London, and the British Council, as well as for many publishers. Her special interests are in the history and philosophy of science and in science education.

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*.

To learn how to use this code, see page 53.

Chemistry

Purple fumes: the importance of iodine

Iodine, with its characteristic purple vapours, has myriad applications – from the familiar disinfectant to innovative solar cells.

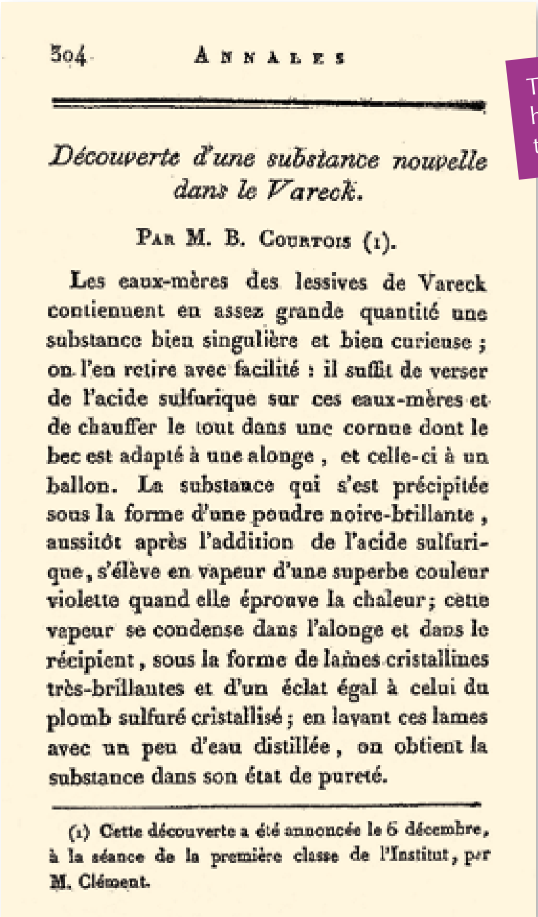
By Frithjof C Küpper, Martin C Feiters, Berit Olofsson, Tatsuo Kaiho, Shozo Yanagida, Michael B Zimmermann, Lucy J Carpenter, George W Luther III, Zunli Lu, Mats Jonsson & Lars Kloo

What makes iodine so important and interesting? Not only does it sublimate into a dramatic purple gas, but it also affects many aspects of life on Earth and of human civilisation. Did you know, for example, that iodine protects marine algae from oxidative damage (for example from the Sun), prevents some congenital abnormalities in humans, and has many industrial applications?

The discovery of iodine can be traced back to the 19th century and the Napoleonic wars. With the British imposing a blockade on European ports, the French were faced with shortages of saltpetre (KNO_3) for manufacturing gunpowder. So chemist Bernard Courtois investigated the potential of seaweed (brown algae, *Laminaria* sp.) as the potassium source for this crucial substance. He added concentrated sulphuric acid to seaweed ash and was surprised by the beautiful purple fumes that were produced (figure 1).

Although Courtois suspected that his purple vapour was a new element, he did not have the financial means to follow up his research. It was left to his colleagues, including Joseph Gay-Lussac, to confirm his results and name the element iodine, from the Greek word *iodes*, which means purple or violet.

Gay-Lussac went on to investigate the chemistry of iodine, and despite the war, the French chemists found ways to correspond with British chemists, notably Sir Humphry Davy. Initially, Davy believed the vapour to be a chlorine compound, but soon concluded that it was indeed a new element.


504 ANNALES

Découverte d'une substance nouvelle dans le Vareck.

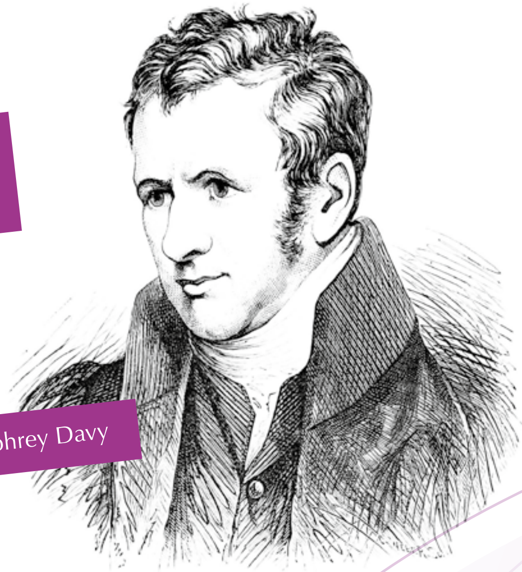
PAR M. B. COURTOIS (1).

Les eaux-mères des lessives de Vareck contiennent en assez grande quantité une substance bien singulière et bien curieuse ; on l'en retire avec facilité : il suffit de verser de l'acide sulfurique sur ces eaux-mères et de chauffer le tout dans une cornue dont le bec est adapté à une alonge, et celle-ci à un ballon. La substance qui s'est précipitée sous la forme d'une poudre noire-brillante, aussitôt après l'addition de l'acide sulfurique, s'élève en vapeur d'une superbe couleur violette quand elle éprouve la chaleur ; cette vapeur se condense dans l'alonge et dans le récipient, sous la forme de lames cristallines très-brillantes et d'un éclat égal à celui du plomb sulfuré cristallisé ; en lavant ces lames avec un peu d'eau distillée, on obtient la substance dans son état de pureté.

(1) Cette découverte a été annoncée le 6 décembre, à la séance de la première classe de l'Institut, par M. Clément.

Image courtesy of Frithjof Küpper

The front page of Courtois' historic publication reporting the discovery of iodine



Sir Humphrey Davy

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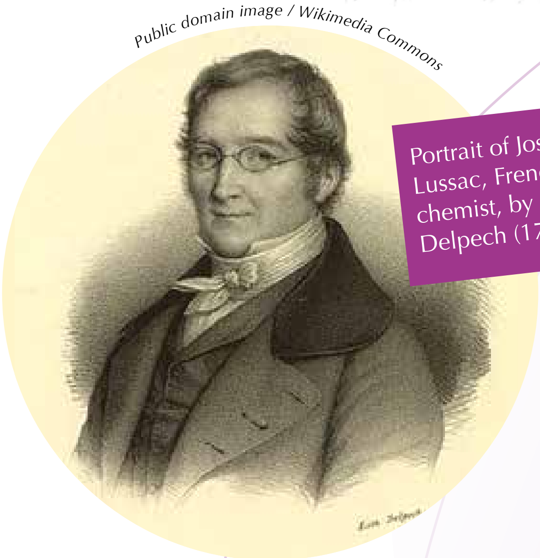


Portrait of Joseph Louis Gay-Lussac, French physicist and chemist, by François Séraphin Delpech (1778–1825)

REVIEW

- **Chemistry**
- **Biology**
- **Physics**
- **History**
- **Ages 13-18**

In this concise update on the element iodine, the authors guide the reader through the history and the many applications of this important element, from medicine to industry and energy production. Suggestions for school laboratory experiments add interest and appeal to the topic.

Given the plain and clear style, I recommend this article not only to European science teachers but also to their students aged 13-18. It could be used in lessons on chemistry (the periodic table, halogens), biology (endocrine glands, the thyroid and its diseases) and physics (isotopes, radioactivity and solar cells). There is also an interdisciplinary opportunity to address the history of science (the discovery of the elements), the role of scientists in the development of weapons, or the relationships between scientists of opposing countries during wartime.

Suitable comprehension questions include:

1. From the article you can deduce that seaweeds accumulate iodine:
   a) To oxidise atmospheric ozone
   b) To absorb atmospheric ozone
   c) To produce atmospheric ozone
   d) To protect themselves from atmospheric ozone.
2. If we do not receive enough iodine:
   a) Our thyroid gland enlarges / atrophies
   b) Our anterior pituitary gland secretes less / more thyroid-stimulating hormone

Giulia Realdon, Italy

With the help of X-ray absorption spectroscopy, we now know that seaweeds accumulate iodine as iodide (I^-), which acts as an antioxidant to protect them against oxidative damage caused by atmospheric ozone (O_3). This goes some way to explaining why trace amounts of molecular iodine (I_2) can be detected in the atmosphere of coastal regions and why human iodine intake in these regions is dependent on seaweed abundance rather than proximity to the sea.

For much of the next century, iodine continued to be extracted from seaweed. Today, however, it is removed from natural iodine-containing brines in gas and oil fields in Japan and the USA, or from Chilean caliches (nitrate ores), which contain calcium iodate ($Ca(IO_3)_2$). The iodine is supplied to the market as a purplish-black solid.

Iodine chemistry

Iodine belongs to the halogens, and thus shares many of the typical characteristics of the elements in this group. Because of its high electronegativity, iodine forms iodides with most elements in its formal oxidation state, -1. Many iodine-containing compounds are frequently used as reagents in organic synthesis – mainly for iodination, oxidation and C-C bond formation.

Iodine in the atmosphere originates mostly from biological and chemical processes in the ocean – such as the iodide antioxidant system in seaweeds. Most iodine is ultimately removed from the atmosphere by cloud formation. In the ocean, iodine is mainly dissolved and exists as iodate (IO_3^-, oxidised form) and iodide (I^-, reduced form). In Earth's outer layer (the lithosphere), most iodine is in marine and terrestrial sediments; iodine levels are low in igneous rocks.

The physiological importance of iodine

Physiologically, iodine is an essential element, required for the synthesis

Image courtesy of Jodi Squirmelia / Flickr

kelp forest, big Sur, California

Image courtesy of FCK

Brown algae such as kelp are the strongest iodine accumulators among living systems. Photograph taken on the shore at Dunstaffnage, near Oban, Scotland, UK

Chemistry

Image courtesy of Eleanor A Merritt

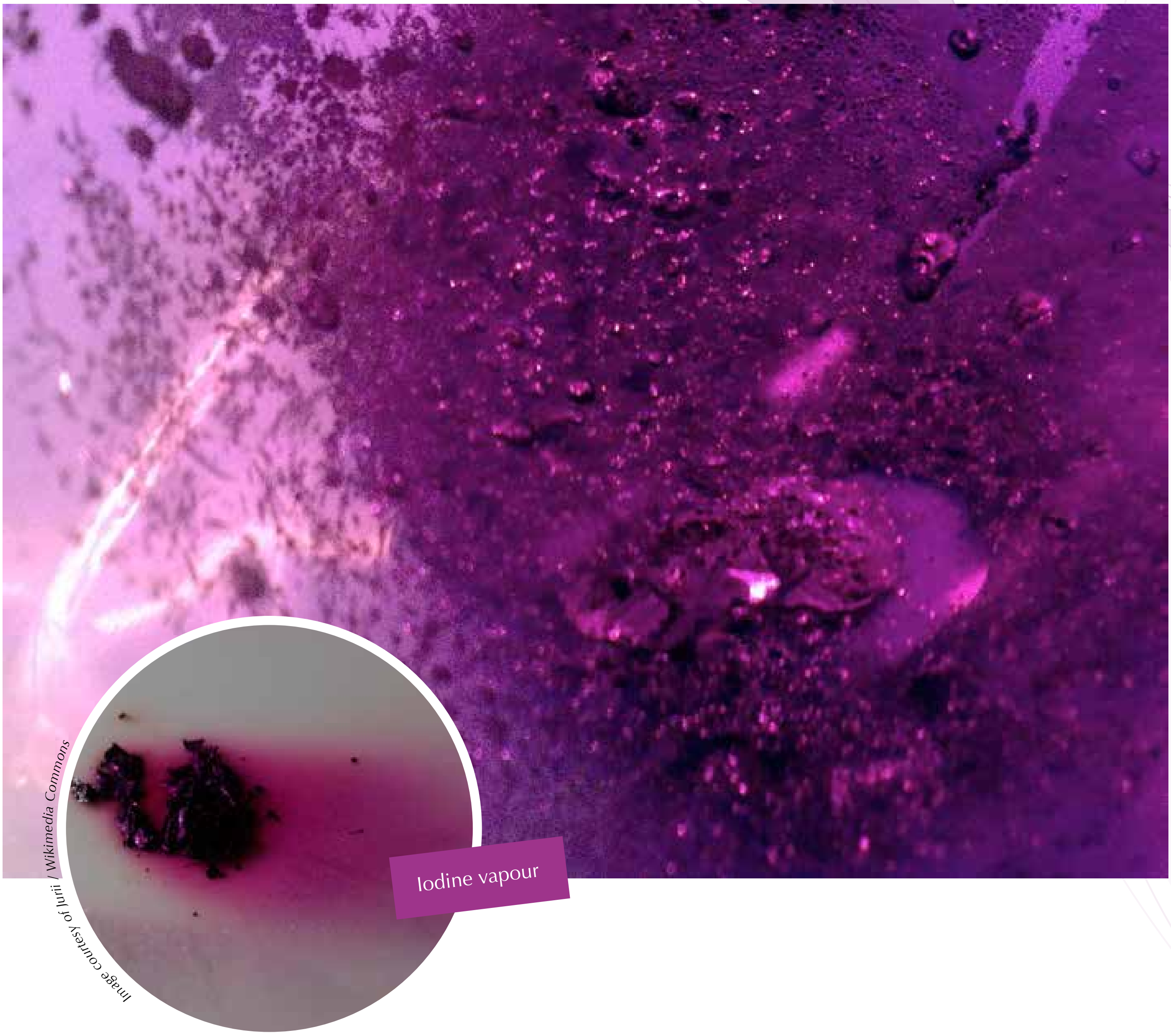


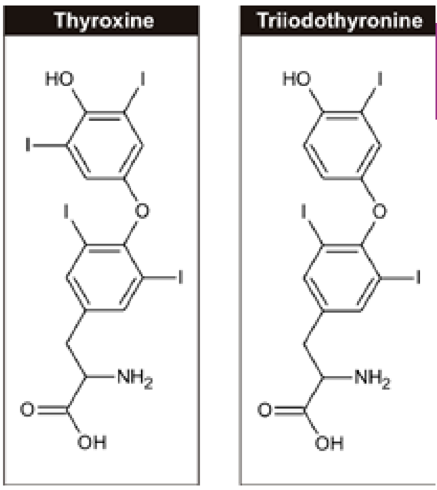
Image courtesy of Jurii / Wikimedia Commons

Iodine vapour

of thyroid hormones – triiodotyrosine and thyroxine (figure 3) – which regulate growth, development and cell metabolism. The recommended dietary intake of iodine for adults is 150 µg/day, which can be obtained from dairy products, seaweed and iodised table salt.

The classic symptom of iodine deficiency is thyroid enlargement (goitre). As iodine intake falls, the anterior pituitary gland secretes increasing levels of thyroid-stimulating hormone in an effort to maximise the uptake of available iodine; this leads to excessive growth of the thyroid gland. But the most damaging effect of a lack of iodine is to the developing brains of babies, leading to mental retardation. Furthermore, severe iodine deficiency during pregnancy is associated with a greater incidence of stillbirth, miscarriage and congenital abnormalities.

The most effective way to prevent iodine deficiency is to add potassium



The thyroid hormones thyroxine (T4) and triiodotyrosine (T3)

Image courtesy of Michael Zimmermann

iodide (KI) or potassium iodate (KIO_3) to table salt. This practice of *salt iodisation* is carried out in around 120 countries, with more than 70% of the world population now having access to iodised salt.

Industrial uses of iodine

Iodine and its compounds are used in myriad products, from food and pharmaceuticals, through to animal feed and industrial catalysts (figure 4). For instance, iodine is a potent antimicrobial. For more than a century, iodine tincture – a mixture of ethanol, water, iodine and potassium iodide – was used as an antiseptic for wounds. This has now largely been replaced by water-soluble ionophores (iodine complexed with surfactants), which are less irritating to the skin. For example, povidone iodine, a mixture of polyvinylpyrrolidone and iodine, is used widely as a surgical scrub.

In the industrial production of acetic acid, iodine compounds such as rhodium iodide (the Monsanto process) or iridium iodide (BP's Cativa process) are used to catalyse the carbonylation of methanol.

Silver iodide (AgI), used in early photographic plates, is used today in cloud seeding to initiate rain and to control climate. Because AgI has a similar crystal structure to ice, it can induce freezing by providing nucleation sites. This was done at the 2008 Beijing Olympics to prevent rainfall during the opening and closing ceremonies.

With its high atomic weight (126.9) and large number of electrons, iodine is also an excellent X-ray absorber and is used in X-ray contrast media. These substances are generally safe to administer to humans and enable the visualisation of soft tissues in X-ray examinations.

A more everyday application of iodine is in liquid-crystal displays for TVs, computers and mobile phones, which use polarising films to filter light. These films are commonly made of polyvinyl alcohol layers doped with iodine. Here, iodine acts as a cross-linker and ensures that the structure is polarising.

Iodine in the energy industry

Iodine is used in one of the most promising solar cells on the market for the production of low-cost 'green energy': the dye-sensitised titanium oxide solar cell. Also known as the Grätzel cell after one of its inventors, it consists of polyiodide electrolytes as the charge transport layer between the cathode and the anode (to learn more, see Shallcross et al., 2009).

Of the 37 known isotopes of iodine, all but one, ^{127}I, are radioactive. Most of these radioisotopes, which are produced via fission reactions in nuclear power plants and weapons, are short-lived, which makes them useful as tracers and therapeutic agents in medicine. For example, iodine isotopes can be used to image the thyroid gland, which absorbs radioactive iodine when it is injected into the bloodstream.

Unfortunately, radioactive ^{131}I, released from nuclear accidents – such as the disaster in Fukushima, Japan, in 2011 – is also taken up by the thyroid. Because it is a high-energy β-particle

Chemistry

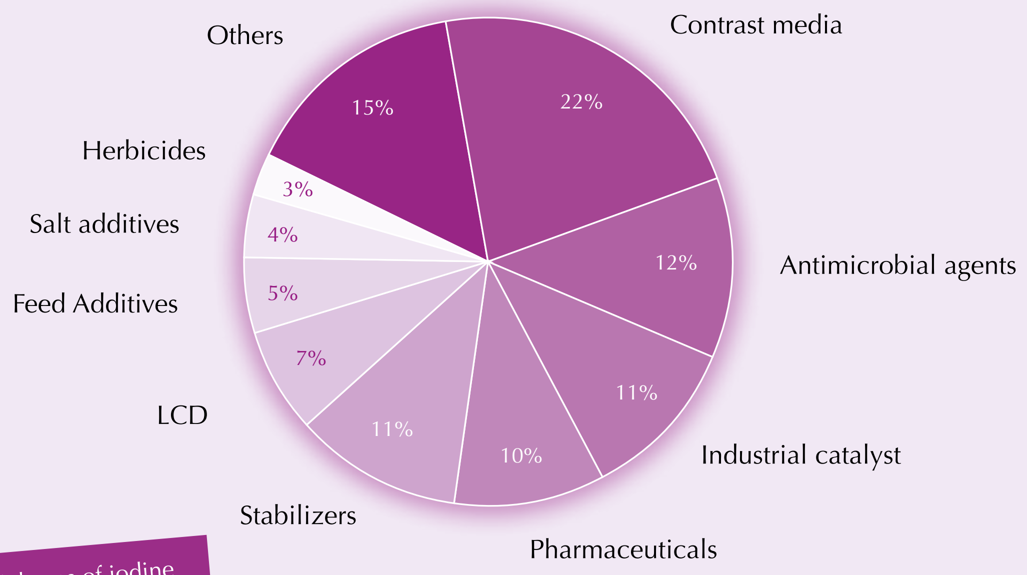
Image courtesy of Michael Zimmermann

A 12-year-old boy with a goitre caused by iodine deficiency

Image courtesy of: Wen-Yan King / Flickr

A Chinese man with a goitre due to hypothyroidism. Hypothyroidism can be caused by a deficiency in iodine that is easily preventable and treatable with just pinches of iodised salt.

Image courtesy of Tatsuo Kaiho



The major industrial uses of iodine

emitter, it damages cells and induces cancer. To counteract this effect, non-radioactive potassium iodide (KI) tablets are ingested to saturate the thyroid's ability to take up radioactive iodine.

These are just a small sample of the many applications of iodine. Clearly, although the element has been known for only two hundred years, it is well established in modern chemistry, physics and medicine.

Acknowledgement

This article was adapted from a much longer publication in *Angewandte Chemie International Edition* (Küpper et al., 2011).

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CLASSROOM ACTIVITY

Iodine in the classroom

No doubt we are all familiar with the colourful 'iodine clock' experiment between hydrogen peroxide, potassium iodide, starch and sodium thiosulphate – but there are many other ways to introduce iodine practically into the classroom. For example:

- When catalysed by water, aluminium and iodine react to produce spectacular clouds of purple iodine vapour.
- In a direct reaction between a metal and a non-metal, zinc powder reacts with a solution of iodine in ethanol to form zinc iodide in an exothermic redox reaction.
- Potassium iodide can be used to detect the presence of starch in a range of foods.
- Various solutions, including aqueous sodium iodide, can be electrolysed and the products at the electrodes identified. Students can then use their practical experience and theoretical knowledge to construct simple ionic equations.

Details of these and many other school experiments can be downloaded from the Learn Chemistry website[w1].

Image courtesy of Christian Jansky / Wikimedia

This Cessna 210 plane has two silver iodide generators on the sides for cloud seeding.

Web reference

w1 – The Learn Chemistry website of the UK's Royal Society of Chemistry offers a wide range of downloadable resources to support the teaching and learning of chemistry. See: www.rsc.org/learn-chemistry

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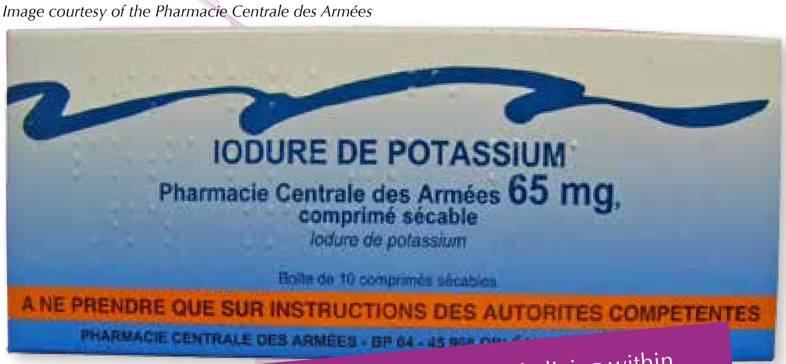
Image courtesy of the Pharmacie Centrale des Armées



Potassium iodide pills are distributed to people living within a radius of 10 km of each nuclear power plant in France, to prevent damage to their thyroid glands in case of an accident.

Image courtesy of the AIEA /Wikimedia

The nuclear power plant at Tricastin, France, is situated close to a densely populated region. Approximately every five years, potassium iodide pills are distributed to the people who live nearby to prevent damage to their thyroid glands in case of a nuclear accident.

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To learn how to use this code, see page 53.

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