Spring 2014 Issue 28

SCIENCE in SCHOOL

The European journal for science teachers

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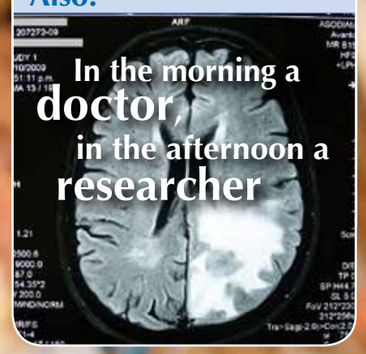

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Editorial

Although this is only the first issue of 2014, the academic year is already starting to draw to a close. By the time this issue reaches you, spring will have sprung and preparations for the end of year, and those dreaded exams, will be well underway. Spring, however, is a season of renewal – a new start – and for *Science in School* that is very apt. With two new staff members in the office, we're full of enthusiasm for the coming year and beyond. There are many plans for new projects and improvements, but this issue demonstrates that we are still committed to producing a wide variety of articles – from the cutting-edge research involved in developing fusion power (p 2) to the modern techniques used to look back hundreds of years to the Black Death (p 7).

New years and new beginnings are also a time to look back and take stock. As well as local assessments and national league tables, teachers and students today are also subjected to the Programme for International Student Assessment (Pisa), the results of which were recently released. Pisa is one way for those working in education to see how different teaching and learning styles can affect learning outcomes, and we at *Science in School* will be coming back to that question, probably more than once, over the next few issues. Although it is tempting to look at the Pisa rankings as absolute, we must remember our scientific training. Averages can hide many variations in the data.

In an increasingly technological world, science is relevant to almost every part of our lives. As science teachers, it is you who are able to equip the next generation for that world. Not every child will discover the next blockbuster drug (p 40) or send a portable laboratory to Mars (p 12), but every child will be affected by those discoveries. Providing students with an understanding of how we interrogate and understand the world around us cannot fail to help them in later life, whether it is by teaching them to calculate fundamental physical properties of energy (p 28) or to ask more questions next time they go to the doctor (p 50).

A century ago, Max von Laue received the Nobel Prize in physics for showing that X-rays could be scattered by crystals. Today, this technique is more important than ever and it is hard to see areas of science that crystallography hasn't touched. It is because of this importance that Unesco has declared this year the International Year of Crystallography. With a variety of educational resources on offer, this is yet another way of showing your students how simple observations and experiments can have a wide impact. Whether you inspire the next von Laue or just help your students appreciate their discoveries, we hope that our journal can also, in some small part, help you to make a difference.

Laura Howes
Co-Editor of *Science in School*
editor@scienceinschool.org
www.scienceinschool.org

To learn how to use this code, see page 57.

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

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

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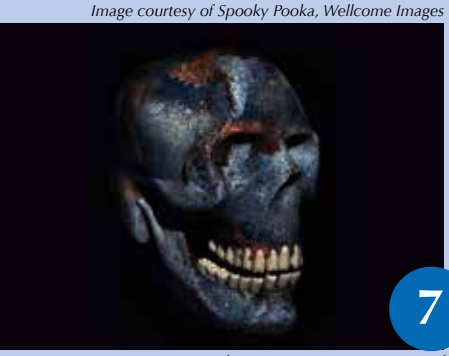

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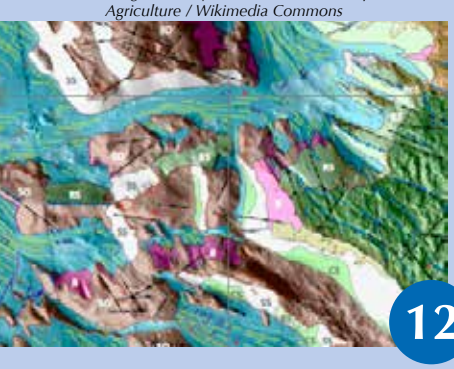

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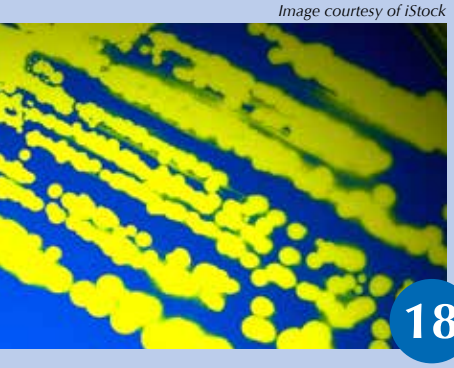

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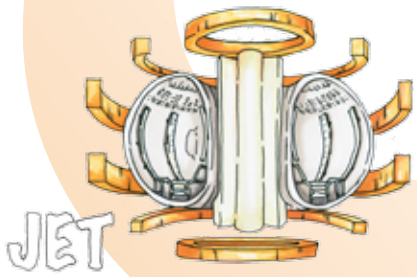


From construction to destruction: building lasers and melting walls

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

CERN:

Between January and March 2013, Valentina Rigamonti, a Master's student at University of Milan in Italy, collaborated with the CERN Communication Group to study the usability of the CERNland Newsroom. CERNland is a CERN website aimed at school children that lets you play with particles and physics. Valentina involved around fifty 4th-grade pupils (aged 10) in the project. The participants played with the website and tested and ranked various types of news (text, cartoon and animation). They also had to draw a scientist (at the beginning and at the end of the project) and investigated the content of a mysterious box to experience the scientific method.

The activities provided insights into the children's understanding of what a scientist is and how he/she works. In her thesis, Valentina concluded that using supporting images when teaching science can facilitate children's understanding of science and can correct their misconceptions.

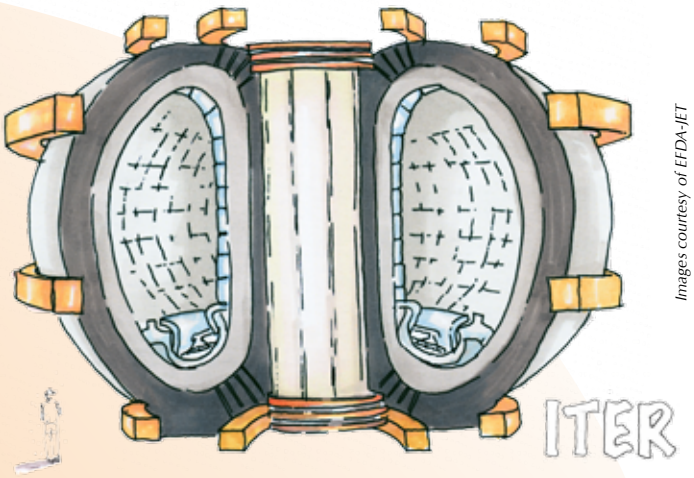
Thanks to Valentina's work, the CERNland team was able to improve the site's navigation, introduce new sections and games, and plan a clear multimedia model for future NewsRoom content.

To explore the new and improved website, which is available in six languages, visit CERNland at: http://www.cernland.net/

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

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

Images courtesy of Valentina Rigamonti



Images courtesy of EFDA-JET

EFDA-JET:
Scientific vandalism helps ITER cut costs

Last August, scientists at the Joint European Torus (JET) deliberately melted some of their wall tiles. The purpose of the destruction was to test materials for the fusion reactor of the future. ITER is a global fusion experiment being built to demonstrate the feasibility of fusion power, and once again JET served as its test bed. This time, JET was used to try out materials for the parts of ITER's reactor wall that will be exposed to hot fusion plasma.

Originally, ITER was to start with a wall made of carbon, which is the most robust and well known material for this purpose. But when the reactor starts to produce real amounts of fusion power, it will need a wall made of tungsten. Today there is little experience with tungsten walls. They can melt under certain circumstances and scientists worried that the debris might reduce the plasma power. The tests conducted at JET proved that molten tungsten does not affect the plasma and as a result, the ITER Organization will start with tungsten tiles, saving the project about 400 million euros.

To watch a video of the tiles melting and to find out more about the experiments, see the press release at: www.efda.org/2013/08/scientific-vandalism-helps-iter/

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

EMBL:
What are you scared of ?

A study led by Cornelius Gross, from the European Molecular Biology Laboratory (EMBL) in Monterotondo, found that different types of fear are processed by different groups of neurons in the brain. Specifically, a brain circuit that is known to be involved in defensive behaviours seems to handle the fear of predators like rats. In contrast, fear of members of the same species uses the brain circuit involved in sex and reproduction; and fear of pain is processed by yet another part of the brain.

The human brain has similar circuits to rats and we also experience different kinds of fear. These findings could help develop more efficient treatments for specific phobias or panic attacks, by targetting the relevant region of the brain.

Thanks to a collaboration with another EMBL research team, led by Detlev Arendt, the scientists are now also looking into how these fears, and the neuronal circuits that process them, may have evolved in time.

More information about this latest discovery from Monterotondo can be found in the press release on the EMBL website: http://bit.ly/1oxc7Or

To read the original publication, see:

Silva, B A, et al. (2013) Independent hypothalamic circuits for social and predator fear. *Nature Neuroscience* **16**: 1731-1733. DOI: 10.1038/nn.3573.

To find out more about the work done by Cornelius Gross' lab at Monterotondo, you can visit the group's website at www.embl.it/research/unit/gross/members/

Detlav Arent's group also has a website at www.embl.de/research/units/dev_biology/arendt/

For an earlier *Science in School* article about how our brains respond to fear see:

Stanley S (2011) A neural switch for fear, *Science in School* **18**: 32-35. www.scienceinschool.org/2011/issue18/fear

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

a mouse facing its natural predator, a rat.

Image courtesy of J. Wood, B. Silva & F. Zonfrillo

European XFEL: Starting to build the laser

The European X-ray Free Electron Laser (European XFEL), currently under construction in the Hamburg area of Germany, is continuing towards completion. At the heart of the facility is a 3.4 km long X-ray free-electron laser that will enable scientists to study matter and chemical reactions in unprecedented nanoscale detail. The last several months saw the European XFEL begin the transition from construction of the facility to installation of the first parts of the X-ray laser. The full subterranean structure includes a 5.8 km of tunnels, which fit within a span from Hamburg to the project's future headquarters in Schenefeld, Schleswig-Holstein, and a 4500 m² experiment hall where the project's six planned scientific instruments will be housed. The instruments will be where scientists from around the world will conduct their experiments.

Five months after the end of underground construction, the project recently installed the first part of the laser's accelerator, the electron gun. The gun contains the source of the free electrons, a piece of caesium telluride (Cs_2Te). When excited by a laser beam, the compound will release electrons, which will then be "kicked" into the accelerator by a radiofrequency pulse within the gun. From there the electrons will be accelerated to nearly the speed of light, beginning the first step toward generating European XFEL's X-ray flashes.

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

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

Image courtesy of D. Nölle, DESY

Workers prepare the European XFEL electron gun for installation.

EIROforum

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

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

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

Images courtesy of D. Cornuejols, ESRF

ESRF:
Immersed in world-class scientific research

Want to make a career in science? Students can now come to the ESRF and discover their (maybe hidden) skills for becoming a researcher.

ESRF has developed a programme, called "synchrotron@school", for secondary school students of the "Académie de Grenoble". A physics teacher worked in residence at the ESRF during six months to help set-up hands-on experiments to illustrate the interactions between light and matter. Different types of light, lasers, ultraviolet and infrared – and of course X-rays – will reveal some of their secrets to curious students.

Students can visit the institute, carry out an experiment, test different conditions, discuss the findings, make a poster and present it in front of the class. All this can be done in one day, in an extraordinarily stimulating research environment.

The first three sessions of "synchrotron@school" took place in the brand new ESRF Visitor Centre in February 2014 and more will be organised in April. The programme is already a success and the organisers hope that it will be possible to extend it to more schools in the future.

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

Image courtesy of Wellcome Images

ILL:
CSI Neutrons

When your finger touches a surface, it leaves behind deposits of sweat and oil that mirror the ridges and troughs on your fingertips. The classical approach to see these is to 'dust for prints' but there needs to be a lot of fingerprint material and only 10% of fingerprints taken from crime scenes are usable in court.

Instead of sticking something to the fingerprint, researchers from the University of Leicester have developed a new technique that uses the fingerprint as an insulating mask, so that the reagent – an electrochromic polymer that changes colour when a charge is applied- is only deposited on the bare metal surface. The polymer creates a negative image of the print and is highly sensitive so much less fingerprint residue is required.

After deposition, the team also chemically modified the film to make it fluoresce. The ILL was key to watching the modification of the polymer to check it worked because neutrons can easily distinguish the polymer and fluorescent molecules.

To learn how to turn your students into forensic scientists see : Gardner G. (2006) The detective mystery: an interdisciplinary foray into basic forensic science. *Science in School* **3**:35-38 www.scienceinschool.org/2006/issue3/detective

If you'd like to learn more about luminescence visit: Welsh E. (2011) What is chemoluminescence? *Science in School* **19**: 62-68 www.scienceinschool.org/2011/issue19/chemoluminescence

ILL is an international research centre at the leading edge of neutron science and technology, based in Grenoble, France.

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

To learn how to use this code, see page 57.

Citizen science: have you used it in your classroom?

Science in School would like to hear about your experiences!

Do your students like to experiment with real data coming straight from a mass spectrometer or a satellite? Or do they feed their own careful observations into the database of an ongoing research project? Perhaps they do both!

Citizen science web-based platforms, which allow classrooms to interact directly with real-time research projects, are becoming increasingly common. They offer a diversified panel of activities that teachers can choose from to build on the latest advancements in science, but they can also improve students' computer skills, provide them with a realistic glimpse of what scientists' work is really like… and obviously give them the satisfaction of playing an integral part in furthering our knowledge.

At *Science in School*, we feel that these platforms offer valuable support for teaching science. We would like your help to investigate in more detail just how they can be used in practice.

Have you used these tools in your classroom?

If so, did you think they were effective and valuable? Why?

How did you integrate them into your lesson plan?

What were the main challenges you faced when using these tools?

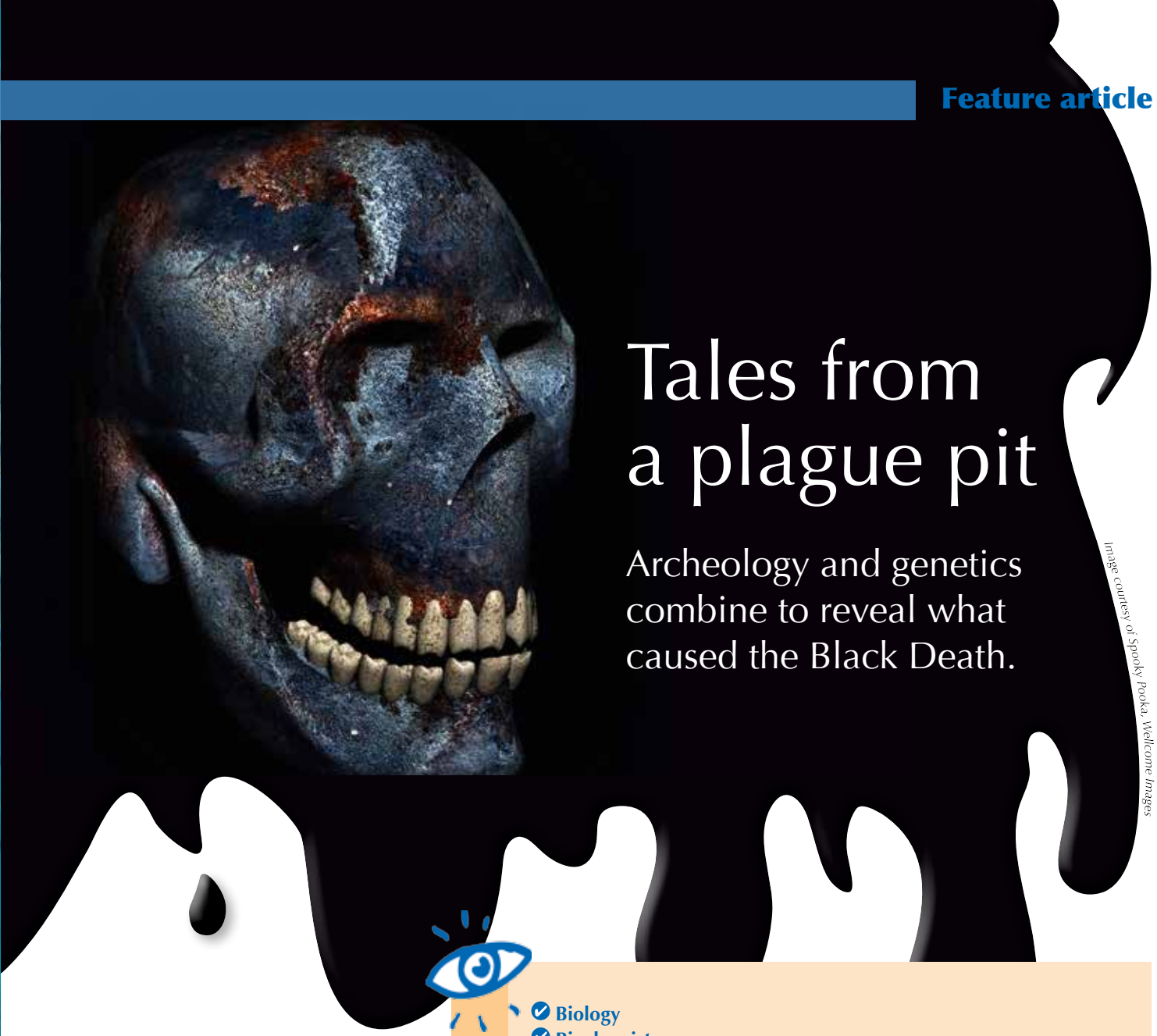
We would like to hear about your experiences and maybe share them with our readers!

Please contact us at editor@scienceinschool.org

Citizen science platforms broadly fall into two categories: those that ask non-scientists to provide researchers with data for further scientific analysis in the lab; and those that give free access to data generated in research labs, for anybody to use and analyse.

These platforms also vary in their design and function. They can look like games, such as Foldit (http://fold.it/portal), or like databases, such as the NASA Giovanni website (http://disc.sci.gsfc.nasa.gov/giovanni). They can also be active platforms where students can report on their observation and post data online, like for the Great Sunflower Project (www.greatsunflower.org), or classify the enormous amount of data generated by astronomers, such as in Galaxy Zoo (www.galaxyzoo.org). Many more examples are available on the web, in various countries and languages.

Image courtesy of the Fermi National Accelerator Laboratory



Tales from a plague pit

Archeology and genetics combine to reveal what caused the Black Death.

Image courtesy of Spooky Pooka, Wellcome Images

By Kirsten Bos

The Black Death is without a doubt one of the most famous infectious diseases in history. Sweeping across Asia and Europe during the mid-fourteenth century, it reduced European populations by as much as 50 % in urban centres, in the space of just five years (1347–1351)[w1]. This huge death toll had a long-lasting effect on European culture: large declines in the peasant class destabilised the feudal system, paving the way for more favourable economic systems. Soon citizens could own their own land and cultivate their own crops.

Many historical records document the path of the Black Death across

REVIEW

- Biology
- Biochemistry
- History of medicine
- Ages 12-17

This article is appropriate for learning in an interdisciplinary way. Science teachers could use this article as a basis for projects in subjects such as molecular biology, biochemistry of DNA or microbiology, and even link in elements of bioinformatics.

The article could be used with students for a discussion about the transmission, diffusion and evolution of some infectious diseases such as the Black Death. Students will understand the active research underway about the biology of *Y. pestis* and the extent of infections of this bacterium each year in Europe and throughout the world, and can compare this information with the history of the Black Death.

The article could also be used to start a project analysing the structure of the human tooth and how it is used for DNA extraction, as well as the techniques used to compare modern and ancient fragments of *Y. pestis* DNA and other bacteria with human DNA. A more intriguing activity is to ask students to hypothesise about the future of this research and, particularly, about its utility in helping us to understand changes in some of our genes.

Marina Minoli, Didactic expert at Agora University Active Science, Italy

medieval Europe, and some even include graphic descriptions of the disease's gruesome symptoms. The hallmark feature of the 'pestilence', as it was called at the time, was the presence of a single egg-sized swelling somewhere on the body. Based on this feature, medical historians today assume the disease was an unusually aggressive outbreak of bubonic plague, caused by the bacterium *Yersinia pestis*. Plague is normally found in rodents, which transmit the disease to each other through flea bites. Humans are one of about 200 mammalian species that are susceptible hosts to *Y. pestis* infections, and under certain conditions that we don't fully understand yet, the disease can pass from rodents to humans. Today we still see about 2000 *Y. pestis* infections per year in the world, but they're nothing of the scale of the Black Death[w2].

Image courtesy of Rob Young, Wellcome Images

Fleas help spread the disease

Image courtesy of Wellcome Library, London

A physician wearing a plague preventive costume, people thought the disease was spread by foul air

The question of why humans succumbed to the Black Death is still unsolved. After all, a quick stroll though a subway station of any major city will tell you that we're not exactly free of rats. So was it that humans were living under conditions more conducive to bacterial infections in the past? Were medieval people simply more vulnerable to the disease, perhaps due to something in their genes? Or was the bacterium itself different in some special way that made it more virulent? An answer might come from the skeletons of people who were buried in plague pits in the city of London, England, during the height of the Black Death.

Digging down

Have you ever been to Tower Hill tube station in London? If so, you were right across the road from an ancient burial ground for plague victims. From 1986 to 1988, archaeologists at the Museum of London excavated this medieval plague pit and recovered the skeletons of 600 people (and there are still about 2000 more in the ground!)[w3].

I am part of a research team that took teeth from these skeletons to screen them for tiny pieces of *Y. pestis*

Images courtesy of the Museum of London Archaeology

The excavation of the plague pit

DNA that might have survived being buried in the soil for almost 700 years. Teeth are the best part of the skeleton to use because the hard outer enamel works like a shell, protecting the DNA in the interior of the tooth for centuries.

You can think of this combination of archaeology and molecular biology as our lens to look into the past. Thanks to scientific developments in the past few years, we can now catch tiny pieces of DNA from ancient diseases and look for clues about how their genes have changed over time. We can then use these differences to figure out how pathogens evolve.

Tooth extraction

After collecting the teeth, we take them through a chemical process to isolate the DNA molecules from the cells that we've recovered. Unfortunately this process indiscriminately takes DNA from all sources – plant, human, soil, bacteria – and somewhere in this giant molecular haystack are the tiny pieces of ancient pathogen DNA. The problem is finding them.

We use something called DNA capture to get these specific pieces of DNA. It's kind of like fishing, only rather than catching fish, we catch molecules. We design baits that match parts of the genetic code of the *Y. pestis* target we are looking for

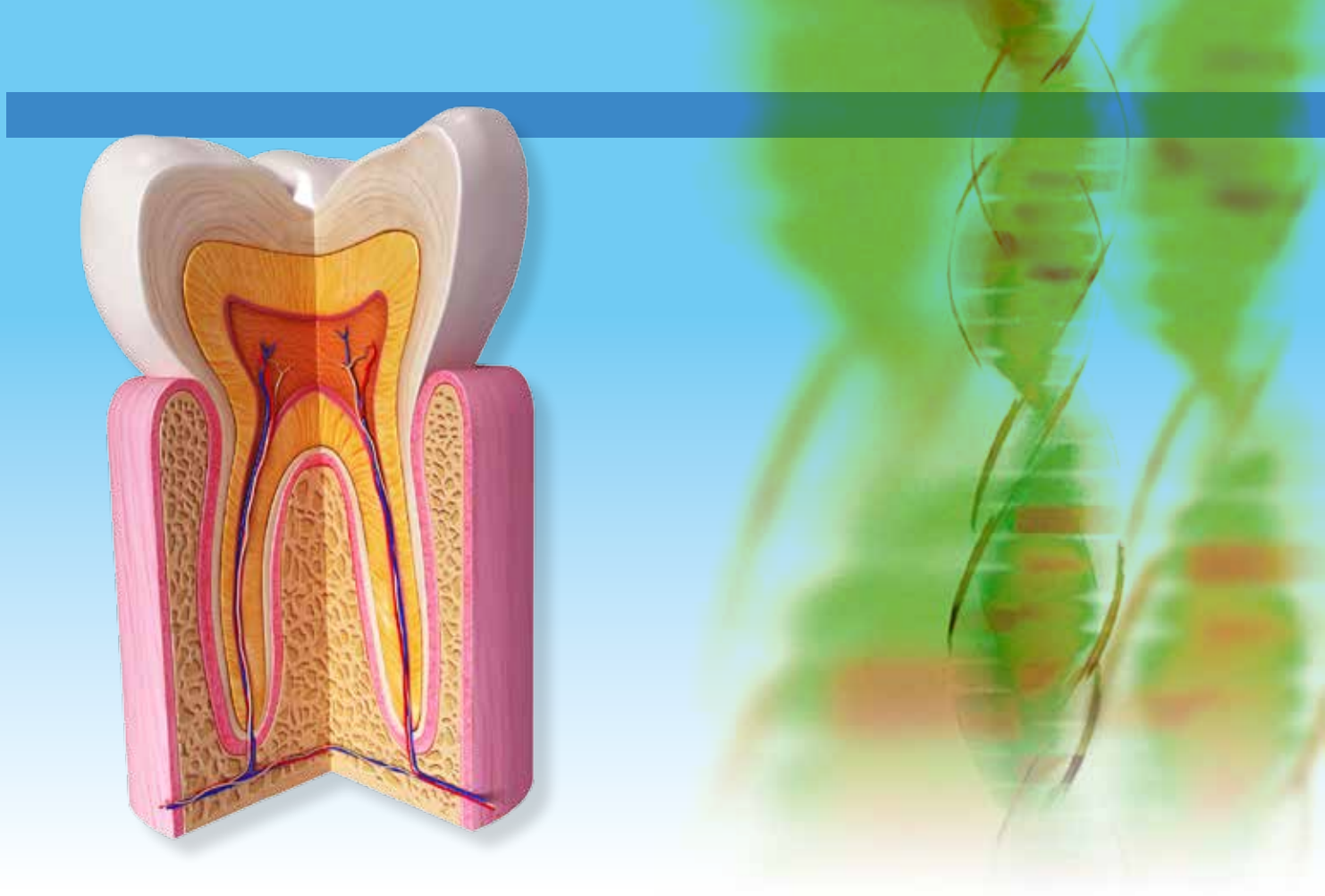


Image courtesy of iStock

Structure of the tooth. The hard enamel shell of teeth can protect DNA in the pulp for years

and go fishing in our giant molecular haystack, pulling out fragments that match. The whole process takes about a week, and at the end we have a raindrop-sized amount of liquid that hopefully contains pieces of the genetic code of the ancient pathogen that have survived for hundreds of years inside the tooth.

We don't end up with one long string of DNA coding for *Y. Pestis*. Instead, we have a whole bunch of tiny fragments of DNA. We can then use a computer (and a computer specialist!) to put the puzzle back together, giving us the reconstructed ancient genome of the disease. But don't worry – it's just a file on a computer, it's not in our lab!

With the reconstructed genome on file, we can compare the ancient disease to the versions of *Y. pestis* that circulate today, to see if it has changed over time. Interestingly, we found that the ancient plague was almost identical to the *Y. pestis* bacteria that is around today, which was something we weren't expecting.

This means that the ancient disease was probably no more virulent than the one we see today. So perhaps, rather than the disease changing, humans themselves have changed. We could simply be living under conditions that prevent large-scale infections like the one that plagued medieval Europe, but a more intriguing possibility is that *our* genes may have changed to make us better able to deal with this particular infectious disease. The next step will be to look at ancient humans to see if their genes are different from ours. Clearly there are more secrets in ancient bones, and now we have the knowledge and expertise to do our detective work!

Web references

w1 – An interactive map shows how the Black Death spread across Europe in a few short years. See: http://tinyurl.com/o4hjh56

w2 – The Education Portal discusses the microbiology of *Yersinia pestis*, including videos and quizzes. See: http://tinyurl.com/p558467

w3 – For more information from the Museum of London about plague in the city, visit http://tinyurl.com/ngy8au4

Resources

The game Plague Inc., developed in association with the Wellcome Trust, is a mix of strategy and realistic simulation available for mobiles and PCs. As a pathogen, you must continually evolve to become a global plague. See: www.ndemiccreations.com/en/22-plague-inc

Plague is a zoonotic infection, passed from animals to humans. You can find out more about how infectious agents can make the leap in issue 27 of *Science in School*.

Heymann J (2012) Evolving threats: Investigating new zoonotic infections. *Science in School* **27:** 12-16.

www.scienceinschool.org/2013/issue27/zoonosis

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

Dr Kirsten Bos is a postdoctoral researcher at the University of Tubingen's Institute for Biological Archeology, where she researches the genetics of ancient diseases. Kirsten received her PhD from McMaster University in Canada for her work on investigating the genetics of the Black Death.

Image courtesy of Wellcome Library, London

A physician wearing a plague preventive costume

To learn how to use this code, see page 57.

Glaciers on Mars: looking for the ice

One of the scientists' main interests in Mars research is water. Is there water on Mars?

Image courtesy of ESA 2007 MPS for OSIRIS Team MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA

True-colour image of Mars. The image was acquired in 2007 from a distance of about 240 000 km; its resolution is about 5 km/pixel.

By Miguel A. de Pablo and Juan D. Centeno

At the expected time, the orbiter, flying at about 300 km in altitude and around 3.5 km.s^{-1}, focused toward the surface of the arid, cold and reddish planet and opened the shutter of the complex and precise camera. A new image from the Martian surface, and gigabytes of data, were then recorded at the same time. This process has been repeated many times in recent decades by the different orbiters, landers and rovers[w1] that we have sent to our nearest planet. Every new image and data set increases the incredibly huge database[w2,w3] of information on Mars. Scientists from all around the world use these resources to study the planet's chemical, physical, climatic and geological environment, with the aim of understanding more about Mars and how it – and even Earth – has evolved. This widespread availability of images[w4] and data is one of the most amazing phenomena in the history of science – never before have so many experts shared so much information and produced so many models and results.

BACKGROUND

Do you know the composition of the Martian polar caps?

The northern polar cap of Mars is mainly H_2O ice. However, the southern polar cap comprises H_2O ice and CO_2 ice.

Water and ice on Mars

One of the scientists' main interests in Mars research is water. Is there water on Mars? Where is it? Is it liquid or frozen? In the past, were there oceans, seas, lakes and rivers on Mars? How did they disappear? Is their disappearance related to the past and present climate of the planet? But also: Is there, or was there, life on Mars? And could humans live there one day?

Thanks to the data acquired by orbiters, landers and rovers[w5], we know that Mars had liquid water millions of years ago – flowing on its surface, filling the basins of impact craters, forming lakes, flowing downslope of some volcanoes' flanks, from the Martian highlands to the lowlands, where an extensive ocean could have existed (referred to as Oceanus Borealis).

Solid water is a different matter. Ice polar caps on Mars were identified from telescopes and clearly recognisable on orbiters' images[w6], and frozen soils have been confirmed in several places on the planet, mostly thanks to

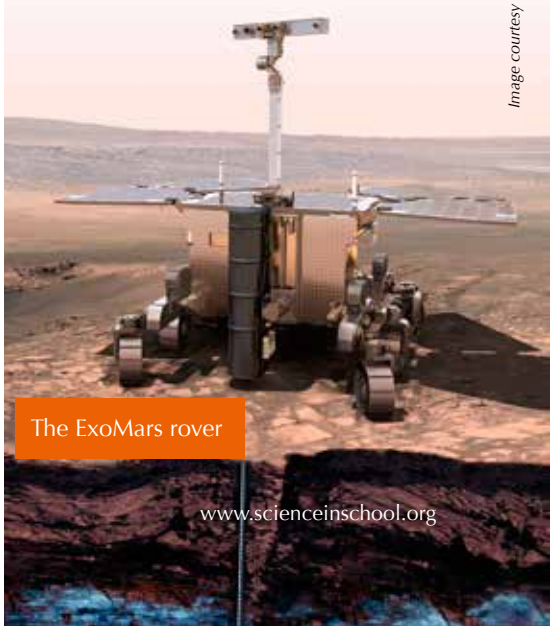
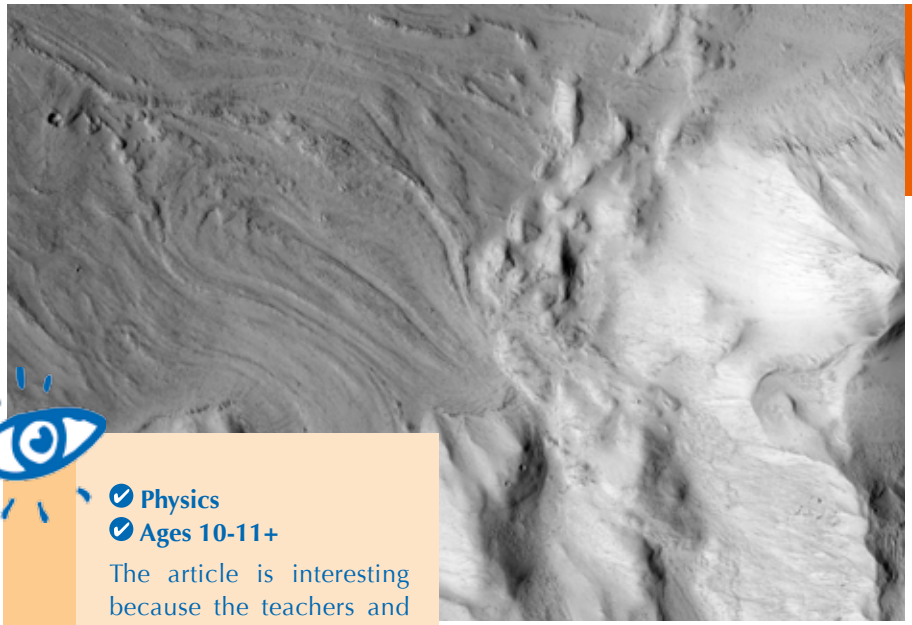


Image courtesy of ESA

The ExoMars rover

Image courtesy of NASA/JPL/HiRISE/University of Arizona



HiRISE image of Mars from NASA's Mars Reconnaissance Orbiter mission, showing the surface with very high resolution (0.35 m/pixel), enough to identify features as small as 1 m in size.

REVIEW

Physics
Ages 10-11+

The article is interesting because the teachers and students can understand that currently research can be done if you spend many hours in search of free international databases, if you compare many images and of course if you have expertise in a scientific field. Then you can emit a theory which has to be proved by another research and so on.

The supplementary links and educational resources can be the starting point for inquiry based learning projects with the title like these: Earth and Mars Similarities, Studying the Mars Planet or Life on Mars.

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

the images reported by NASA's *Phoenix* mission at high latitudes. The low temperatures of the planet throughout the year, measured by different landers and rovers (such as *Viking I and II, Mars Pathfinder, Spirit, Opportunity* and *Curiosity*, which arrived on Mars in August 2012), confirm that ice is stable at all latitudes. In fact, the mean temperature of Mars is about -80 ºC during daytime; at the Equator, the sunny slopes in the summer at noon hours can reach a surface temperature of 15 ºC.

Studying martian glaciers

Today, research on Martian ice[w7] focuses on finding evidence of the presence of ice and glacial-related features using new high-resolution (as high as 35 cm/pixel) images acquired by the active missions of NASA and the European Space Agency (ESA). Our research group focused on the northwest flank of the Hecates Tholus volcano in the Elysium region of Mars, at tropical latitudes of the northern hemisphere. We analysed all the available images from different orbiters covering this region (at different spectral, temporal and spatial resolutions), and observed features that we interpreted to be caused by glacial erosion or sedimentation: moraines, crevasses, roches moutonnées, glacial cirques, hanging valleys, eskers, drumlins or arêtes, among others[w9].

Our interpretations were based on the comparison between the *marsforms* (the reliefs observed on Mars)

Image courtesy of NAS/JPL/HiRISE/University of Arizona

This unusual structure with traces of a glacier is located in Promethei Terra at the eastern rim of the Hellas Basin. A so-called 'block' glacier flowed from a flank of the massif, past mountains several thousand metres high, into a bowl-shaped impact crater, nine kilometres wide, which has been filled nearly to the rim. The block glacier then flowed into a 17 kilometre wide crater, 500 metres below, taking advantage of downward slope.

Images courtesy of NASA/JPL/University of Arizona

Polygonal terrain, typical of frozen soil areas on Earth, surrounding the *Phoenix* landing site.

Polygonal terrain near the northern polar cap of Mars, where water ice was observed just a few centimeters below the surface.

and the terrestrial landforms in the Alps, Iceland or Antarctica, where we conducted fieldwork looking for terrestrial analogues. We also used the 'multiple working hypotheses' scientific method to discard other processes that are able to produce similar features as the origin of the *marsforms* we observe. Then, after months of work in front of the computer[w8] and on different field trips, and thanks to the satellite images and topographic, spectrometric and thermal data, we carried out a detailed description, mapping and age determination of the features observed on the flank of the Martian volcano. Our first conclusion, based on the long list of glacial-related features on the Hecates Tholus volcano, is that an important amount of ice existed there for a long time, forming glaciers that flowed downslope, sculpting the flanks of the edifice.

The problem is… we couldn't find ice anywhere! However, we could see some glacial features that we know can't survive for long after ice melts. This is the case for crevasses: fractures in the glacier disappear when ice melts or sublimates. We didn't see the ice on this part of Mars, but we could recognise the crevasses sculpted in the dust layer that covers the ice. For that reason, our second conclusion is that the ice causing the extensive fields of glacial *marsforms* must still be below the surface – or it melted very, very recently.

BACKGROUND

Did you know that Martian volcanoes had glaciers?

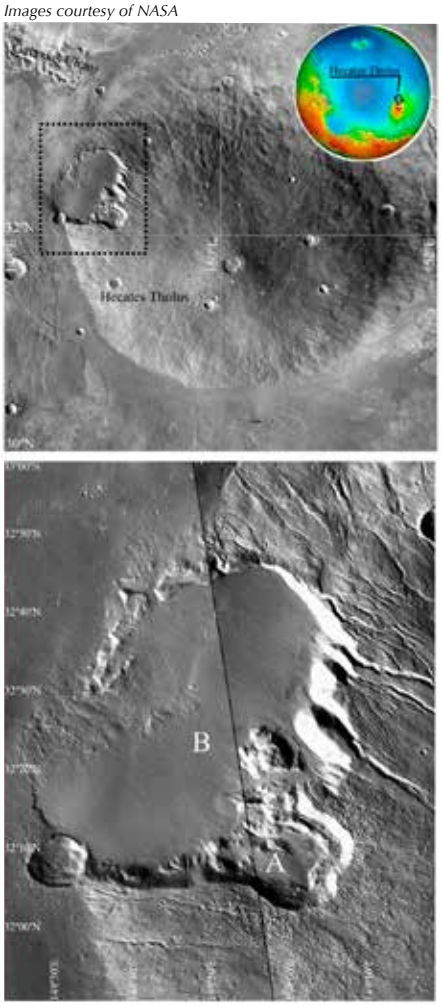
Many Martian volcanoes show reliefs on their flanks that are caused by glacial ice flows – just as we see on Earth. Those volcanoes are located not at polar but at tropical latitudes. Olympus Mons, Ascraeus Mons and Hecates Tholus are examples of volcanoes with glaciers, similar to Mount Kilimanjaro (Tanzania) and Cotopaxi (Ecuador) on Earth.

BACKGROUND

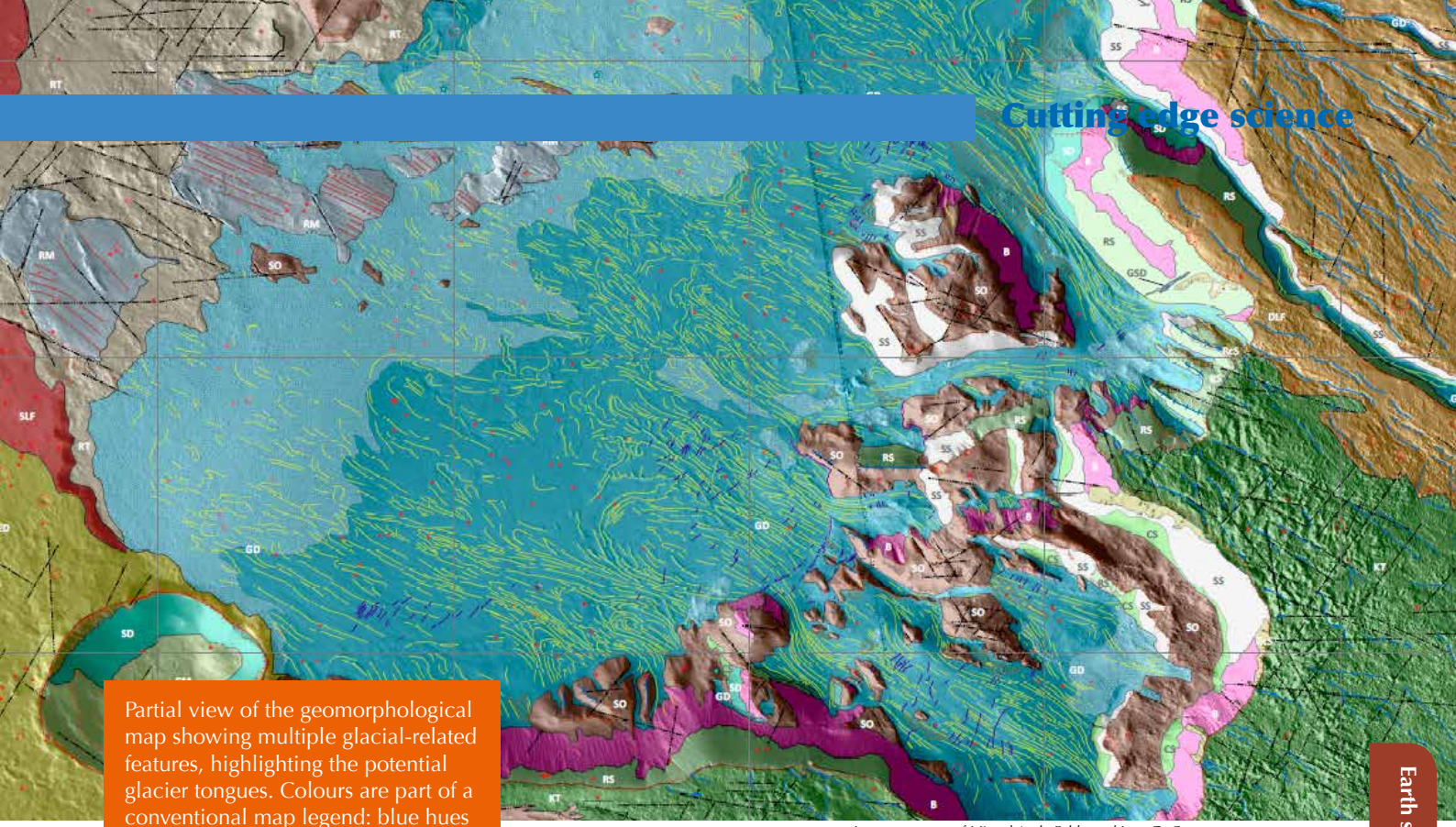
Did you know that Mars had ice ages?

Crater counting has provided evidence of glacial activity, both ancient (more than 1000 million years ago) and recent (less than 2 million years ago). The cold periods in Mars history are related to orbital changes (mainly changes to spin axis angle) – just like Earth, where the orbital cycles control most of the Quaternary climate change, as discovered by Milutin Milankovic in 1922!

Images courtesy of NASA



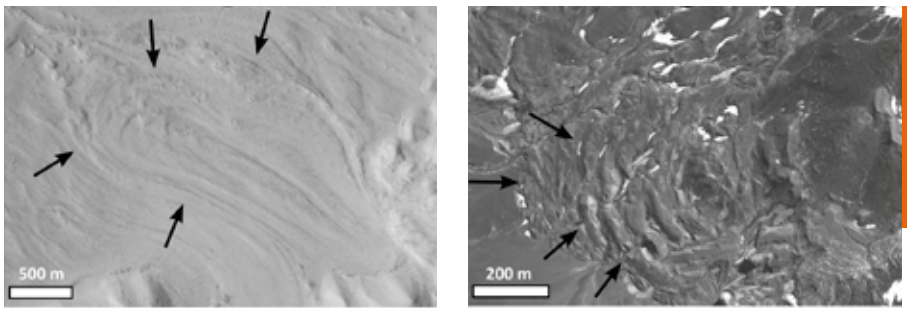
View of the Hecates Tholus volcano, in the Elyisum region of Mars, and the area in which glacial marsforms have been observed. The area was chosen because its high concentration of glacial forms found during general exploration of the volcano slopes.



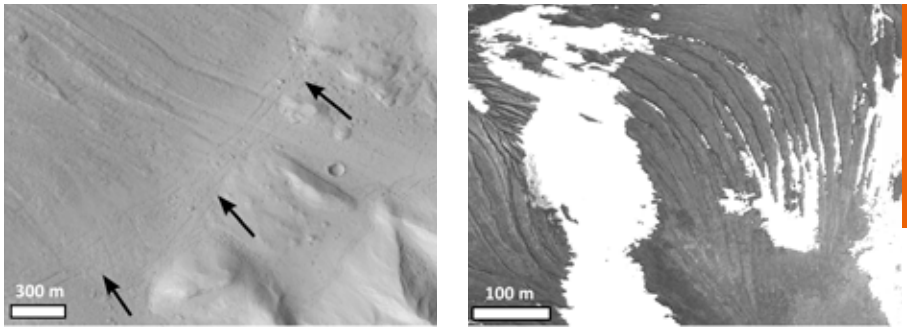
Partial view of the geomorphological map showing multiple glacial-related features, highlighting the potential glacier tongues. Colours are part of a conventional map legend: blue hues represens glacial areas.

Image courtesy of Miguel A. de Pablo and Juan D. Centeno

Images courtesy of HiRISE/UA/NASA and DigitalGlobe



Similarities between marsforms in Hecates Tholus (A) and landforms in Deception Island, Antarctica (B) help scientists to deduce their origin – in this case, glacial ridges are observed in the images (black arrows).



Crevasses (fractures on the ice due to its flow) on Hecates Tholus (A) and on glaciers on Deception Island, Antarctica (B), where they are covered by volcanic deposits from the last eruption in 1970.

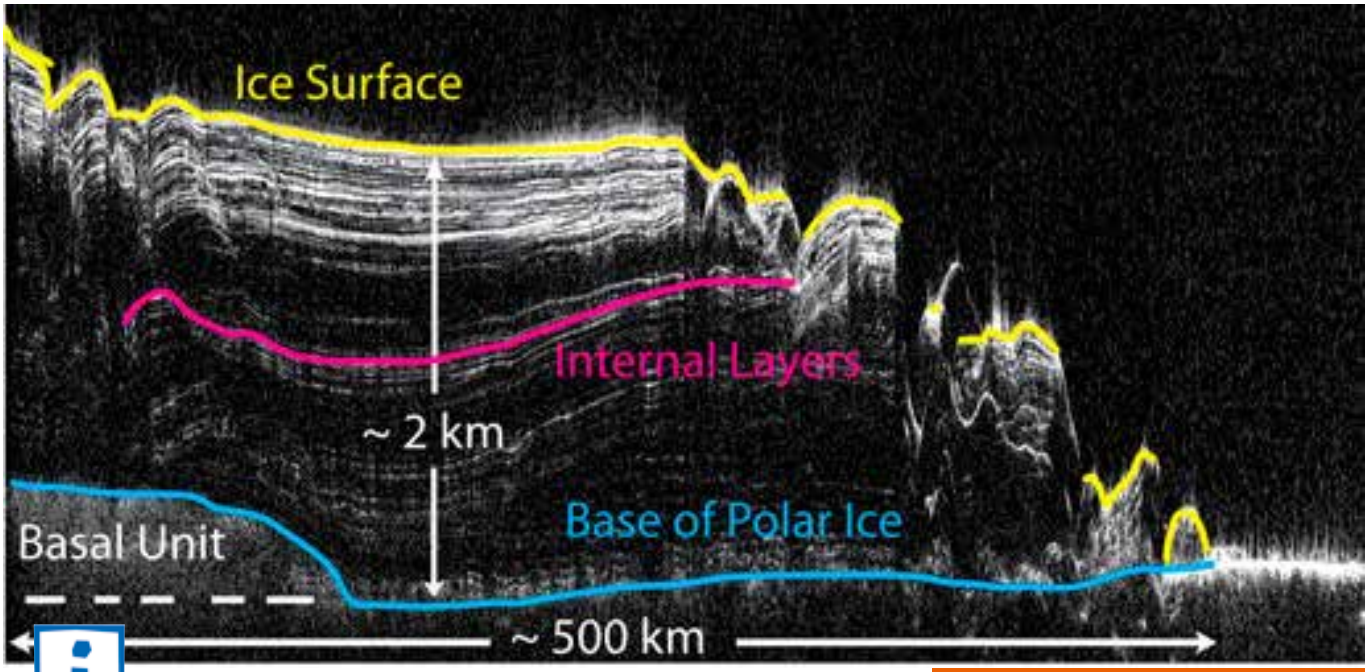
Image courtesy of HiRISE/UA/NASA and DigitalGlobe

Through crater counting (see box p.17), we also calculated the age of the different glacial deposits that we observed on the images. We found a wide range of ages – from 1000 million years to 350 000 years – which means that the Hecates Tholus volcano had a long history in which the glaciers slowly sculpted its northwestern flank. In fact, we proposed the existence of cold periods, in which the ice tongues covered an important part of the volcano and its surroundings, and also warmer periods, in which the glaciers were smaller and covered only parts of the flank, such as in the present time.

Future steps

We plan to repeat our observational study in other volcanic regions on Mars to see if the same pattern exists and to get a better idea of the global distribution of glaciers and ice on Mars. These studies will further our understanding of the climate, its evolution and its characteristics on our neighbouring planet. The presence of glacial features on volcanic edifices could also mark the location of sites

Image courtesy of NASA/ESA/JPL-Caltech/University of Rome/Washington University in St. Louis



Mars northern polar ice cap section, based on ground penetration radar data showing the ice and sediments layers.

BACKGROUND

Did you know that liquid water is not stable on Mars?

All the water that has been found on Mars exists in a gas or solid state. Mars' atmospheric pressure is very low (around 6 mbar, compared with Earth's average of 1013 mbar) and below the minimum required for liquid water stability.

where life, if it existed, could have found water and heat to survive, even in the cold and dry environment on Mars.

Upcoming studies will use a new kind of tool: penetration radar. This technique allows us to measure the properties of materials below the surface and to investigate their variations: if there is ice below the surface, it should be distinguishable in the radar data, just as we observed in the Martian polar caps. Radar data from NASA and ESA will allow us to corroborate our interpretations of observations from the Hecates Tholus glaciers and other areas on the red planet, thanks to a modern, collaborative and interplanetary effort to further science.

Web references

w1 – NASA's Mars Exploration Missions website provides information on all the past, present and future missions to Mars by different countries and space agencies. See: http://mars.jpl.nasa.gov/programmissions/missions/

w2 – The Planetary Science Archive of the ESA stores data from planetary and universe exploration missions. It is free to use. See: www.rssd.esa.int/PSA

w3 – NASA's Planetary Data System stores all the data from the planetary and universe exploration missions. It is free to use. See: http://pds.nasa.gov/

w4 – The All Mars images webpage from Arizona State University (USA) shows all the images from Mars acquired since the Viking missions in the late 1970s. To investigate this user-friendly resource, see: http://themis.asu.edu/maps

w5 – The Mars Orbital Data Explorer has a user-friendly search tool to extract data from any mission to Mars. See: http://ode.rsl.wustl.edu/mars/

w6 – The Mars Odyssey's THEMIS has generated many images that can be searched by topic (including ice-related topics). The site is useful for learning and develop of didactic activities. See: http://themis.asu.edu/topic

w7 – The website of the Mars Ice Consortium contains links to free educational resources about Mars from different institutions. See: www.mars-ice.org

w8 – JMars is a freeware and multiplatform Geographic Information System that is used by planetary scientists to visualise different types of data from Mars, such as images, topography, spectrometry and many other data. The site requires free registration and can be found at http://jmars.asu.edu/

w9 – You can search for glacier-related terminology and photos on the Glaciers online photo glossary for secondary education. See:

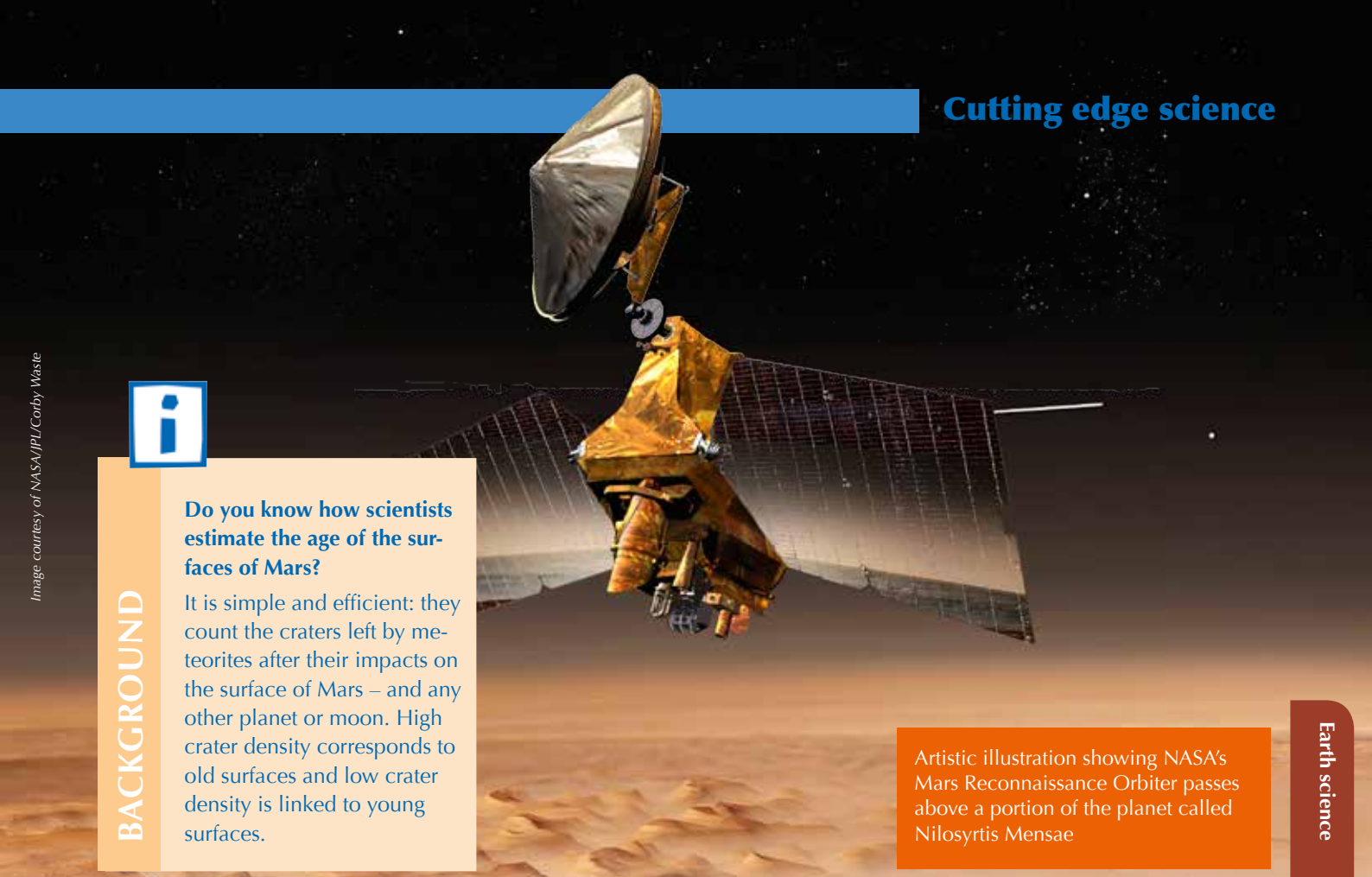


Image courtesy of NASA/JPL/Corby Waste

BACKGROUND

Do you know how scientists estimate the age of the surfaces of Mars?

It is simple and efficient: they count the craters left by meteorites after their impacts on the surface of Mars – and any other planet or moon. High crater density corresponds to old surfaces and low crater density is linked to young surfaces.

Artistic illustration showing NASA's Mars Reconnaissance Orbiter passes above a portion of the planet called Nilosyrtis Mensae

www.swisseduc.ch/glaciers/glossary/index-en.html

References

De Pablo MA, Centeno JD (2012) Geomorphological map of the lower NW flank of the Hecates Tholus volcano, Mars (scale 1:100,000). *Journal of Maps* **8**: 208-214

Resources

The Google Earth freeware allows viewers to visualise images at different resolutions and scales not only of Earth but also of Mars (and the Moon). and can be used to make comparative analysis. See: www.google.com/earth/index.html

The Google Mars webpage contains a simple map of Mars with topography, and mosaics of visible and infrared images. See: www.google.com/mars/

To learn more about the history and evolution of Mars, see:

Forget C, Costard F, Lognonné P (2006) *Planet Mars: story of another world*. Chichester, UK: Springer-Verlag/Praxis. ISBN: 978-0387489254

Ever thought of visiting Mars? This book might give you all the good-tips to do so:

Hartmann WK (2003) *A travelers' guide to Mars*. USA:Workman Publishing Company. ISBN: 978-0761126065

To learn more about the story of water on Mars, see:

Carr MH (1996) *The water on Mars*. Oxford, UK: Oxford University Press. ISBN: 978-0195099386

To lean more about the geology of Mars, see:

Carr MH (2006) *The surface of Mars*. Cambridge, UK: Cambridge University Press. ISBN: 978-0521872010

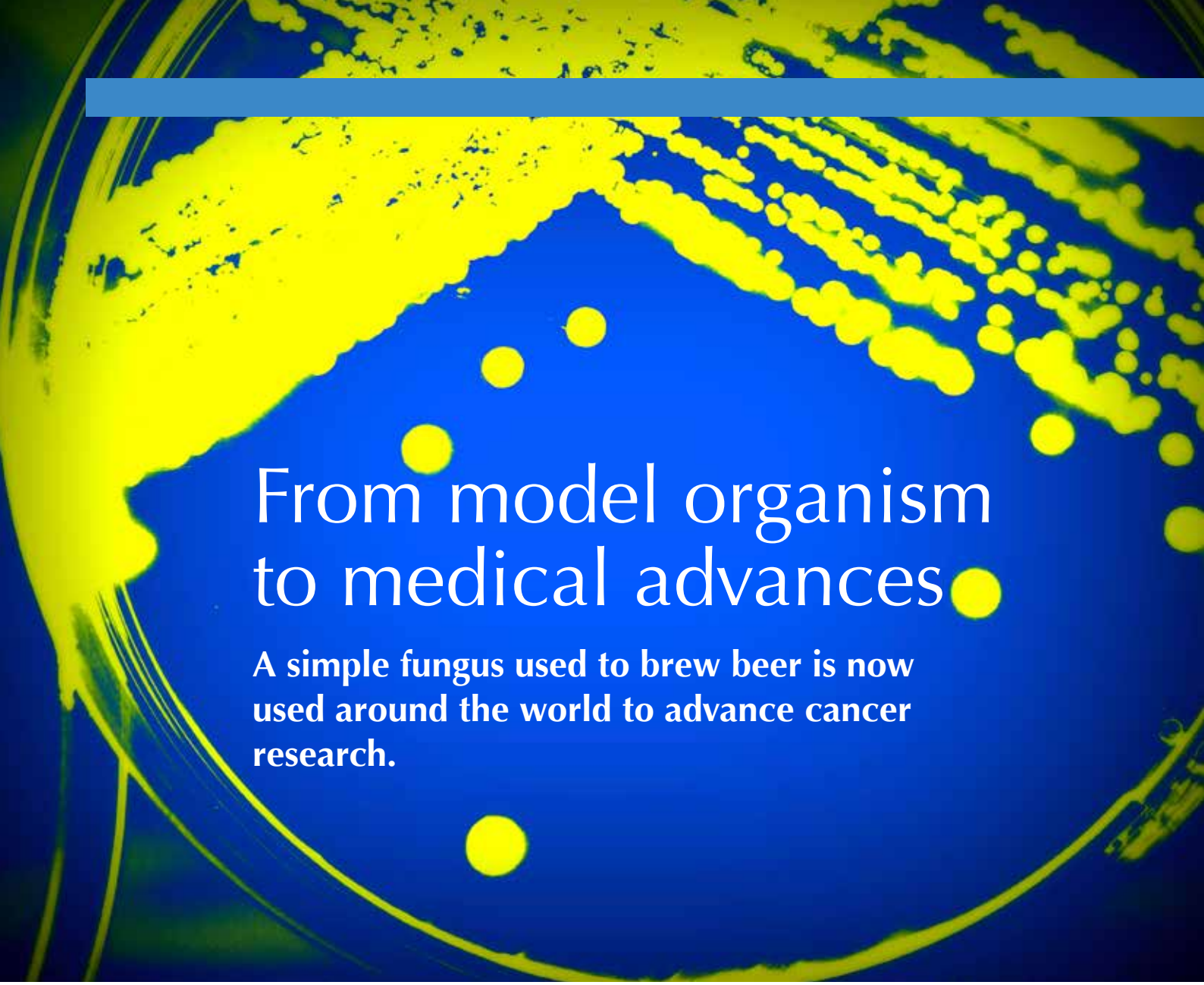
To learn more about the evolution of the climate on Mars, and how it was once wet and warm, read:

Kargel JS (2004) *Mars: a warmer and wetter planet*. Chichester, UK: Springer-Verlag/Praxis. ISBN: 978-1852335687

Miguel Ángel de Pablo is an Assistant Professor at the University of Alcalá in Madrid, Spain. He is a geologist and has focused his interests on Mars since 1996. He has experience in geological and geomorphological cartography, volcanism and glaciers, which he has studied in Iceland and Antarctica. He is also a member of the Science Team of NASA's Mars Science Laboratory on *Curiosity*.

Juan D. Centeno is Associate Professor at the University Complutense in Madrid, Spain. He is also a geologist with more than 25 years experience teaching geomorphology and environmental geology and studying glacial, periglacial and granitic landscapes all around the world.

Miguel and Juan are now working together to study glacial landforms in the flanks of the Hecates Tholus volcano of Mars.



From model organism to medical advances

A simple fungus used to brew beer is now used around the world to advance cancer research.

Image courtesy of iStock

By Louise Weston

Cancer affects millions of people worldwide each year. However, thanks to ongoing research into cancer and the underlying cell biology, treatments and survival rates are improving all the time. Perhaps surprisingly, the yeast *Schizosaccharomyces pombe* is an important tool for cancer researchers. This well-studied model organism (see box, p. 20) has enabled groundbreaking, Nobel Prize-winning discoveries and for more than 50 years has provided insights into how both normal and cancerous cells grow and divide.

Cancer is the human equivalent of a weed – unwanted abnormal cells grow out of control and in the wrong place. It is often the result of a series of changes in the DNA of a cell, known as mutations, that accumulate over time. These mutations can make cells grow too fast and divide too frequently, eventually forming tumours that invade nearby tissues and organs and cause damage. To understand how these mutations cause cancer, it is first important to understand how the cells work under normal circumstances.

Unfortunately, human cells are not ideal for cell-cycle research. The human genome contains about 20 000 genes, many of which have more than one function. In addition, human cells and DNA can be difficult to manipulate in the lab, making it tricky to unpick the function of one particular gene in this way. The yeast *S. pombe* has provided a solution. This single-celled organism, also known as fission yeast, is just 4 μm wide and 14 μm long and only has about 5000 genes.

S. pombe was first described in 1893 by German scientist Paul Lindner, who discovered the yeast in East African millet beer. Because of this, he named it after the Swahili word for beer, pombe. Researchers began studying the genetics and cell cycle of *S. pombe* in the 1950s. It is ideal for research for many reasons: it is easy to grow and non-pathogenic, and the cells are big enough to see under a microscope, contain just three chromosomes and divide every 2–4 hours (see box, p. 20).

A major strength of *S. pombe* as a model organism is the ease with which its genome can be manipulated – specific genes can be completely removed or extra DNA can be added. Scientists can grow these genetically altered cells and the resulting phenotype (the organism's observable characteristics) then helps them to understand the function of the altered gene. *S. pombe* cells are also haploid, meaning there is only one copy of each gene. This makes it even easier to look at gene function. In a diploid cell (where there are two copies of each gene), great care needs to be taken to ensure both copies of a gene are changed in order for the phenotype to be meaningful. Having just one copy of a gene, as in *S. pombe*, makes this process simple.

In addition, *S. pombe* has a well-characterised cell cycle and its regular rod shape makes it ideal for studies of growth and division. The cells maintain their rod shape and elongate at the ends until a precise cell length has been reached. The

REVIEW

- **Biology**
- **Medicine**
- **Genetics**
- **Biotechnology**
- **scientific interdisciplinary teamwork**
- **Ages 14-18**

Yeasts and fungi are with us, in us, and all around us. Students should learn about them while at school. Textbooks recommend safe handling of fungi growth but often provide no further detailed experimental procedures to follow. Starting with the usage of fungi in everyday food conservation and production will ignite students' interest in the topic. (Teachers should shy away from any practical using mould experiments, even under enclosed petri dishes.)

Using a safe yeast strain (e.g. baking with yeast, fermenting food or brewing beer or wine) in a well-defined experiment should encourage any biology teacher to give students the opportunity not only to learn good lab habits but also to understand why certain procedures need to be followed precisely and recorded correctly before one can draw any conclusions. This is how scientific practice should be taught before the students are introduced to the article, which is exemplary for a scientific report. The facts presented can lead to virtually planning experiments by using the described model organism. The questions concluding the report will generate more hypotheses for further research and discussions in class.

Friedlinde Krotscheck, Germany

Figure 1. The cell cycle

a

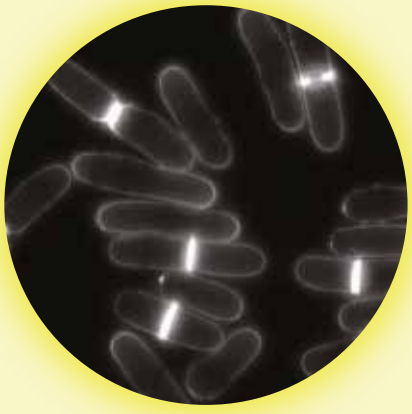
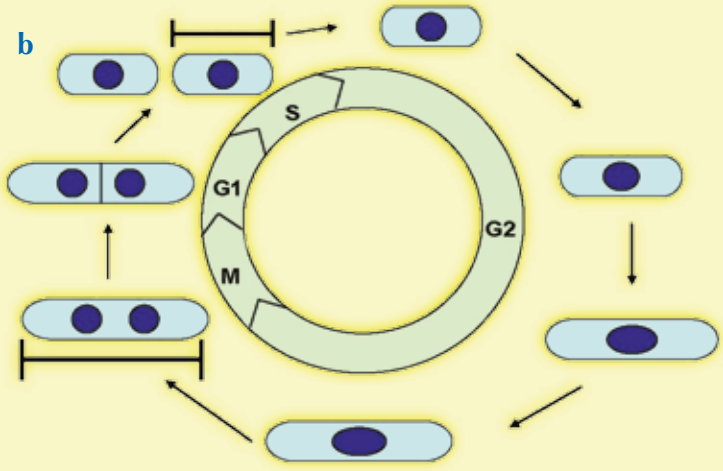


Image courtesy of Louise Weston

a) Microscope image of *S. pombe* cells stained with calcofluor, a fluorescent stain that binds to the yeast cell walls. Cells replicate their DNA and grow until they reach a critical length, at which point a septum forms and the cell divides.

b



b) The G1 (gap phase 1), S (DNA replication), G2 (gap phase 2) and M (mitosis) phases of the S. pombe cell cycle. The phase that an *S. pombe* cell is in can be estimated by measuring its cell length.

BACKGROUND

Model organisms

Many basic life processes, particularly at the cellular level, are almost identical in all living things. This means that scientists can use organisms such as fruit flies, zebrafish, mice or even yeast to study the fundamentals of cell growth and development and to apply that knowledge to humans. Certain species have proven particularly useful for research, so they have become known as *model organisms*. These organisms tend to be small, robust and easy to look after, with a short life cycle.

S. pombe is a particularly useful model organism because:

- It is a single cell with just 5000 genes (compared to 20 000 in human cells);
- The genome is easy to manipulate – genes can be added, mutated and removed. They can also be tagged with fluorescent markers, enabling proteins to be visualised using specialised microscopes;
- The genome is usually haploid (there is only one copy of each chromosome), which means that genetic changes will be expressed in the phenotype and not masked by another gene;
- The cell cycle is simple and it is easy to tell what stage the cell is in by simply looking at it;
- Many of the genes in *S. pombe* have homologues (equivalents) in human cells;
- Cells are quick, cheap and easy to grow and can be stored at –80 °C for many years.

DNA is replicated and one copy of the genome moves to each half of the cell, then a septum (brightly stained with a fluorescent dye) forms across the centre of the cell and it divides (see figure 1). This cycle repeats, with each cell growing and dividing into two daughter cells as long as the conditions are suitable for growth (e.g. plentiful nutrients are present).

In the 1970s, Paul Nurse and his colleagues began isolating and characterising cell-cycle mutants in *S. pombe* – work that ultimately led to a Nobel Prize in 2001. Initially the researchers looked for genetic alterations that caused cell death or unusually elongated cells that failed to divide (Nurse et al., 1976). Figure 2(b) shows elongated cells that have failed to divide following inhibition of a gene called *cdc* (which stands for cell-division cycle).

The benefits of model organisms become clear when the research advances our understanding of similar processes in humans. Many of the genes found in *S. pombe* to regulate DNA damage and repair, checkpoint controls and the cell cycle have homologues (equivalents) in human cells. For example, after identifying the gene *cdc2* in *S. pombe*, Nurse and his colleagues went on to find the corresponding gene, *cdk1* (cyclin dependent kinase 1), in humans (Lee & Nurse, 1987). This gene codes for a protein that initiates and regulates cell division in humans. Mutations in this gene can trigger unscheduled cell division and the duplication or deletion of chromosome sections, which may lead to cancer. Today, the therapeutic benefit of selective CDK inhibition in human cancer treatment is being studied. The opportunities go beyond addressing cancer – in fact, homologues of at least 50 *S. pombe* genes are associated with human diseases as varied as cystic fibrosis, hereditary deafness and type 2 diabetes.

S. pombe is so essential for research that, in 2002, it was the sixth

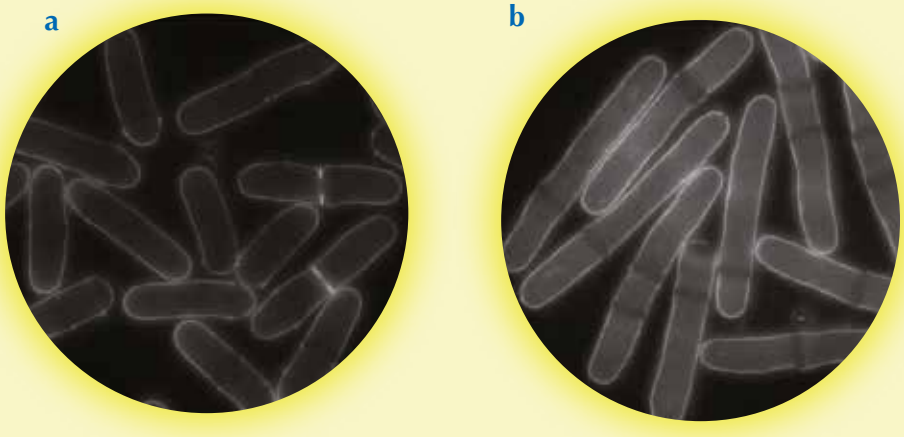


Image courtesy of Louise Weston

Figure 2. *S. pombe* cells containing a temperature-sensitive mutation in the gene *cdc25* can grow normally (a), but elongate and fail to divide when grown at a certain temperature (b). The gene *cdc25* encodes a protein that controls progression through the cell cycle. Inhibiting *cdc25* means cells get stuck in the G2 phase (see figure 1), and are unable to enter mitosis and divide.

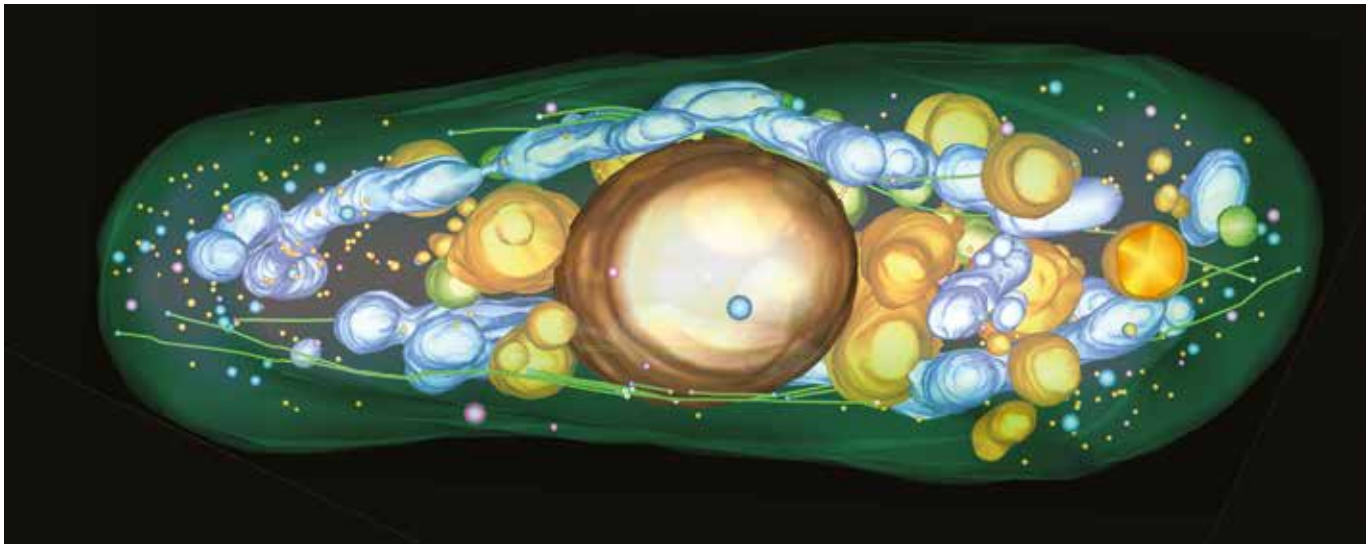


Image courtesy of Johanna Höög, EMBL

Architectural plan of the inside of fission yeast. There is still more to understand about the inside of this fungus.

eukaryotic organism to have its entire genome sequence published. This has led to the development of more important tools for studying *S. pombe*. For example, a library of 3308 strains of *S. pombe* has been created, each of which is missing one of the yeast's non-essential genes. In addition, each protein in *S. pombe* has been tagged with green fluorescent protein (which glows bright green under ultraviolet light), allowing its exact location within the cell to be observed with a fluorescent microscope. These tools will make *S. pombe* an even more useful model organism for investigating gene function (Yanagida, 2002).

We still don't fully understand how processes such as growth and cell division are controlled, and global controls over cell growth are particularly poorly understood. There is much we can learn from this simple single-celled organism about the complex processes that are so important to our healthy development as well as the development of diseases like cancer.

References

Lee MG, Nurse P (1987) Complementation used to clone a human homologue of the fission yeast cell cycle control gene cdc2. *Nature* **327:** 31-35

Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2014/issue28/fungus_cancer#resources), or subscribe to *Nature* today: www.nature.com/subscribe

Nurse P, Thuriaux P, Nasmyth K (1976) Genetic control of the cell division cycle in the fission yeast *Schizosaccharomyces pombe*. *Molecular & General Genetics* **146:** 167-178

Yanagida M (2002) The model unicellular eukaryote, *Schizosaccharomyces pombe*. *Genome Biology* **3**: comment2003.4

Resources

For more information about *S. pombe* and how it can be used in scientific research, visit PombeNet, a resource produced by the Forsburg Lab in California: www-bcf.usc.edu/~forsburg/main.html

The Cancer Research UK website offers accessible information on all the major cancers and current research. See: http://info.cancerresearchuk.org/cancerandresearch

For more information on how genetic mutations cause diseases, see:

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

For a classroom activity to discuss the ethics of knowing what your genes have in store for you, including the possibility of cancer, see:

Strieth L et al. (2008) Meet the Gene Machine: stimulating bioethical discussions at school. *Science in School* **9**: 34-38. www.scienceinschool.org/2008/issue9/genemachine

If you enjoyed this article, why not take a look at other medicine-related articles in *Science in School*? See: www.scienceinschool.org/medicine

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Louise Weston completed her DPhil at the University of Oxford, UK, researching cell migration in human cancer cells. She is now a postdoctoral research fellow at Cancer Research UK, using *S. pombe* to research cellular growth control.

The way of the dragon: chemistry for the youngest

In Sweden there lives a small, green dragon called Berta, who invites young children to join her adventures in Dragon Land – all of which are about chemistry.

By Anna Gunnarsson

At the NAVET Science Center in Borås, Sweden, we created Berta the Dragon as a way of introducing science to very young children (4-8 years). The dragon character is a hand puppet who teaches children about the wonderful world of chemistry through experiments, using Berta's own stories as a starting point. The first stories about Berta were so popular that they were published in 2010 as a book, *Berta's Book of Experiments: Exciting chemical fairy tales from Dragon Land*. A second Berta book has since followed.

The aim of all Berta's activities is to promote the understanding and use of chemistry in real life, with everyday materials that are familiar to everyone. The materials are non-toxic and most of them are easy to find on grocery shelves, so children can handle them without complicated or expensive laboratory equipment.

The experiments cover many different areas of chemistry – such as solutions, gases, and acids and alkalis – and are all designed to be done not just in science centres or schools, but also at home.

Portrait of Berta.

Image courtesy of Karin Södergren

Photo of Berta

Image courtesy of Adam Danielsson

Image courtesy of Joakim Lenell

Children doing chemistry experiments.

REVIEW

- Chemistry
- Physics
- Ages 4-12

Usually chemistry lessons are not part of primary-school education, especially in earlier years. This paper illustrates some novel and interesting activities and offers an alternative way to teach chemistry that any pupil could participate in and understand. I don't think that many teachers in Cyprus include chemistry in the first three or four classes of the primary school education. This article could form the basis for changing this tradition and call on young students to participate in fun and inspiring lessons. It is important, however, that these activities are not used only as show-and-tell experiments. Teachers should be well prepared for the discussion that will follow. They should be prepared from the pedagogical perspective of the lesson. For example, the questions posed by the teacher, the discussion held among the pupils of the same group and the explanations that they develop (with the help of the teacher) is the most vital part of the experiment. These are not provided here, but are left to the teacher to prepare.

Christiana Th. Nicolaou, University of Cyprus

What makes a good Berta activity?

All the Berta activities have been tried out with young children many times over several years to ensure that they are interesting and easy to do. When we choose activities for Berta and her young experimenter friends, we always look for these key elements:

- Safety: can the children safely experiment with the ingredients, *even if some of them happen to end up in their mouths* (it doesn't matter if they taste bad – but they have to be edible to find this out)?
- Child appeal: are the results fun, clear enough to see or touch, and a bit unexpected or even amazing?
- Exploration: does the chemistry raise interesting questions, and will it lead to new experiments and experiences?

There also needs to be an element of interacting with other people, as this is often the way we learn the most. Some of the experiments are most successful when carried out with a large group of children gathered around an activity, discussing, exploring and pouring in ingredients together as we go along; others work best with pairs of children or smaller groups.

In this article we describe three popular activities that are typical of Berta's style. While the experiments are different all three share the same characteristic for making the familiar intriguing.

Image courtesy of Roger Public domain imge / Wikimedia Commons

Citrus fruits

Activity 1: Floating bubbles

Age-group: 4-8 years

Materials

- 4 Tbsp sodium hydrogen carbonate ($NaHCO_3$ also known as bicarbonate of soda)
- Water - enough to fill the container with a 2cm high volume
- 2 Tbsp citric acid
- Ready-made soap bubble mixture
- Small aquarium or similar container with straight sides
- Large piece of paper to cover the container

Procedure

1. Mix 4 Tbsp of sodium hydrogen carbonate with 2 Tbsp of citric acid.
2. Spread the mixture over the bottom of the container.
3. Pour some water over the mixture: where does the sound come from?
4. Cover the top of the container with paper: why is it important to do that?
5. Wait for 3–4 min.
6. Blow soap bubbles while you wait – the kids can do this too. What kind of gas do we fill soap bubbles with when we blow them? What do we know about the gas that comes out of our mouths?
7. Lift the paper from the container and blow bubbles above it, letting some fall into the carbon dioxide gas formed. Why do the bubbles seem to float well above the liquid and not fall to its surface?

Image courtesy of Emelie Gunnarsson

Bubbles floating well above the liquid.

About what happens

When water is added, the sodium hydrogen carbonate and citric acid dissolve in it and start reacting. Carbon dioxide gas is produced, which makes a distinct fizzing sound as the gas spreads through the container.

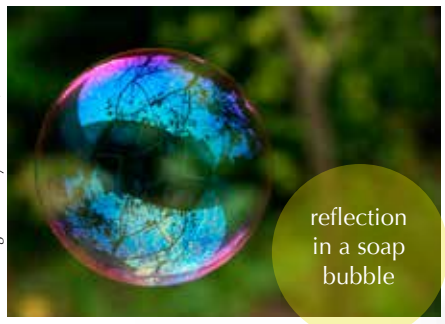


Image courtesy of Trodel / Flickr

reflection in a soap bubble

Carbon dioxide gas is denser than the surrounding air so it doesn't all float away, but there is still a chance of it escaping due to turbulence in the air (and it's really hard to see where it goes as it has no colour). This is why we put the paper over the container and keep it there until all the gas is formed and everything is ready for the bubbles. The soap bubbles contain air, so they have a lower density than the carbon dioxide gas; this means they float on top of the gas, showing that it's there and where it ends.

If a soap bubble floats for a while, you'll see that it slowly increases in size. This is because carbon dioxide gas travels into the bubble faster than air travels out. This also makes the bubble heavier, and it will eventually sink to the bottom of the gas layer.

Idea for a follow-up experiment

What will happen if carbon dioxide gas is formed inside a plastic bag?

Image courtesy of Roger McLassus/ Wikimedia Commons

Impact of a drop of water

Image courtesy of Emelie Gunnarsson

Berta the dragon with citrus fruits.

Different citrus fruits behave differently when dropped in water.

Image courtesy of Emelie Gunnarsson

Activity 2: Taking citrus fruits for a swim

Age-group: 4-8 years

Materials

- 1 lime
- 4 other citrus fruits, e.g. lemon, grapefruit, orange, tangerine etc.
- Knife for peeling fruit
- Large transparent container (at least 20 cm deep)

Procedure

1. Fill the large container with water.
2. Discuss what might happen when the fruits are dropped into the water.
3. Let the fruits 'go for a swim'. Why are some of them floating better than others?
4. Peel the fruits very carefully - so that the peel stays in one compact piece – and remove all the white pith from the fruits.
5. Discuss what might happen when the fruits are dropped back into the water without their peel.
6. Let the fruits 'swim' again, and watch what happens. Discuss what has changed and why this might be.
7. Pick up each fruit and put its 'life jacket' (its own peel) back on, then let them go back into the water. What effect does the peel have?
8. Discuss what will happen when the peels are dropped into the water without the fruit – then do this, and watch.

About what happens

Most whole citrus fruits float in water, but this changes once their peel is removed. The intact fruits float because of the large amounts of air held in the spongy white pith, which gives them a lower density than the peeled fruits. If the peel is removed in one piece, we can put it on and take it off like a life jacket, and it becomes obvious that it is the peel that is making the difference to the fruit's buoyancy.

The difference between lemons and limes is interesting in this respect. Both fruits have a density very close to that of water. However, limes always sink as they have a density slightly higher than water (because

Green citrus fruits have very little white pith, so sometimes they fall to the bottom of the container.

Images courtesy of Emelie Gunnarsson

Oranges have enough white pith to float when they are dropped into water.

they have hardly any white pith), whereas lemons sometimes float and sometimes sink, depending on how much pith the fruit contains.

Idea for a follow-up experiment

What will happen if we try other fruits and vegetables in the same way?

Activity 3: Droplet drama

Materials

- Vegetable oil
- 1 Tsp sodium hydrogen carbonate (also known as bicarbonate of soda)
- 1 lemon
- 100 ml red cabbage juice[w1] or blueberry juice
- Tall, narrow vase
- Drinking glass
- Spoon

Image courtesy of Joakim Lenell

Image courtesy of Thavox, Wikimedia

Sodium bicarbonate, or sodium hydrogen carbonate

Lemon

Image courtesy of André Karwath aka / Wikimedia Commons

Procedure

1. Put 1 Tsp of sodium hydrogen carbonate into the vase.
2. Pour vegetable oil on top of it to fill about two-thirds of the vase.
3. Watch the vase closely. What kinds of bubbles are rising to the top? Where do they go after reaching the surface?
4. Mix 100 ml of juice with a little water – just enough to show its real colour (purple for cabbage, blue for blueberry).
5. Discuss what colour the juice might turn if we make it sour using lemon juice.
6. Squeeze a little lemon into the juice and stir. Why does it change colour?
7. Pour some of this juice mixture into the vegetable oil. What happens to the juice droplets? How do they move? What about the transparent bubbles that are formed?
8. Look at the juice at the bottom of the vase. What colour is it? How does it change after a while?
9. If the reaction slows down, put some more lemon juice into the vase.

About what happens

The sodium hydrogen carbonate at the bottom of the vase contains some air trapped in the powder. When the vegetable oil is poured on top of it, the air forms bubbles that rise to the surface.

Red cabbage and blueberries contain natural dyes that are sensitive

Olive Oil

Image courtesy of Lenore / Wikimedia Commons

to changes in acidity, and they both become red when mixed with lemon juice, which is acidic (pH 3). The red juice droplets sink through the vegetable oil because they contain mostly water, which has a higher density than the oil. Once the acidic juice hits the sodium hydrogen carbonate, a chemical reaction takes place, producing carbon dioxide gas and making the juice less acidic. (Sodium hydrogen carbonate is alkaline when dissolved in water, so it neutralises the acid when they react together.)

The larger bubbles of carbon dioxide gas then rise quickly to the surface of the oil, while smaller ones gather on the surfaces of the juice droplets, making these float upwards too. Once the gas is released at the top, the juice droplets sink again to the bottom where they pick up more gas from the reaction, and rise again. They also become a bit more alkaline each time, which we see as a change in colour back towards blue or purple.

Idea for a follow-up experiment

See how many different colours you can get just by adding different amounts of lemon juice and sodium hydrogen carbonate to blueberry and/or cabbage juice.

References

Gunnarsson A., Södergren K. (2010) Berta's Book of Experiments: Exciting chemical fairy tales from Dragon Land. Navet and P&K (The Swedish Plastics and Chemicals Federation), Sweden. ISBN: 978-91-85107- 22-3 (available in Swedish, English and Norwegian)

Gunnarsson A., Södergren K. (2013) Berta´s New Chemistry Adventures. Navet and IKEM (Innovation and Chemical Industries), Sweden. ISBN: 978-91-85107-23-0 (available in Norwegian and Swedish)

Image courtesy of Joakim Lenell

Teachers observing the bubbles in the vase at the end of the experiment.

Web reference

w1 – You can download the recipe for how to extract cabbage juice from the *Science in School* website at: www.scienceinschool.org/2014/issue28/berta_dragon#resources

Resources

To learn more about the NAVET Science Center, see: www.navet.com. The website is mostly in Swedish, but some parts are also in English.

To see more Berta experiments, visit her website at: www.draknet.se or her Facebook page: www.facebook.com/berta.drake?fref=ts (both in Swedish).

To find out more about the use of cabbage juice as a pH indicator, visit: http://chemistry.about.com/od/acidsbase1/a/red-cabbage-ph-indicator.htm

For more activities on acid/base reactions, visit: www.kidsplayandcreate.com/what-hapens-when-you-mix-acid-with-a-base-fun-and-easy-acid-and-base-science-projects-for-kids/

If you found this article useful, you may like to explore the other teaching activities published in *Science in School*. See: www.scienceinschool.org/teaching. Otherwise you can also browse through the rest of the *Science in School* articles for primary school. See : www.scienceinschool.org/primary

Anna Gunnarsson works at NAVET Science Center in Borås, Sweden, as a teacher and project manager. She is responsible for the development of activities in chemistry for young children and other projects in science, mathematics and technology, nationally and internationally.

To learn how to use this code, see page 57.

Chemistry

Physics

Image courtesy of Akimbomitget/Wikimedia

Classroom fundamentals: measuring the Planck constant

Bring discovery into the classroom and show students how to evaluate Planck's constant using simple equipment.

By Maria Rute de Amorim e Sá Ferreira André and Paulo Sérgio de Brito André

When we think of the evaluation of fundamental physical constants, such as the speed of light or the force of gravity, we probably think of famous, large-scale experiments – but classroom equipment can also be used to calculate these unvarying values.

The Planck constant may seem a rather rarefied concept unlike, say, the speed of light, but it plays an absolutely central role in understanding the behaviour of matter at the subatomic level. It is a cornerstone of the theory of quantum mechanics, which describes the strange behaviour of particles at this level. Here energy, as well as matter, is made up of particles. Light and other electromagnetic radiation[w1], for example, consists of particles called photons.

Named after German physicist Max Karl Planck (1858–1947), the Planck constant tells us how the energy of individual photons relates to the wavelength of their radiation, as this key equation shows:

$$E_p = \frac{h c}{\lambda}$$

Where E_p is the energy of a single photon (in joules), h is the Planck constant, c is the speed of light in a vacuum, and λ is the radiation's wavelength.

Image courtesy of Public Domain Image/Wikimedia

Max Planck

Perhaps surprisingly, even though the value of the Planck constant is extraordinarily small, we have developed a method of determining this value in a classroom experiment. The activity needs no special equipment – just a few coloured light-emitting diodes (LEDs) and standard electrical apparatus. This activity is suitable for a wide range of students, from the age of about 16 up to postgraduate level.

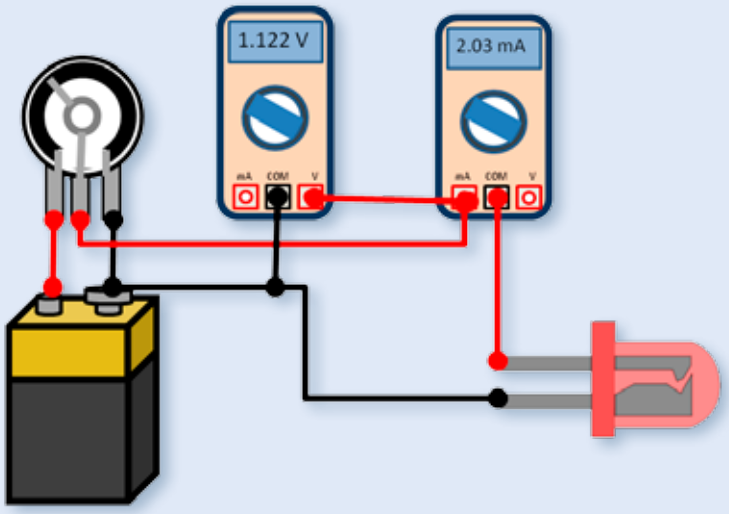


Image courtesy of the authors

Electric circuit for measuring the voltage-current response of each LED. From left to right: battery, potentiometer or rheostat, voltmeter, ammeter, LED.

How LEDs work

LEDs are produced by the junction of two 'doped' semiconductor materials, one of which has an excess of electrons (n-type) and the other a lack of electrons – also designated as holes (p-type). When an electrical current is injected through this so-called 'p-n' junction, the recombination of electrons and holes releases energy in the form of photons.

The colour of the light emitted from an LED is determined by the energy of the photons, which can be tailored by changing the chemical composition of the semiconductor materials. LEDs are most commonly made from alloys of gallium, arsenic and aluminium, and changing the proportion of these constituents can produce LEDs that emit light in specific colours – such as red and green in the visible region of the electromagnetic spectrum, or beyond into the ultraviolet and infrared regions.

As with any light, it is the wavelength that determines its colour. The human eye is sensitive to light with wavelengths from about 390 to 700 nanometres (0.00039–0.0007 mm). We see the shortest wavelengths as violet and the longest as red, and each wavelength in between corresponds to a particular colour in the spectrum. For example, green-emitting LEDs typically produce light with a wavelength of around 567 nanometres.

We use LEDs in this experiment because each colour of LED has a different threshold voltage at which electrons start being produced. Measuring this voltage, together with known values for the emission wavelengths, provides a path to finding a value for the Planck constant.

Materials

- Four LEDs emitting coloured light – one each of red, orange, green and blue. Choose LEDs with a clear, colourless casing surrounding the LED, so that the colour of the light comes from the device itself, not from the coloured casing.
- 9 V battery
- Two multimeters (one to be used as a voltmeter and the other as an ammeter).
- 1 kΩ potentiometer or rheostat.

Procedure

1. Set up the circuit as shown in the diagram below. Connect the ammeter in series with the LED to measure the current through it, and connect the voltmeter in parallel to the LED to measure the voltage across it. The applied voltage can be changed by using the potentiometer or rheostat.
2. Change the voltage in steps of 0.05 V from 0 V to 3 V, and meas-

Physics

REVIEW

Physics
Ages 16+

This article presents a simple, practical experiment that can be used to verify the value of the Planck constant, which is widely used in quantum physics. The set-up is easily reproducible in class, as the materials used are commonly found in physics labs. It can therefore be used either as a demonstration in class or as an investigation performed by students themselves.

The theory involved in this topic can initially appear to be abstract for students to understand, but such an experiment will help them to clarify some concepts and understand better the theories involved.

The article and the experiment demonstrates some very important concepts, such as:

- the photo-electric effect, where 'packets of energy' are absorbed by a material and consequently cause a diode to emit electromagnetic waves;
- the activation voltage in diodes;
- calculation of the Planck constant.

Catherine Cutajar, Malta

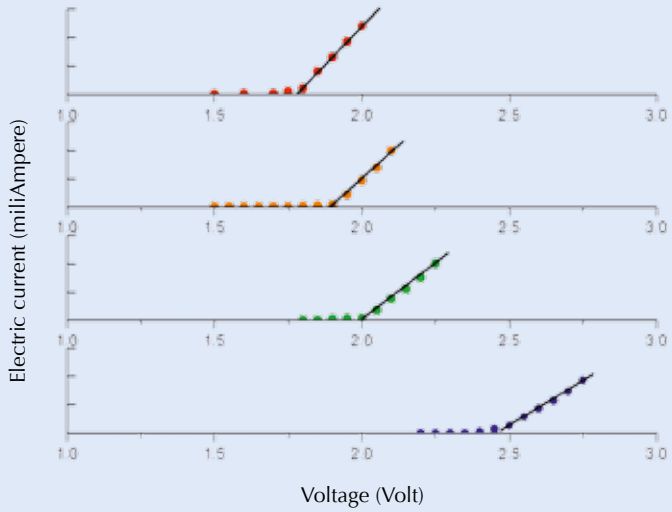


Image courtesy of the authors

Voltage-current response of LEDs emitting red, orange, green and blue light (from top to bottom).

ure the resulting electrical current. Note that when the current flowing through the LED is small, the LED might not light up, but the ammeter can still measure the current. To protect the LED, take care to keep the current below 5 mA.

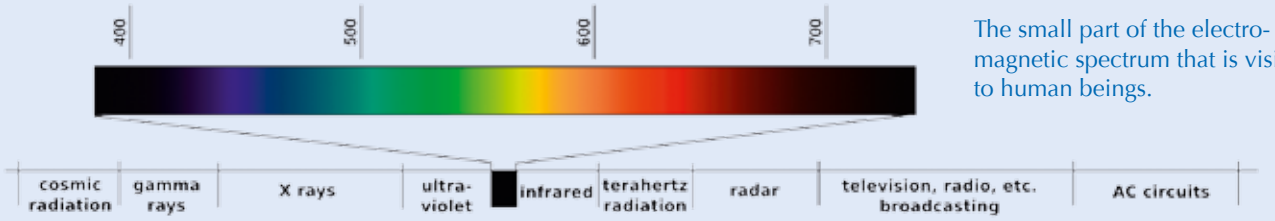
3. For each LED, plot a graph of current against voltage, similar to the graphs shown to the left. On each graph, find the straight line of 'best fit' to join up the points that slope up from the x-axis. If the points lie close to the line, this shows that a linear relationship holds between the applied voltage and the current in this region of the graph.
4. Finally, determine the activation voltage (V_a) from the collected data. This is the point at which the current begins to increase linearly with voltage. It can be read off the graph by extrapolating the straight line representing the linear response region backwards

LED colour	Typical wavelength, λ (nm)	Activation voltage (V)
Red	623	1.78
Orange	586	1.90
Green	567	2.00
Blue	467	2.45

Light painting, orb and domes on the bank of the Swan River, Perth, Western Australia.

Image courtesy of Changarra/ Wikimedia

Humanly visible spectrum
wavelength in nanometres



The small part of the electromagnetic spectrum that is visible to human beings.

Image courtesy of entirelysubjective/Flickr

The wavelength of light determines its colour. The human eye is sensitive to light with wavelengths from about 390 to 700 nanometres (0.00039–0.0007 mm). We see the shortest wavelengths as violet and the longest as red.

until it intercepts the *x*-axis. Students can do this visually using a ruler, or mathematically by applying linear regression to the experimental data points in the linear region[w2].

To obtain the most accurate values of V_a for each colour of LED, you can calculate an average value using the results obtained by several students.

Typical values for activation voltages obtained via this experiment are shown on the right, together with wavelength values for the light emitted by colour LEDs. You can provide students with these wavelength values for the next stage of the classroom activity. Alternatively, the wavelengths can be measured using a homemade spectrometer, such as the one described in the web resource below[w3].

Analysis and results

As we saw earlier, the energy of emitted photons, E_p (measured in joules), is related to the Planck constant (h), the speed of light in a vacuum (c), and the wavelength of the light (λ):

$$E_p = \frac{hc}{\lambda} \qquad (1)$$

In this experiment, we have a range of values for λ from the known wavelengths of the LED light colours, and we know the value for c (2.9979 x 10^8 m s^{-1}). But how do we use our experimentally obtained values of V_a to calculate the Planck constant? To find out, let's consider what is happening within the LEDs.

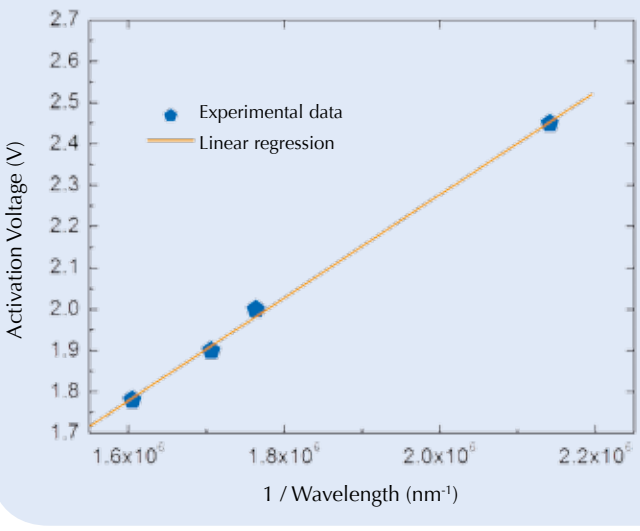
When the LEDs are operating at low voltage values, the energy input is not enough to produce photons and the electrical current is very small. At a certain voltage, the LED starts to emit photons: this is the activation voltage, V_a. This minimum voltage for each colour of LED correlates with the energy of the emitted photons, E_p (equation 2). And in fact, like E_p V_a is mathematically related to the Planck constant and the wavelength of the emitted light, as shown in the equation below:

$$V_a = \frac{E_p}{e} + \frac{\phi}{e} \qquad (2)$$

Where e is the charge on the electron

LED colour	Typical wavelength, λ (nm)	Activation voltage (V)	1/λ (m^{-1})
Red	623	1.78	1.60514 x 10^6
Orange	586	1.90	1.70648 x 10^6
Green	567	2.00	1.76367 x 10^6
Blue	467	2.45	2.14133 x 10^6

Typical values for the activation voltage, LED wavelengths and their reciprocals (1/λ)



Graph of the activation voltage, V_a, against the inverse of the wavelength for each LED. The Planck constant can be calculated from the gradient of the line.

Image courtesy of the authors

Physics

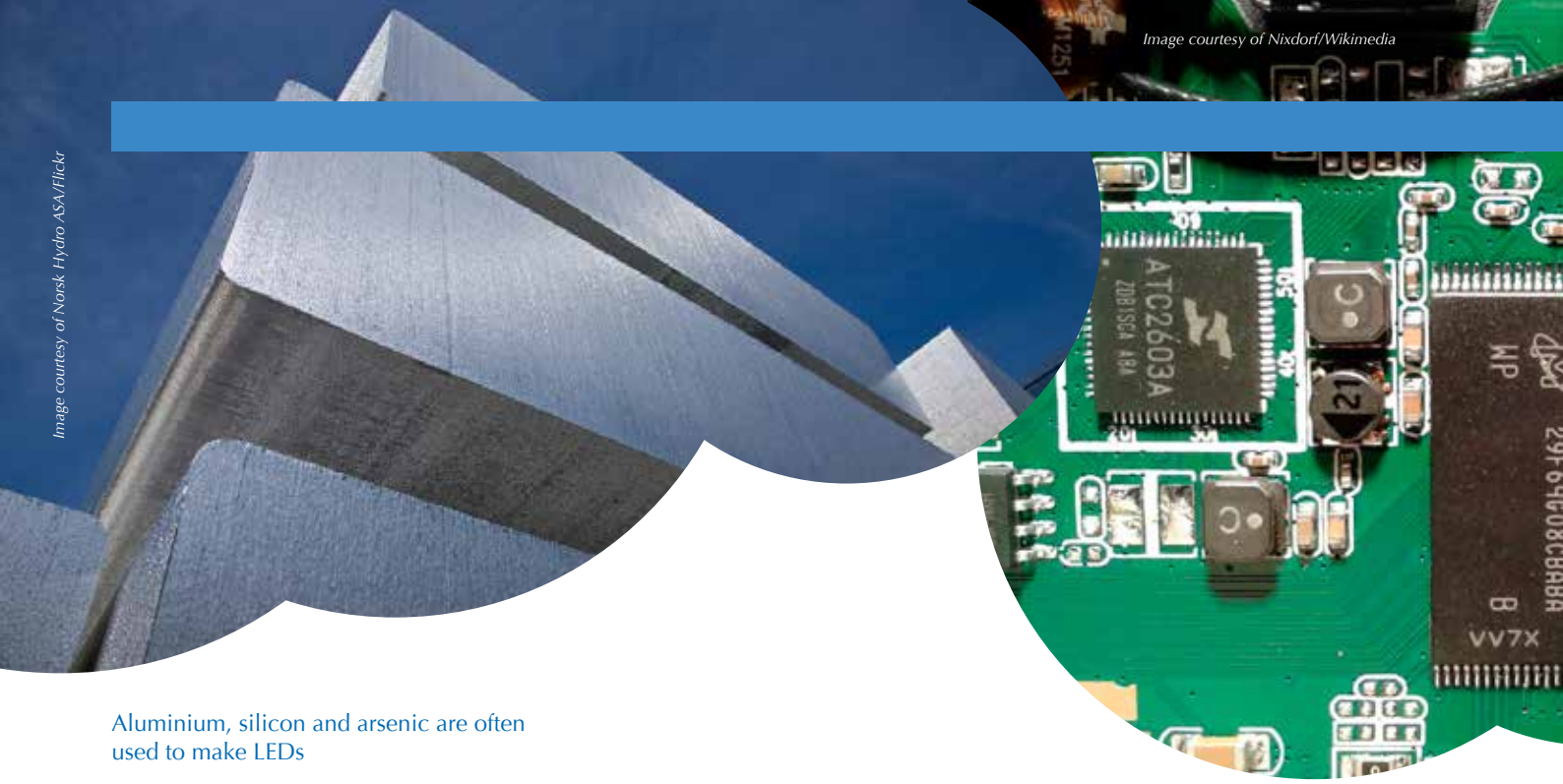


Image courtesy of Nixdorf/Wikimedia

Image courtesy of Norsk Hydro ASA/Flickr

Aluminium, silicon and arsenic are often used to make LEDs

(1.6022 × 10^{-19} coulombs).

For voltages higher than V_a the electrical current is determined by the LED's internal resistance. From Ohm's law, voltage = current x resistance, producing a linear relationship between the electrical current and the applied voltage, as seen in the voltage-current graphs above.

In equation 2, the term (ϕ/e) is a constant that relates to the energy losses inside the semiconductor's p-n junction. (For simplicity, we can assume this constant to be equal for all the LEDs.) Since ϕ is unknown, it is not possible from equation 2 to determine the Planck constant by measuring the activation voltage alone. However, if the activation voltage is measured for several LEDs emitting at different known wavelengths, then we can find a value for h by plotting a graph of V_a as a function of the reciprocal of the wavelength ($1/\lambda$).

This is because rearranging (2) gives this equation:

$$V_a = \frac{hc}{e}\frac{1}{\lambda} + \frac{\phi}{e} \qquad (3)$$

Thus, the graph of V_a against $1/\lambda$ will take the form of a straight line with a gradient of hc/e, from which the Planck constant can easily be calculated, given the known values of e and c. This gradient can be found graphically by plotting the graph and drawing a line of best fit to the data, or mathematically using a linear regression calculator[w2].

Linear regression gives the following value for the gradient (m):

m = 1.24811 × 10^{-6} Vm (volt metres)

From this, the Planck constant can finally be calculated. From above, $m = hc/e$, so:

$$h = \frac{e\,m}{c} \qquad (4)$$

$$= \frac{1.6022 \times 10^{-19} \times 1.24811 \times 10^{-6}}{2.9979 \times 10^{8}}$$

= 6.6704 × 10^{-34} Js (joule seconds)

This value compares well with the accepted value for the Planck constant of 6.62606957 × 10^{-34} Js – an error of just 0.7 per cent[w4]. The values your students obtain may be a little wider of the mark, but should still provide a satisfyingly good approximation to one of nature's fundamental constants.

Web references

w1 –To learn more about light and the electromagnetic spectrum, see: Mignone C.. Barnes R. (2011) More than meets the eye: the electromagnetic spectrum. *Science in School* **20**:51-59 www.scienceinschool.org/2011/issue20/em

w2 – Online linear regression calculators that can help analyse your data: www.alcula.com/calculators/statistics/linear-regression/www.wessa.net/slr.wasp

w3 – To learn how to build your own spectrometer, see: Tiele Westra M. (2007) A fresh look at light: build your own spectrometer. *Science in School* **4**:30-34 www.scienceinschool.org/2007/issue4/spectrometer

w4 – The National Institute of Standards and Technology (NIST) reference value for the Planck constant is available at: http://physics.nist.gov/cgi-bin/cuu/Value?h

Resources

The University of Nottingham's 'Sixty Symbols' project has produced a short video explaining the importance of Planck's constant, which you can find at www.sixtysymbols.com/videos/planck.htm

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

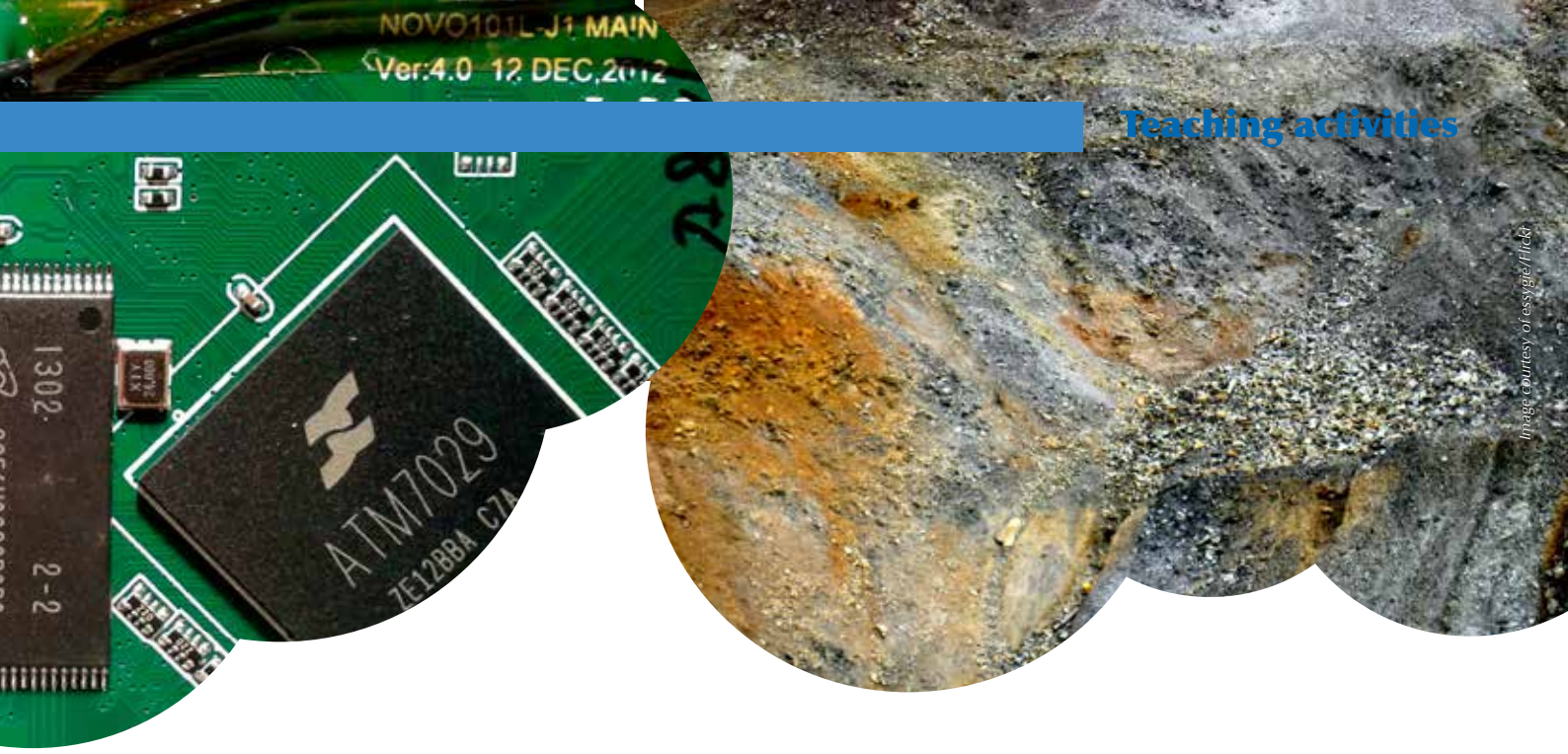


Image courtesy of essygirl/Flickr

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Paulo Sérgio de Brito André received his first degree in physics and engineering in 1996, and his PhD in physics in 2002, from the Universidade de Aveiro, Portugal.

He works at the University of Lisbon's Instituto Superior Técnico as an Associate Professor, lecturing on telecommunications. His current research interests include optoelectronic components, optical sensors, integrated optics and optical communications systems.

To learn how to use this code, see page 57.

Image courtesy of kaiyanwong223/Flickr

Food that shapes you: how diet can change your epigenome

You are what you eat – quite literally. Our diet can influence the tiny changes in our genome that underlie several diseases, including cancer and obesity.

By Cristina Florean

When you look at yourself in the mirror you may ask, 'How, given that all the cells in my body carry the same DNA, can my organs look so unlike and function so differently?' With the recent progress in epigenetics, we are beginning to understand. We now know that cells use their genetic material in different ways: genes are switched on and off, resulting in the astonishing level of differentiation within our bodies.

Image courtesy of Marcel Theisen / Wikimedia Commons

Fruit market in Spain

REVIEW

- **Biology**
- **Medicine**
- **Ages 14-18**

The article establishes a link between diet during pregnancy and changes in the expression of genes due to the mechanisms of histone acetylation (enhancing transcription) and methylation (reducing transcription). Using examples in humans, mice and honeybees, the article shows that the lack of certain nutrients can affect the development of traits in children. It also deals with dietary effects on epigenetics in adult life, listing a number of foods that are known to have a positive influence on health.

This article could be used as the basis for a discussion about healthy dietary choices compared with junk food, in order to increase students' awareness of the possible consequences of their eating behaviour.

The article could be used in a lesson reviewing some basic topics about gene expression.

Potential questions could include:

- What is the structure and function of histones?
- What are the main mechanisms of regulation of gene expression?
- How does genotype affect phenotype expression?
- How do environmental conditions (internal or external) influence gene expression?
- Diabetes is a good example of a disease that is linked to diet. Can you describe the causes of diabetes?

Monica Menesini, Liceo Scientifico Vallisneri Lucca, Italy

Image courtesy of McKay Savage / Wikimedia Commons

Green tea

Epigenetics describes the cellular processes that determine whether a certain gene will be transcribed and translated into its corresponding protein. The message can be conveyed through small and reversible chemical modifications to chromatin (figure 1). For example, the addition of acetyl groups (acetylation) to DNA scaffold proteins (histones) enhances transcription. In contrast, the addition of methyl groups (methylation) to some regulatory regions of the DNA itself reduces gene transcription. These modifications, together with other regulatory mechanisms, are particularly important during development – when the exact timing of gene activation is crucial to ensure accurate cellular differentiation – but continue to have an effect into adulthood.

Epigenetic modifications can occur in response to environmental stimuli, one of the most important of which is diet. The mechanisms by which diet affects epigenetics are not fully understood, but some clear examples are well known.

During the winter of 1944–1945, the Netherlands suffered a terrible famine as a result of the German

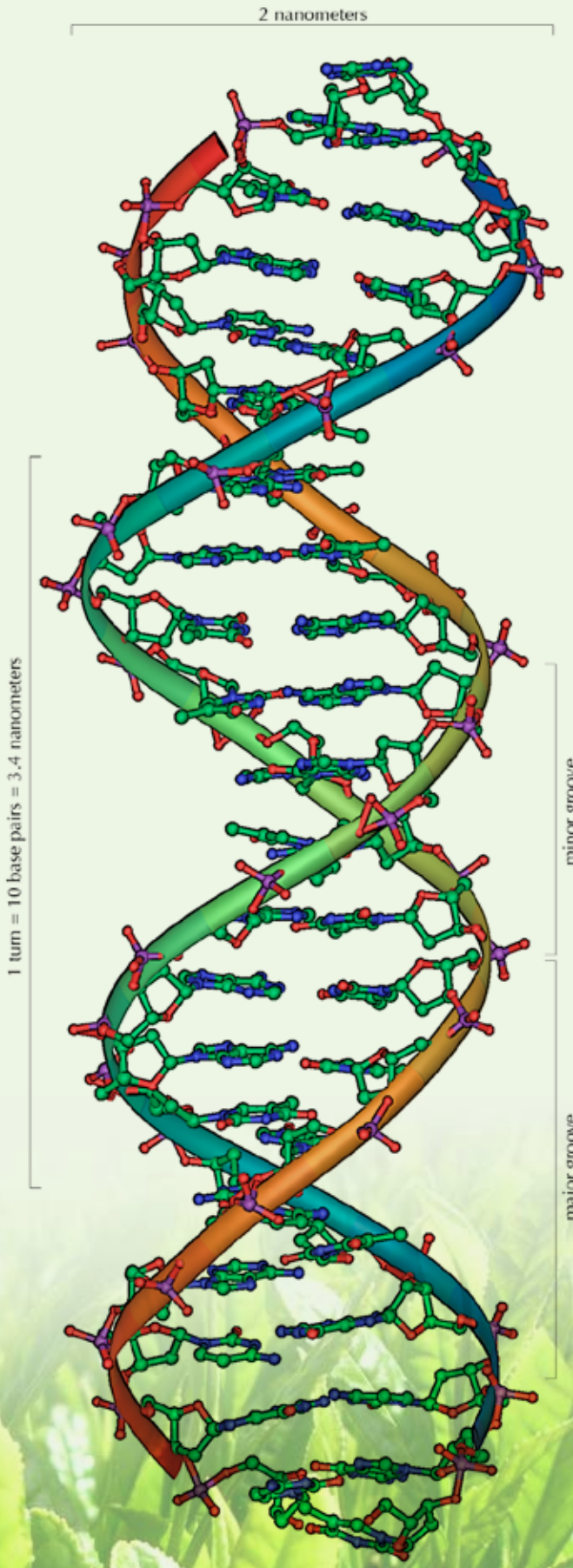


Image courtesy of mstroeck / Wikimedia Commons

Image courtesy of Ic.ta. / Wikimedia Commons

Green tea leaves from Japanese Yabukita tea plant.

Image courtesy of Cristina Florean

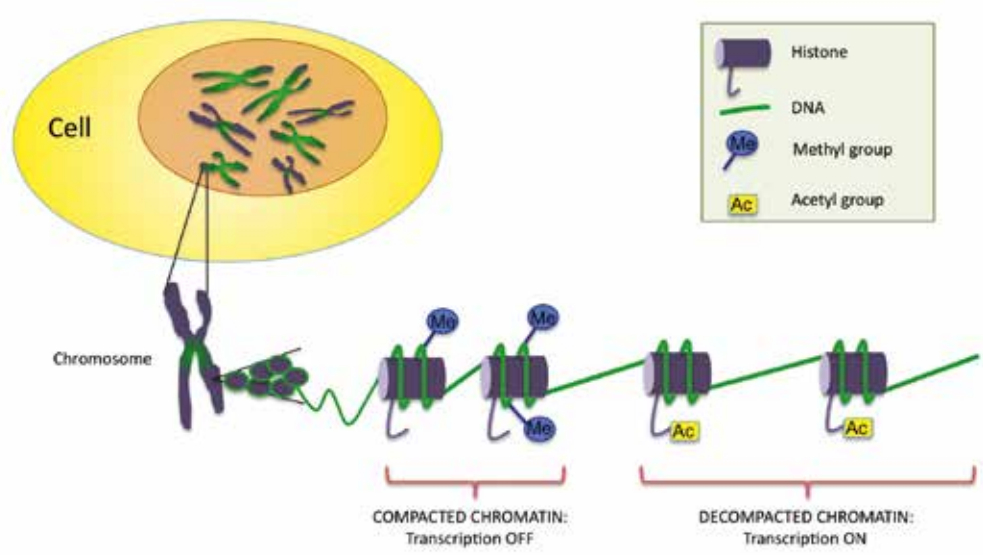


Figure 1: Epigenetic changes to the chromatin structure involve mainly histone acetylation – which enhances transcription – and DNA methylation, whereby methyl groups are covalently bound to cytosine, making the chromatin structure less accessible. These changes are reversible, allowing gene activity to be adapted to changing environmental conditions or signals.

occupation, and the population's nutritional intake dropped to fewer than 1000 calories per day. Women continued to conceive and give birth during these hard times, and these children are now adults in their sixties. Recent studies have revealed that these individuals – exposed to calorie restrictions while in their mother's uterus – have a higher rate of chronic conditions such as diabetes, cardiovascular disease and obesity than their siblings. The first months of pregnancy seem to have had the greatest effect on disease risk.

How can something that happened before you were even born influence your life as much as 60 years later? The answer appears to lie in the epigenetic adaptations made by the foetus in response to the limited supply of nutrients. The exact epigenetic alterations are still not clear, but it was discovered that people who were exposed to famine in utero have a lower degree of methylation of a gene implicated in insulin metabolism (the insulin-like growth factor II gene) than their unexposed siblings (Heijmans et al., 2008). This has some startling implications: although epigenetic changes are in theory reversible, useful changes that take place during embryonic development can nonetheless persist in adult life, even when they are no longer useful and could even be detrimental. Some of these changes may even persist through generations, affecting the grandchildren of the exposed women (Painter et al., 2008).

Image courtesy: Andy Olsen / NWHCM staff / Flickr

Many people in the world depend on international food aid to avoid famine and its many consequences on health and development, like here in Haiti.

The effects of early diet on epigenetics are also clearly visible among honeybees. What differentiates the sterile worker bees from the fertile queen is not genetics, but the diet that they follow as larvae (figure 2). Larvae designated to become queens are fed exclusively with royal jelly, a substance secreted by worker bees, which switches on the gene programme that results in the bee becoming fertile.

Another striking example of how nutrition influences epigenetics

Image courtesy of João Antonio Sarno Bonfim

Broccoli: a healthy diet during pregnancy can positively influence the health of the child after birth.

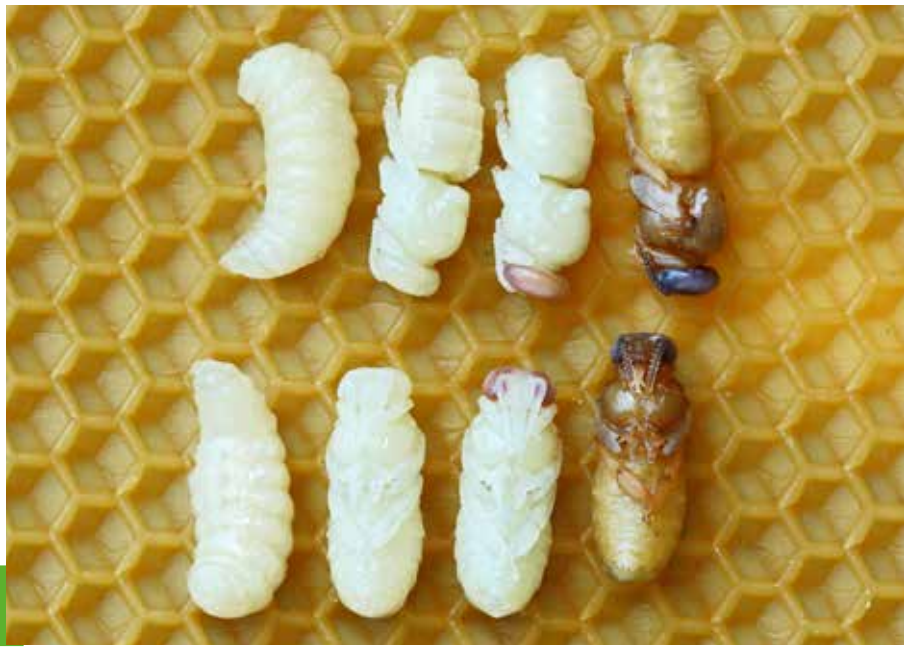
Image courtesy of W. Oelen / Wikimedia Commons

Folic acid

Image courtesy of Waugsberg / Wikimedia Commons

Figure 2: Two queen honeybee larvae floating in royal jelly in their queen cell. Queen larvae are fed exclusively with royal jelly, which triggers the development of the queen phenotype, allowing reproduction.

Image courtesy of Waugsberg / Wikimedia Commons



Larvae of honeybee workers at different stages of development

during development is found in mice. Individuals with an active agouti gene have a yellow coat and a propensity to become obese. This gene, however, can be switched off by DNA methylation. If a pregnant agouti mouse receives dietary supplements that can release methyl groups – such as folic acid or choline – the pups' agouti genes become methylated and thus inactive. These pups still carry the agouti gene but they lose the agouti phenotype: they have brown fur and no increased tendency towards obesity (figure 3). An insufficient uptake of folic acid is also implicated in developmental conditions in humans, such as spina bifida and other neural tube defects. To prevent such problems, folic acid supplements are widely recommended for pregnant women and for those hoping to conceive (see Hayes et al., 2009).

What about the dietary effect on epigenetics in adult life? Many components of food have the potential to cause epigenetic changes in humans. For example, broccoli and other cruciferous vegetables contain isothiocyanates, which are able to increase histone acetylation. Soya, on the other hand, is a source of the isoflavone genistein, which is thought to decrease DNA methylation in certain genes. Found in green tea, the polyphenol compound epigallocatechin-3-gallate has many biological activities, including the inhibition of DNA methylation. Curcumin, a compound found in turmeric (*Curcuma longa*), can have multiple effects on gene activation, because it inhibits DNA methylation but also modulates histone acetylation. Figure 4 shows further examples of epigenetically active molecules.

Image courtesy of Cristina Florean

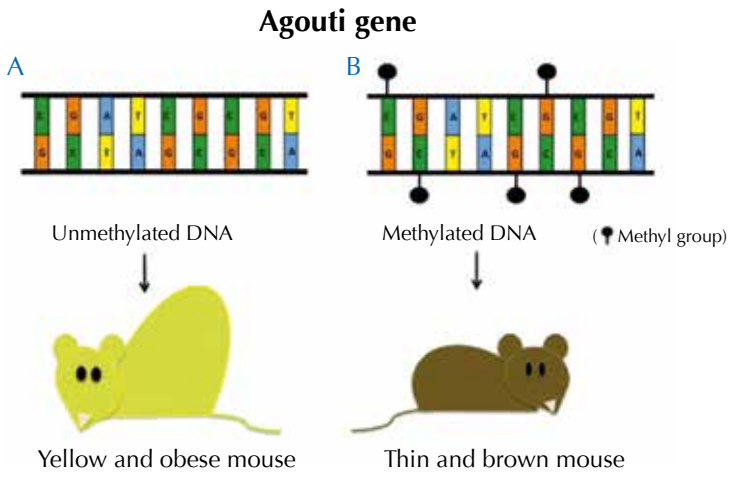


Figure 3: The agouti mouse model. The phenotype depends on the mother's diet during pregnancy. A: Normally, the agouti gene is associated with yellow fur and a tendency towards obesity. B: Mice born to a mother receiving dietary supplements of methyl donors, however, have a methylated and thus inactivated agouti gene, resulting in a thin, brown-fur phenotype.

Image courtesy of Cristina Florean, modified from Wikipedia Commons

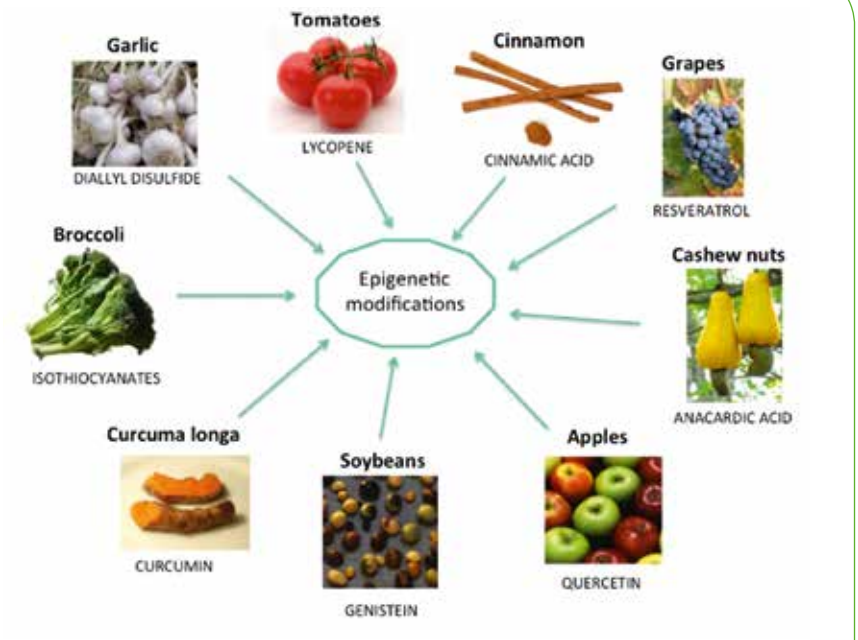


Figure 4: Some epigenetically active ingredients, each with an example of a dietary source.

Most of the data collected so far about these compounds come from in vitro experiments. The purified molecules were tested on cellular lines, and their effects on epigenetic targets were measured. It remains to be proved if eating the corresponding foods has the same detectable effect as has been seen in cellular models (Gerhauser, 2013).

Epidemiological studies, however, suggest that populations that consume large amounts of some of these foods appear to be less prone to certain diseases (Siddiqui et al., 2007). However, most of these compounds not only have epigenetic effects but also affect other biological functions. A food may contain many different biologically active molecules, making it difficult to draw a direct correlation between epigenetic activity and the overall effect on the body. Finally, all foods undergo many transformations in our digestive system, so it is not clear how much of the active compounds actually reach their molecular targets.

As a result of their far-reaching effects, epigenetic changes are involved in the development of many illnesses, including some cancers and neurological diseases. As cells become malignant, or cancerous, epigenetic modifications can deactivate *tumour suppressor genes*, which prevent excessive cell proliferation (Esteller, 2007). Because these epigenetic modifications are reversible, there is great interest in finding molecules – especially dietary sources – that might undo these damaging changes and prevent the development of the tumour.

We all know that a diet rich in fruit and vegetables is healthy for our everyday life, but it is becoming increasingly clear that it might be much more important than that, having significant implications for our long-term health and life expectancy.

Image courtesy of davitydave / Flickr

Purple Cauliflower

References

Esteller M (2007) Epigenetic gene silencing in cancer: the DNA hypermethylome. *Human Molecular Genetics* **16(1)**: R50-R59. doi:10.1093/hmg/ddm018

Gerhauser C (2013) Cancer chemoprevention and nutri-epigenetics: state of the art and future challenges. *Topics in Current Chemistry* **329**: 73-132. doi:10.1007/128_2012_360

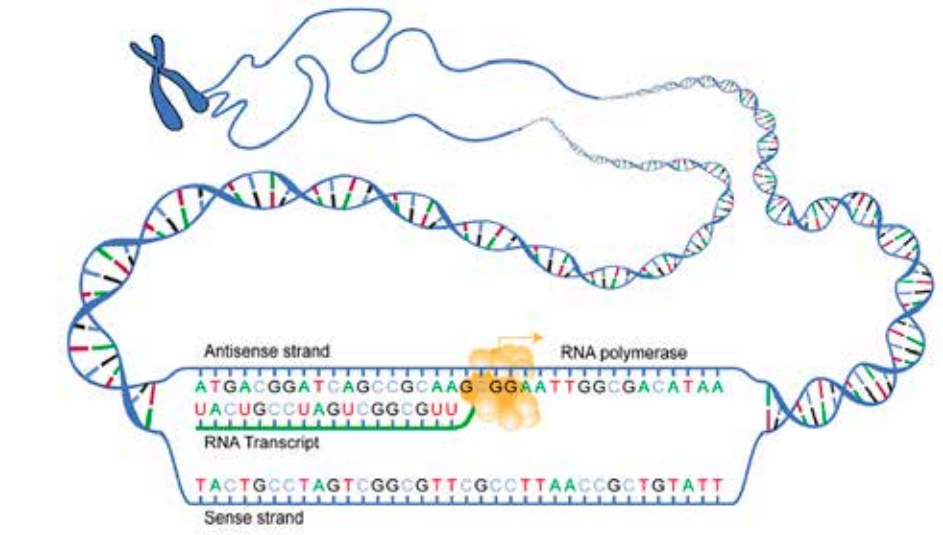
Hayes E, Maul H, Freerksen N (2009) Folic acid: why school students need to know about it. *Science in School* **13**: 59-64. www.scienceinschool.org/2009/issue13/folicacid

Heijmans BT et al. (2008) Persistent epigenetic differences associated with prenatal exposure to famine in humans. *Proceedings of the National Academy of Sciences of the USA* **105**: 17046-17049. doi:10.1073/pnas.0806560105

Painter R et al. (2008) Transgenerational effects of prenatal exposure to the Dutch famine on neonatal adiposity and health in later life. *BJOG: An International Journal of Obstetrics & Gynaecology* **115**: 1243-1249. doi:10.1111/j.1471-0528.2008.01822.x

Siddiqui IA et al. (2007) Tea beverage in chemoprevention and chemotherapy of prostate cancer. *Acta Pharmacol Sinica* **28(9)**: 1392-1408. doi:10.1111/j.1745-7254.2007.00693.x

Image courtesy of public domain image / Wikipedia Commons



DNA Transcription

Resources

For a simple introduction to epigenetics, see:

McVittie B (2006) Epigentics. *Science in School* **2**: 62-64. www.scienceinschool.org/2006/issue2/epigenetics

To learn more about nutrition and epigenetics, see:

Link A et al. (2010) Cancer chemoprevention by dietary polyphenols: Promising role for epigenetics. *Biochemical Pharmacology* **80(12)**: 1771-1792. doi:10.1016/j.bcp.2010.06.036

The Learn Genetics website: http://learn.genetics.utah.edu/content/epigenetics/nutrition

For more information about the effect of the Dutch famine on adult life and gene methylation, see:

Roseboom TJ et al. (2001) Effects of prenatal exposure to the Dutch famine on adult disease in later life: an overview. *Molecular and Cellular Endocrinology* **185**: 93-8. doi:10.1016/S0303-7207(01)00721-3

The website of the University of Leiden: www.news.leiden.edu/news/dutch-hunger-winter.html

The website of the Dutch Famine Study: www.hongerwinter.nl/item.php?id=32&language=EN

Image courtesy of smith_cl9 / Flickr

We know a healthy diet should have lots of vegetables but we are only just realising how important vegetables are for our well being

For a fascinating and very readable explanation of some recent research into honeybee epigenetics, see:

Chittka A, Chittka L (2010) Epigenetics of royalty. *PLOS Biology* **8(11)**: e1000532. doi:10.1371/journal.pbio.1000532

PLOS Biology is an open-access journal, so this article is freely available online.

For more information about honeybee epigenetics: www.nature.com/scitable/spotlight/epigenetics-26097411

For a simple overview of epigenetics and the agouti gene in mice, see:

Adams J (2008) Obesity, epigenetics, and gene regulation. *Nature Education* **1(1)**. www.nature.com/scitable

To learn how hormone levels during pregnancy can affect the sex of the child, see:

Notman (2012) Intersex: falling outside the norm. *Science in School* **23**: 48-52. www.scienceinschool.org/2012/issue23/intersex

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Cristina Florean received her PhD in biomedical sciences from the universities of Padua and Bordeaux. During her doctorate studies she worked on Alzheimer's disease and drug screening optimisation. She spent one year at the University of Udine working on cancer and epigenetic enzymes, and now works in Luxembourg at the Laboratory of Molecular and Cellular Biology of Cancer *(Laboratoire de Biologie Moleculaire et Cellulaire du Cancer)* as a post-doctoral fellow. Her current research interests are natural compounds displaying epigenetic activity as anti-cancer drug candidates and epige netic events linked to carcinogenesis.

To learn how to use this code, see page 57.

Inspired by nature: modern drugs

Many naturally occurring compounds are useful in medicine – but they can be fabulously expensive to obtain from their natural sources. New scientific methods of synthesis and production are overcoming this problem.

By David Sucunza

The first patient ever treated with penicillin died one month later. The few grams of this antibiotic that were available at the beginning of 1941 were not sufficient to save the life of Albert Alexander, an English police officer who had been unlucky enough to get a bad infection from a scratch on his face. Although Alexander's urine was processed to recover some of the used penicillin, this still did not produce enough. After a few hopeful days, Dr Howard Florey and his team were forced to admit an irrefutable fact: drugs are not truly useful unless there is an adequate supply.

Fortunately, the immense amount of scientific research carried out during the Second World War quickly remedied this situation and

Image courtesy of Nobel Foundation / Wikimedia Commons

Sir Howard Walter Florey (24 September 1898 – 21 February 1968) was an Australian pharmacologist and pathologist who shared the Nobel Prize in Physiology or Medicine in 1945 with Sir Ernst Boris Chain and Sir Alexander Fleming for his role in the making of penicillin.

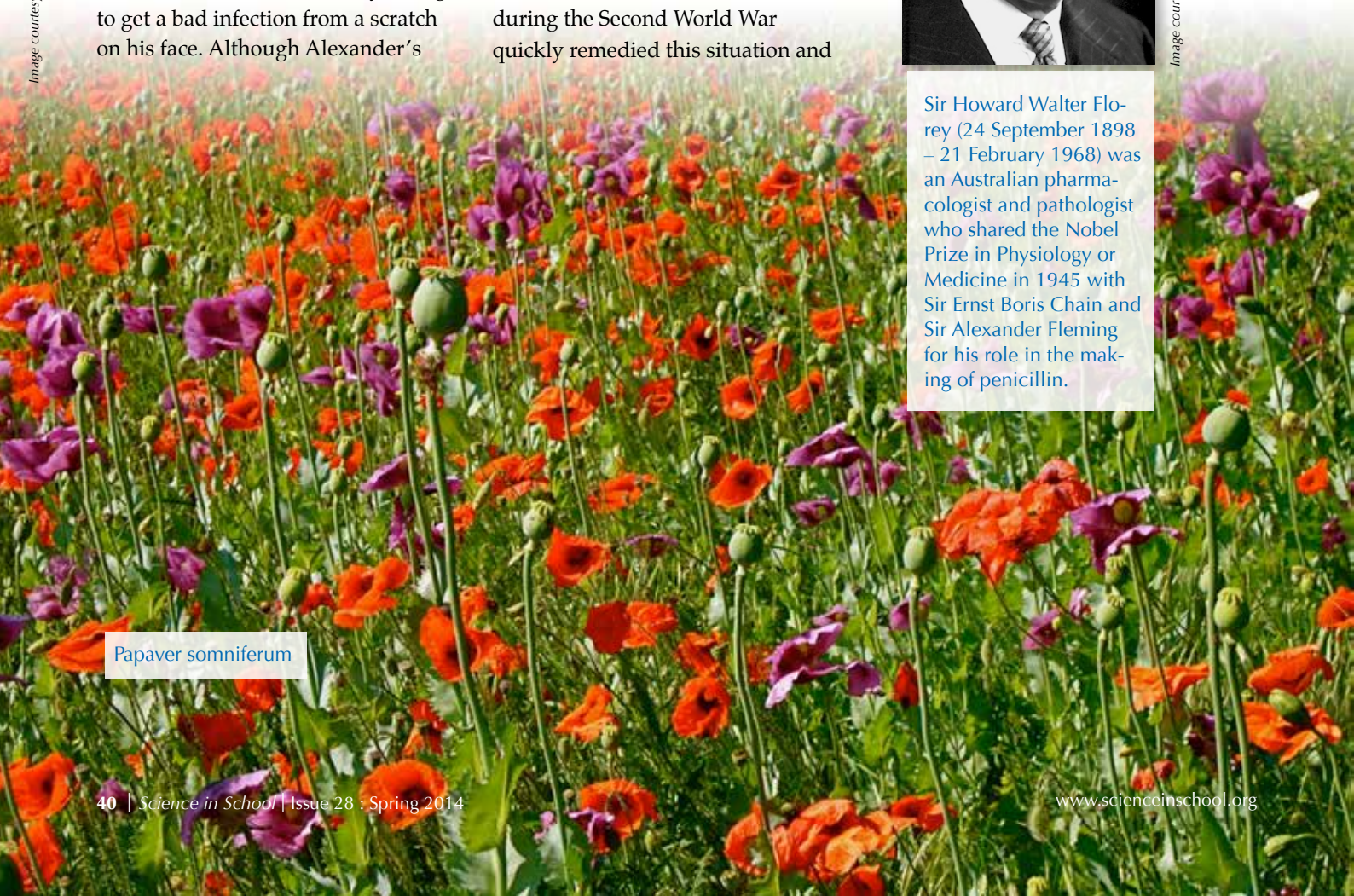


Image courtesy of Nuuuuuuuuuul / Flickr

Papaver somniferum

REVIEW

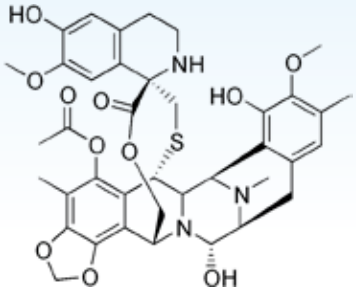
- Chemistry
- Biology
- Organic chemistry
- Ecology
- Conservation
- Ages 15+

The article could be used in chemistry or biology lessons, particularly when teaching organic chemistry, ecology or conservation. For example, it could be used as the basis of a discussion about why natural products have been and still are so important for human health, and whether drugs developed in laboratories are always better than the remedies used by our ancestors. It could also be used as a starting point for a discussion about how chemistry, although often seen as an environmental threat, can in fact help to protect the environment.

Suitable comprehension questions include:

- How have natural products helped to preserve human health in the past?
- How are natural products helping to preserve human health today?
- How can chemistry help to protect endangered species?
- Why is it not possible to obtain all natural products we need from their natural sources?

Mireia Güell Serra, Spain



Chemical structure of trabectedin

Image courtesy of Edgar181 / Wikimedia Commons

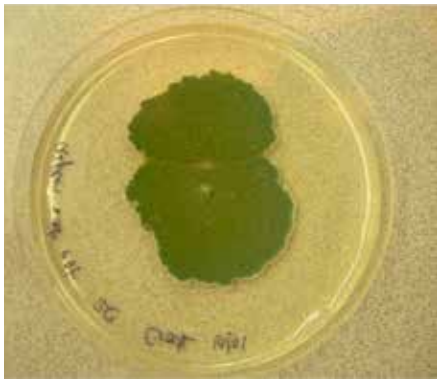


Image courtesy of Ninjatacoshell / Wikimedia Commons

Penicillium growing on a potato dextrose agar plate.

by 1943, an efficient method had been developed for cultivating large quantities of the *Penicillium* fungus and extracting the precious penicillin.

Drug development doesn't always work like this, however. There are many potentially useful natural products that, even today, can be obtained only in minimal amounts from their natural sources. Plants, fungi and sessile marine organisms are particularly promising sources: unable to flee their predators, many of them specialise in chemical defence and this can be exploited to our advantage. One example is bryostatin, which is produced by *Bugula neritina*, a species of tiny marine invertebrates called bryozoans. Bryostatin could prove to be an effective treatment for oesophageal cancer – if it weren't for the fact that it requires several tonnes of the animal to produce a few grams of the pure substance.

Natural compounds and modern medicines

People have used natural products medicinally since ancient times, and some four-fifths of the current world population still do so today. Although these products are traditionally used in the form of medicinal plants or fungi, improved versions of these drugs have more recently become available by isolating the active elements from the plant or fungal source. Since the first natural product (morphine from the opium poppy, *Papaver somniferum*) was isolated in 1804, the use of pure compounds rather than crude plant or fungal preparations soon spread throughout the Western world.

In fact, the application of scientific knowledge and methods has dramatically increased the number of drugs of natural origin that are now at our disposal. By 1990, about 80% of drugs approved in the USA were either natural products or inspired by them (see Li & Vederas, 2009). There are hundreds of examples: antibiotics such as penicillin or erythromycin, anti-tumour drugs such as trabectedin and vinblastine, immunosuppressants such as cyclosporine and rapamycin that facilitate organ transplants, analgesics such as morphine and codeine, and antimalarials such as quinine and artemisinin. These new drugs have become available via two main routes: clinical trials that have proved the effectiveness of some traditional remedies (for example, see Watt & Hayes, 2013); and the discovery of previously unknown, medicinally useful natural substances. Taken together, they have contributed to the success of modern medicine in extending our life expectancy from about 50 years at the beginning of the 20th century to the almost 80 years that it is today.

Among all the sciences, chemistry stands out as having contributed perhaps most to this achievement. Chemical synthesis has made it possible to provide many drugs of natural origin in the dosage required for therapeutic

Image courtesy of Frank Vincentz / Wikimedia Commons

Taxus baccata

Opium poppy (*Papaver somniferum*)

Image courtesy of Chixoy / Wikimedia Commons

Image courtesy of Chixoy / Wikimedia Commons

Flower of *Papaver somniferum*

use, despite the often very limited supply from their original sources. This is the case with galantamine, a compound produced by a rare flower from the Caucasus mountains that is proving to be one of the few substances capable of slowing the symptoms of Alzheimer's disease. Despite its complex structure, this natural product is now produced commercially by synthesis from simple chemicals – a method that is much more affordable than its extraction from the *Galanthus caucasicus* flower itself.

In addition, semi-synthetic processes – in which extracts from natural sources and chemical synthesis are combined – are now very common in the development of new drugs. One example of this is Taxol, used to treat patients with ovarian, breast and lung cancers or with advanced forms of Kaposi's sarcoma. Originally isolated from the bark of the Pacific yew tree (*Taxus brevifolia*), clinical use of this source alone would have led to the tree's extinction. As part of semi-synthetic drug development, natural products are categorised into families on the basis of their chemical structure, with members of the same family often sharing many similarities. This process revealed that the compound from the Pacific yew shared a similar structure with a much more accessible initial substance: 10-deacetylbaccatin III, found in the leaves of the European yew (*Taxus baccata*). A pathway to convert 10-deacetylbaccatin III to Taxol via just three simple chemical reactions was developed, providing an affordable and environmentally sustainable source of the drug (see box on page 43)[w1].

Taking this a step further, we now often use natural products as molecular models for potential new drugs, rather than as the actual source or compound to be synthesised. In this strategy, a variety of synthetic compounds, or analogues, are produced with chemical structures that are similar to the original compound but easier to synthesise. The efficacy of each is then investigated, to identify compounds that are sufficiently simple to synthesise on an industrial level, and which also preserve the medicinal properties of the natural substance (see box on page 44). This is being done in the case of bryostatin, and it is very probable that one of these analogues will form the biologically active part of a drug in the near future.

3D representation of the atomic structure of *Penicillin g.*

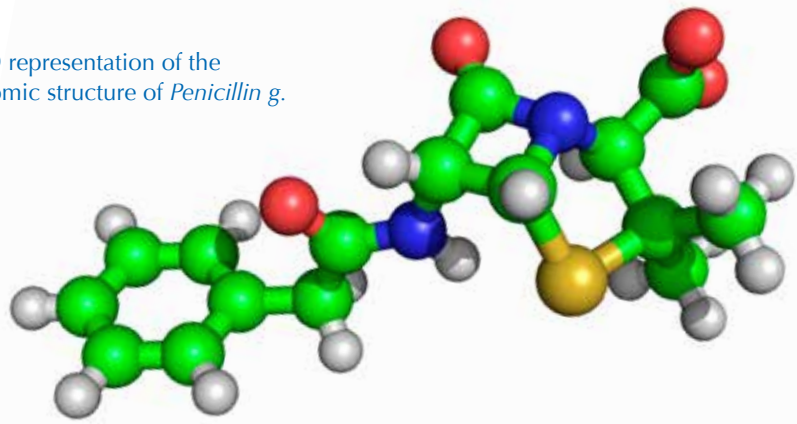
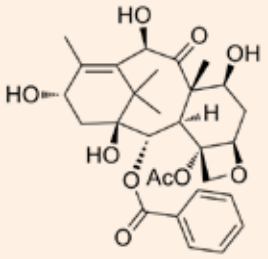


Image courtesy of Bassophile / Wikimedia Commons

BACKGROUND

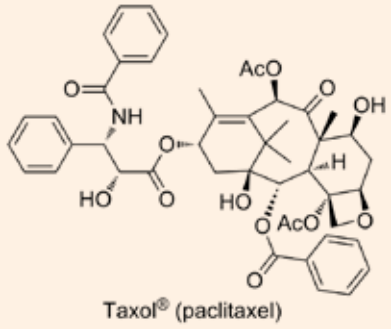
The semi-synthetic synthesis of Taxol

The extraction of Taxol (paclitaxel, figure 1) from the bark of the Pacific yew yields small amounts of the compound: 2000-2500 trees need to be felled to extract 1 kg of Taxol. The semi-synthetic synthesis of Taxol from 10-deacetylbaccatin III (figure 2), a related compound found in the foliage of the European yew, involves three simple chemical reactions (figure 3). Although 3000 kg of leaves from European yew are needed to obtain 1 kg of 10-deacetylbaccatin III, harvesting the leaves does not kill the trees[w1].



10-deacetylbaccatin III

Figure 2: The chemical structure of 10-deacetylbaccatin III. Note the similarity to the structure of Taxol.



Taxol® (paclitaxel)

Figure 1: The chemical structure of Taxol

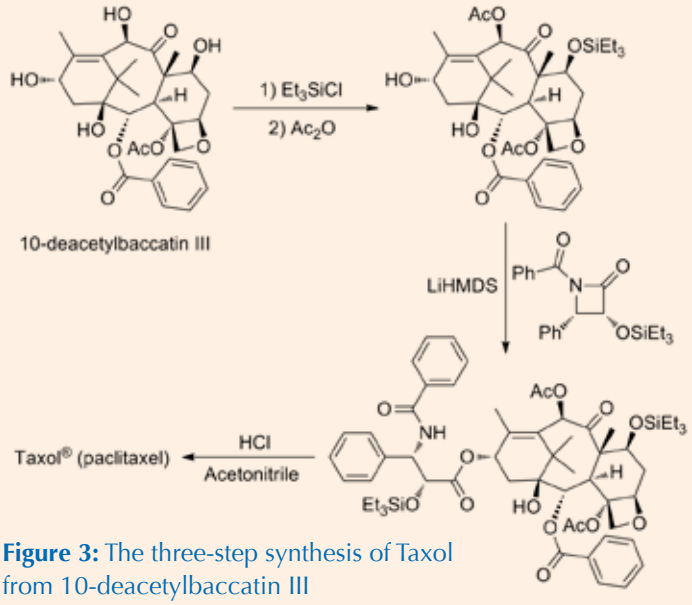


Figure 3: The three-step synthesis of Taxol from 10-deacetylbaccatin III

Images courtesy of David Sucunza

Bioreactors and beyond

Although chemical synthesis methods are often commercially competitive, another even more recent technique is gaining momentum: the artificial cultivation of cells from the natural product source. Growing cells in bioreactors to produce useful substances is now a widespread practice, and designing genetically modified organisms expressly for this purpose is swiftly becoming a more common reality (see box on page 44).

The science of natural medicines continues to evolve. In the search for possible drugs, there are still thousands of plants, marine animals and micro-organisms left to study. This search continues alongside the hunt for new ways of obtaining useful products on a larger scale. After two centuries of intense scientific development, nature is no longer our limit, although it does continue to be our main source of inspiration.

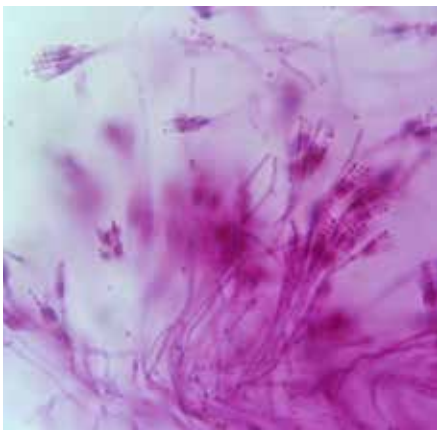


Image courtesy of Peter Halasz / Wikimedia Commons

Penicillium sp. (stained, under the microscope)

References

Li JWH, Vederas JC (2009) Drug discovery and natural products: end of an era or an endless fron-

BACKGROUND

Bioreactor synthesis to combat malaria

Malaria remains a major global health problem, killing more than half a million people each year. Currently, the most effective treatment is the natural product artemisinin, in combination with another drug (artemisinin combination treatments or ACTs). Artemisinin is produced by sweet wormwood (*Artemisia annua*) but this plant contains only a tiny fraction of artemisinin (between 0.001% and 0.8%). Supplies from sweet wormwood farms are limited, so ACTs cost US$1-2 per treatment course: too expensive for many patients in malaria-ridden countries.

In 2008, the pharmaceutical company Sanofi licensed a genetically modified yeast (*Saccharomyces cerevisiae*) to mass-produce artemisinic acid, a precursor of artemisinin, in bioreactors[w3, w4]. By 2012, using this method (figure 4), the company has already produced almost 39 tonnes of artemisinic acid, the first industrial-scale deployment of synthetic biology for drug production. The stock could be converted to at least 40 million treatments. Although these treatments are not yet cheaper than the standard ACTs, researchers hope to make the fermentation process more efficient – and less expensive – in the near future.

However, ACT resistance has already been detected in South-East Asia[w5]. As the antimalarial activity of artemisinin comes from its endoperoxide bridge (figure 5), several synthetic analogues based upon the 1,2,4-trioxolane pharmacophore, such as OZ439, are being studied as clinical development candidates.

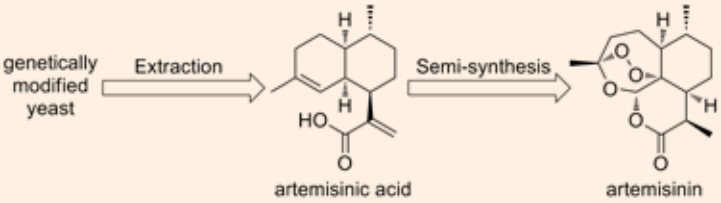


Figure 4: The extraction and semi-synthetic synthesis of artemisinin from genetically modified yeast

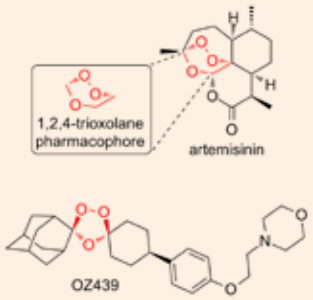


Figure 5: The structure of artemisinin and its synthetic analogue OZ439

Images courtesy of David Sucunza

tier? *Science* **325(5937)**: 161-165. doi: 10.1126/science.1168243

Watt S, Hayes E (2013) Monastic medicine: medieval herbalism meets modern science. *Science in School* **27**: 38-44 - www.scienceinschool.org/2013/issue27/monastic

Web references

w1 – *Research in Review*, published by Florida State University, tells the story of Taxol. See: www.rinr.fsu.edu/fall2002/taxol.html

w2 – The USA's National Library of Medicine's Drug Information Portal provides comprehensive details of Taxol (search for 'paclitaxel'). See: http://druginfo.nlm.nih.gov/drugportal

w3 – *Science Now* describes the synthesis of artemisinin (*Malaria drugmakers see the light*). Search http://news.sciencemag.org/sciencenow or use the direct link: http://tinyurl.com/ppy7ek4

w4 – The website of Path, an international non-profit organisation focusing on global health, describes the organisation's involvement in the development of semi-synthetic artemisinin. See: www.path.org/projects/artemisinin.php

w5 – Nature Education's Scitable website details the problems of ACT resistance (Artemisia annua*: a vital partner in the global fight against malaria*). Search www.nature.com/scitable or use the direct link: http://tinyurl.com/pp9ajw8

Resources

The Plant Cultures website provides easy-to-read information about the roles that plants play in people's

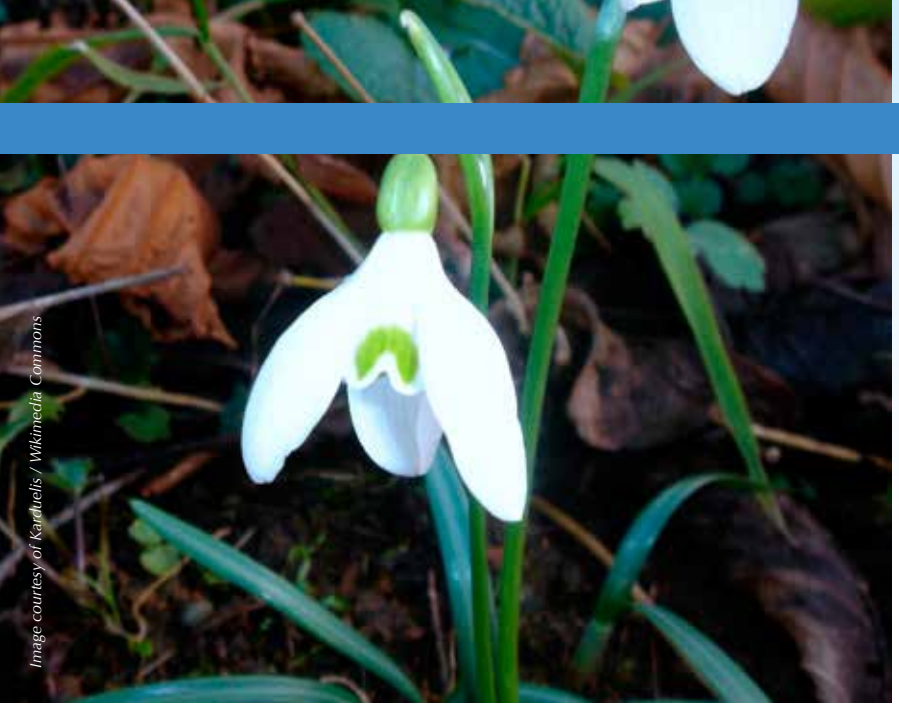


Image courtesy of Kanthuelis / Wikimedia Commons

Galanthus caucasicus – Galantamine is obtained synthetically or from its bulbs and flowers

Image courtesy of Walter Siegmund / Wikimedia Commons

Pacific Yew foliage

Image courtesy of Chixoy / Wikimedia Commons

Artemisia annua

lives all over the world. See: www.kew.org/plant-cultures

The Xplore Health website offers educational resources to teach about drug development. See: www.xplorehealth.eu/en/educators/how-are-drugs-developed

Based on one of the Xplore Health activities, one *Science in School* article explores the genetics of obesity:

McLusky S, Malagrida R, Valverde L (2013) The genetics of obesity: a lab activity. *Science in School* **26**: 25-30. www.scienceinschool.org/2013/issue26/obesity

Nicolaou KC, Montagnon T (2008) *Molecules that Changed the World*. Wiley-VCH: Weinheim, Germany

Raviña Rubira E (2011) *The Evolution of Drug Discovery: From Traditional Medicines to Modern Drugs*. Wiley-VCH: Weinheim, Germany

This book is freely available via Google Books. See: books.google.com

Le Couteur P, Burreson J (2003) *Napoleon's Buttons: How 17 Molecules Changed History*. Jeremy P. Tarcher/Putnam: New York, NY, USA

This book can be freely downloaded from Scribd. See: www.scribd.com/doc/65240357/Napoleon-s-Buttons

A summarised version is available on the Napoleon's Buttons website: http://napoleonsbuttons.blogspot.com.es

Stuart DC (2004) *Dangerous Garden: The Quest for Plants to Change Our Lives*. Harvard University Press: Cambridge, MA, USA

If you found this article useful, you may like to explore the other science topics published in *Science in School*. See: www.scienceinschool.org/sciencetopics

David Sucunza received his PhD in organic chemistry from the University of La Rioja, Spain, in 2003. He focused on the field of natural product synthesis during his postdoctoral research at the universities of Cologne, Germany, and Manchester, UK. He also has experience in science communication, and has collaborated with different media. Since 2010, he has worked as an assistant professor at the University of Alcala in Madrid, Spain.

Making the right moves

Cell's movements are important in health and diseases, but their speed is the crucial point for the 2013 World Cell Race organised by Daniel Irimia

By Sarah McLusky

It might not be the most exciting spectator sport, but the World Cell Race is the equivalent of the Olympics for biologists. This year's race was won by a breast cancer cell line that reached top speeds of 50 μm. h^{-1}. It might sound frivolous, but understanding cell motility, or the ability of cells to move, is important for both health and disease. Cell motility is a factor in cancer, immune response, wound healing and embryo development, as well as other biological functions. However, scientists still don't fully understand the process and there are no drugs that can specifically speed up or slow down cell movement.

Cells need to move for various reasons – to find food, intercept threats, escape an unsuitable environment or colonise a new one. Some cells, including sperm cells and many bacteria, can swim rapidly using tail-like flagellae.

Other cells, like the ones included in the cell race, move in a much less dramatic way by creating membrane protrusions (called pseudopodia), a bit like reaching fingers, which attach themselves to a surface and then pull the rest of the cell along behind them (see figure 1). A cell moving this way can typically cover 1-2 times its own length per hour. To put this into context, a snail moves at around 20 body lengths per hour; in his record-breaking sprint at the 2012 Olympic Games, Usain Bolt ran at the equivalent of 18 000 body lengths per hour.

This movement might not be fast, but it is incredibly important. For example, during embryo development, precisely orchestrated cell movements allow the formation of the distinct layers of tissue that will ultimately grow into the mature organs, systems and body parts. Incorrect cell migration during embryo development can lead to a range of disabilities and birth defects, including spina bifida. Elsewhere in the body, wounds heal as specialised stem cells move into the injury site to regenerate blood vessels, knit the tissues together and build new skin.

In sickness and in health

It is no surprise that a breast cancer cell triumphed in this race. Cancer cells are among the fastest mov-

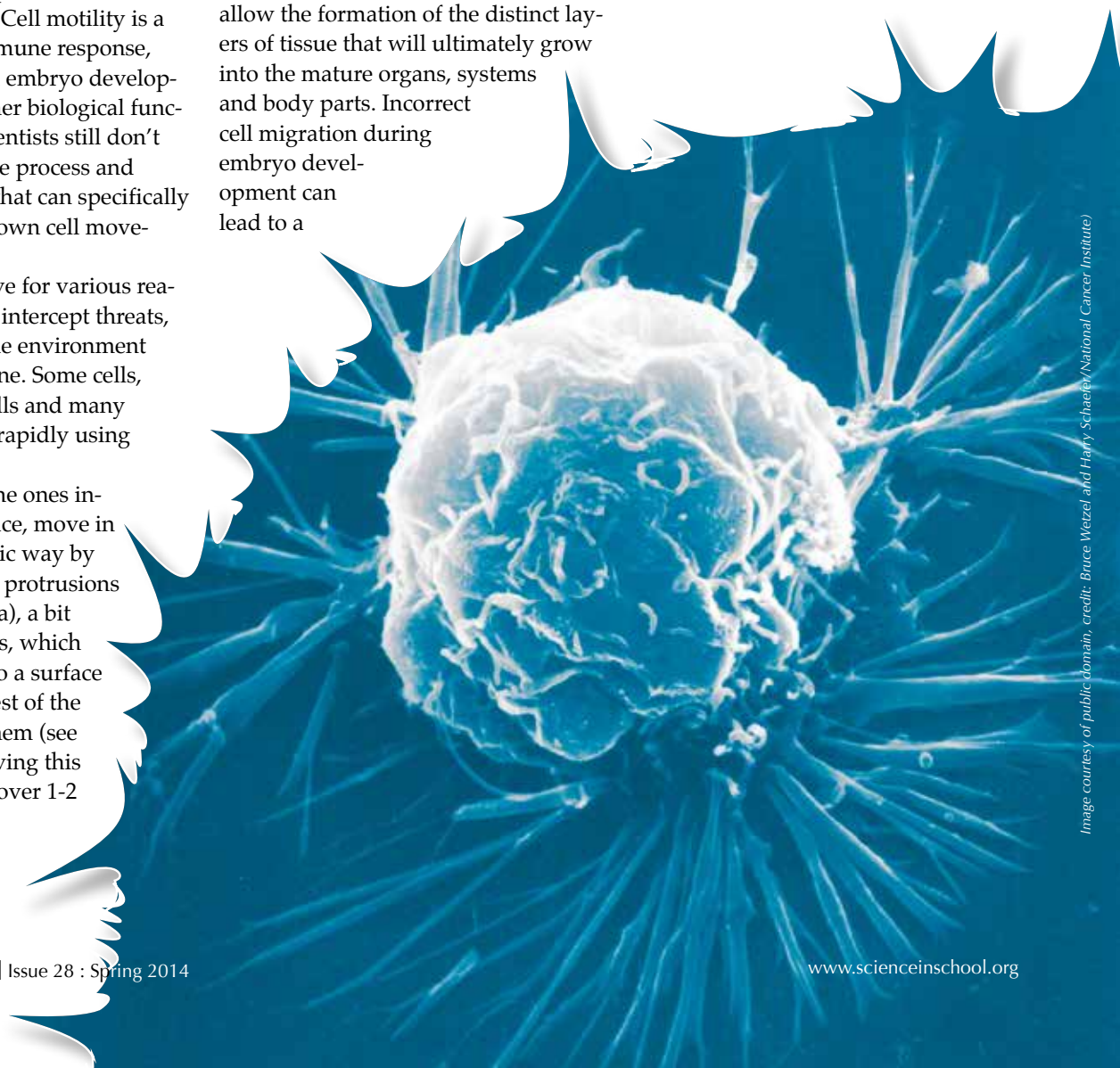


Image courtesy of public domain, credit: Bruce Wetzel and Harry Schaefer/National Cancer Institute)

Breast cancer cell

- Biology
- Physics
- Ages 15-19

This enjoyable article addresses a basic topic of animal cells: motility. Although it is widely known that animal cells can move, the deep understanding of cell motility "is really important for both health and disease", as the authors claim. Here, we have a valuable resource to learn more about motility from a fun and inspiring approach. The idea of a World Cell Race could shock us for a moment, but immediately we take in its importance and significance. The subject of this article is related to other important biological topics such as immunology, embryo development and cancer.

The article could also be useful for raising discussions about the daily work of scientists, sharing of knowledge among laboratories, and the new technologies that allow the speeds of different cell lines to be measured and compared.

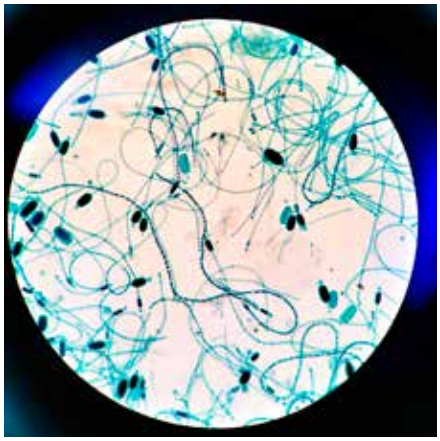
Suitable comprehension questions could include:

1) What is the importance of the study of cell motility?
2) What is the relationship between cell motility and cell migration?
3) What is the aim of the World Cell Race?
4) Why does the shape of the race track change from one year to another in the World Cell Race?
5) Give some examples of cells in which it would benefit researchers to stop motility or to encourage motility.
6) Some cells make self-guided movements and don't seem to need any stimuli to move. What kinds of cells are they? Why are they considered to pose a problem?
7) Using the race track, how would you prove the effect of a drug on cell motility?

Ana Molina, IES Gil y Carrasco, Spain

REVIEW

Image in the public domain. Source: Wikimedia



Cylindrospermum is a genus of filamentous cyanobacteria found in terrestrial and aquatic environments.

Biology

Physics

ing mammalian cells. Cancer has a tendency to spread from the initial tumour site and begin growing in other parts of the body in a process called metastasis. Whereas other motile cells move towards or away from stimuli (such as nutrients or light), cancer cells make self-guided movements to escape small spaces and don't seem to know when to stop. It could take as little as one month for a cancer cell to move 10 cm from a primary tumour in the breast to lodge in a nearby lymph node. Cancer that has spread is much harder to treat and often proves fatal, so understanding and ultimately finding ways to stop the movement of cancer cells could save lives.

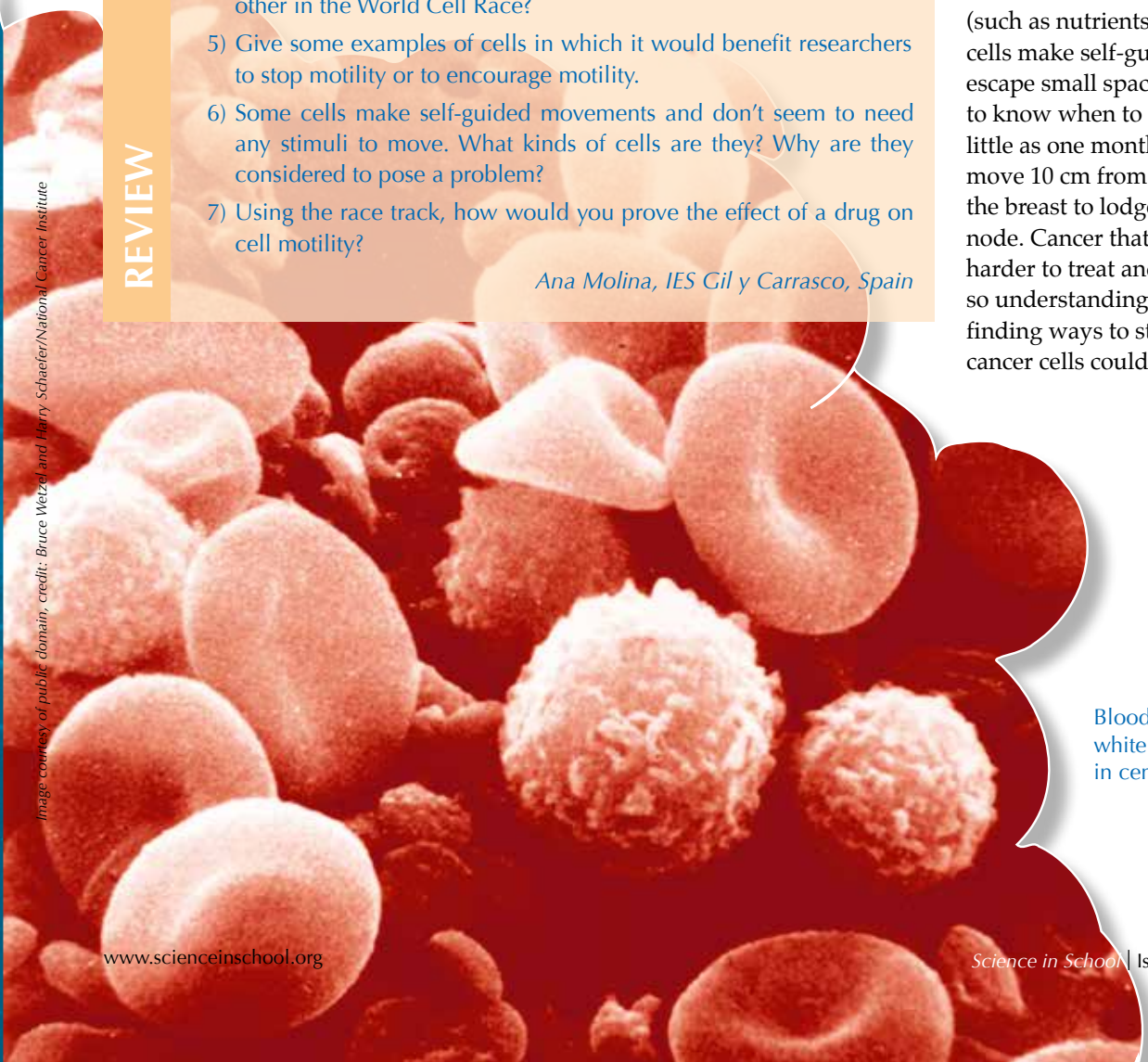


Image courtesy of public domain, credit: Bruce Wetzel and Harry Schaefer/National Cancer Institute

Blood cells with white blood cells in centre

BACKGROUND

The World Cell Race 2013

The 'race track' is an intricate maze of channels just 10 µm wide, arranged on a specially made plate. Created using a micro-fabrication technique called soft lithography, the maze walls are made from silicone, an inert material that can be moulded to precise and intricate shapes.

Labs all over the world were invited to send a sample of their speediest cells for inclusion in the race. The cells were stained with a non-toxic blue dye to make them easier to see and then placed at one end of the maze.

Most cells move only in response to specific stimuli – for example, towards nutrients – but all the competitors in this race were cancer cells, which make self-directed movements into the maze channels and usually move faster than non-cancer cells.

The plates were photographed every 15 minutes for 24 hours and the winner was the culture with the most cells reaching the far end of the 600 µm long track. You can see some of the cells in action on the World Cell Race 2013 website[w1]. In scenes reminiscent of the classic tale 'The Tortoise and the Hare', the winning culture, a breast cancer cell line called MDA MB 231 S1, wasn't the fastest, but moved steadily throughout the race. A cell line from sarcoma (cancer of the connective tissues), MFH 137, was slow to get going and was ultimately the fastest mover, but fewer cells crossed the finish line, relegating it to second place.

The World Cell Race is now in its third year. In the most recent challenge, the organisers raced the cells through mazes with corners and dead ends to test the 'intelligence' of the cells as well as their speed. This is a more accurate representation of what happens in vivo, where migrating cells have to squeeze through intercellular spaces and orient themselves in three dimensions.

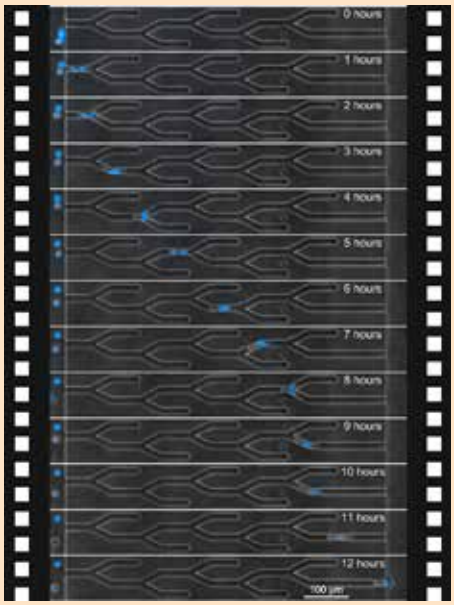


Image courtesy of Daniel Irimia, Massachusetts General Hospital

Figure 1: The progress of the fastest cell, from the MDA MB 231 S1 breast cancer cell line, during the World Cell Race 2013. The cell's nucleus has been stained with a non-toxic blue dye (Hoescht dye).

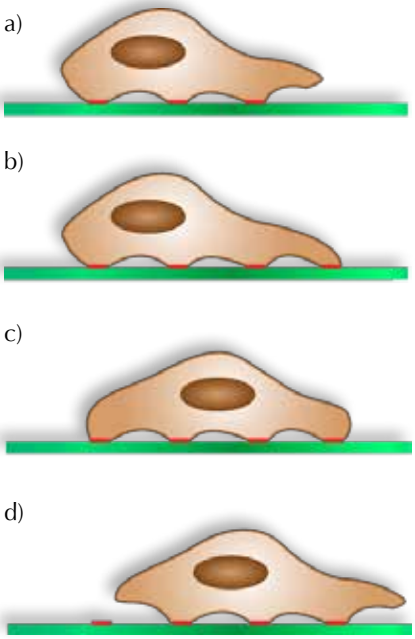


Image courtesy of Alexandre Saez via Wikimedia Commons

Figure 2: Details of cellular motility. a) A protrusion of the membrane called a pseudopodium forms at the leading edge (right) of the cell; b) the pseudopodium attaches to the surface via membrane proteins called integrins (red); c) the main body of the cell is pulled forward; and d) the trailing edge of the cell detaches from the surface and the cycle begins again.

There may be other situations where encouraging cells to move faster would be beneficial. White blood cells are a key part of our immune response. They move rapidly to sites of infection to engulf and destroy microbes, actively choosing the shortest route to reach their target. Patients with severe burns are more prone to infections, apparently because their white blood cells lose their internal compass and are unable to orient themselves, slowing their progress towards the pathogen. Therefore, drugs that could boost the speed or targeting efficiency of white blood cells might be very useful for both preventing and treating infections.

However, boosting the response of white blood cells isn't always desirable. In chronic inflammatory diseases such as rheumatoid arthritis and asthma, white blood cells misinterpret

ACTIVITY

If you would like to investigate cell migration in your classroom, slime moulds, especially *Dictyostelium*, or white blood cells are a good place to start. *Dictyostelium* is fast-growing and easy to maintain on nutrient agar at room temperature. White blood cells are easy to see with a typical school microscope, and horse blood can be obtained from many educational suppliers.

Try setting up a sample of *Dictyostelium* or horse blood under a microscope and taking photographs at regular intervals with a fixed camera. Then compare the images to see if you can catch the cells moving. Putting a gentle heat source, such as a desk lamp with an incandescent bulb, at one side of the slide might help, because both cell types respond to temperature (thermotaxis) and *Dictyostelium* responds to light (phototaxis).

Image courtesy of Mad Max, Kirkland, Washington

The white-lipped snail (Cepaea hortensis)

Image courtesy of Paul Foot

Usain Bolt at the Bolt Crystal Grand Prix in 2009

chemical signals and migrate into healthy tissue, causing pain, inflammation and damage. In these cases, finding a way to suppress this cell migration would be desirable.

There are still many gaps in our understanding of how and why cells move. Daniel and his fellow organisers hope that the World Cell Race will raise awareness of the importance of cell motility and encourage greater co-operation between biologists and engineers. They also hope their methods might lead to standardised ways of measuring cell motility, making it easier to study the impact of drugs or other means of controlling this movement.

After any race, the competitors evaluate their performance and begin to plan for the next challenge. The organisers have already set the date for the next World Cell Race: 14 November 2014. In the next race, white blood cells will also be eligible to race alongside cancer cells in an epic battle of good against evil. The fast-moving slime mould *Dictyostelium discoideum* also gets its own race on 21 March 2014. You can subscribe for updates on the World Cell Race website[w1].

Web reference

w1 – For more information about the World Cell Race 2013, visit the website: https://sites.google.com/site/worldcellrace2013/home/watch-the-race

Resources

You can watch videos of the race and other fast-moving cells on Daniel Irimia's Youtube channel. See www.youtube.com/user/danielirimia

To read more about previous World Cell Races, visit the website of the 2011 challenge: www.worldcellrace.com/index.php

If you found this article interesting, you may like to explore the other science topics published in *Science in School*. See: www.scienceinschool.org/sciencetopics

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Daniel Irimia is an Assistant Professor at Massachusetts General Hospital and Harvard Medical School, USA, studying how the ability of cells to migrate contributes to health and disease. His interests range from the role of white blood cell migration in protecting tissues against microbes to the role of cancer cell migration during cancer invasion and metastasis. For these studies, he is designing robust micro-scale tools to measure cell migration with high precision from clinically relevant samples. The World Cell Race organising team also includes Matthieu Piel from the Institut Curie and CNRS in France, and Elisabeth Wong and Bashar Hamza, both from Massachusetts General Hospital.

Sarah McLusky is a freelance science writer, editor and education consultant. She has a PhD in plant pathology and also teaches biochemistry at Newcastle College, UK.

The hospital where Stefan Pfister works is quite colourful – some doors even have stickers on them. No wonder: it is a hospital for children.

Image courtesy of DKFZ

Doctor in the morning, researcher in the afternoon

For doctor Stefan Pfister, efforts to cure cancer happen at the hospital and in the laboratory.

By Dorotee Schulter

Professor Stefan Pfister is a medical doctor who looks after children suffering from cancer. However, he and his colleagues are not always in a position to help. Sometimes cancers continue to grow in spite of all possible treatments. Unwilling to accept this, Stefan became a researcher as well as a doctor. In the afternoon, he changes from his doctor's coat into his laboratory coat and searches for potential methods of making cancerous cells harmless.

When Stefan walks through the corridors of the paediatric clinic in Heidelberg, Germany, one can hardly keep up with him. The 38-year-old specialist in childhood cancers is in a hurry to reach his patients. Today Stefan is on duty in the outpatients department. His first patient is Felix.* "Felix is 5 years old and has leukaemia," says Stefan. "That is the most common type of cancer among children." Leukaemia, which means 'white blood' in Greek, occurs when white blood cells, the leucocytes, suddenly begin to multiply at an inordinately rapid rate. These cells normally combat bacteria and other pathogens, but when there is a surplus of leucocytes, they can no longer function properly. As a result, a minor infection can be life-threatening. "For that reason, we are treating Felix with chemotherapy. It fights the cancerous cells in his blood." However, the medication damages healthy cells as well. Stefan therefore has to take a blood sample and perform the blood count to gauge the effectiveness of the treatment. A little later, the results are in. "Felix is lucky," says Stefan, who is pleased that his young patient "has a sufficient amount of healthy cells in his blood". That means Felix does not need to stay in the clinic and is allowed to return home with his mother.

In the room next door, the next patient is already waiting. "Alexander* is 10 years old and has a tumour growing in his head," says Stefan. "If the tumour becomes too big, the pressure in Alexander's head will increase

Image courtesy of 2micha Wikimedia Commons

Children's Hospital Medical Center in Heildelberg, called Angelika-Lautenschläger-Klinik

REVIEW

- Biology
- Ages 14-19

The medical practitioners who carry out innovative research in their field have a valuable insight into the potential of new treatment. The article gives an overview of a day in the life of one such person, Professor Pfister. All cancer cells have alterations in their DNA sequences. What exactly are these changes in a particular cancer? This is the subject of ongoing research with a good deal of progress being made, including by Professor Pfister, so that medication can be tailored to target the cancer cells.

This article can be used in several ways. It introduces DNA and the value of DNA sequencing within a medical context. For the 14-16 year old age group it could be linked to DNA structure and gene expression and what happens when DNA changes. They could also look at different types of leukaemia, chemotherapy (such as monoclonal antibody treatments) and immunity. This could be extended for the 16-19 age group into the theory of DNA sequencing and an extension activity on molecular biology, the value of the Human Genome Project and proteomics. The MRI scanner could be investigated within medical physics. Finally, the article could be used in lessons on moral and ethics to start a discussion on cancer therapy, whether it is right to only trial treatments on the sickest patients, the value of palliative care and hospices and perhaps extended into the tricky subject of euthanasia.

Shelley Goodman, UK

and vital nerves could be squashed." To prevent this from happening, Stefan's colleagues, the neurosurgeons, removed a part of the tumour some time ago – in a very complicated operation. Today, Stefan would like to take pictures of Alexander's head with the help of a magnetic resonance imager, or MRI for short. "On these MRI pictures I can detect whether the tumour has begun to grow once again." Although the examination is not painful, Alexander has to lie motionless for half an hour in a narrow tube. He is very frightened of this, and so receives a sedative beforehand to induce sleep.

On this day, many other children arrive together with their parents at the outpatients department. Stefan takes blood samples almost non-stop, listens with his stethoscope to respiratory and cardiac sounds, and replies patiently to questions asked by children and their parents. At lunchtime he picks up his own 6-year-old daughter from school and brings her to the after-school day centre. Then he devotes his time to his patients once again.

"We can save a lot of children by means of an operation, chemotherapy or radiation treatment," says Stefan.

Stefan Pfister makes his way from the paediatric clinic to the German Cancer Research Centre. He usually goes by bicycle, even when it is raining.

Image courtesy of DKFZ

Image courtesy of Rudolf Stricker Wikimedia Commons

The German Cancer Research Center (known as the Deutsches Krebsforschungszentrum or simply DKFZ in German), is a national cancer research center based in Heidelberg, Germany. It is a member of the Helmholtz Association of German Research Centres, the largest scientific organization in Germany.

"Nonetheless, sometimes the cancer continues to grow." He just cannot come to terms with this, and so on some days Stefan not only visits the hospital but also makes his way to the German Cancer Research Centre (DKFZ) in Heidelberg. There, he examines cancerous cells in the laboratory with the aim of finding a way to make them non-harmful. However, today Stefan has to stay a little longer in the hospital: Alexander has finished with his MRI examination, but he is still asleep. Until the sedative wears off, a medical doctor must remain nearby. When Alexander wakes up, Stefan enquires how he is. "A little tired, but otherwise fine," Alexander replies. Stefan is relieved and heads off to the laboratory.

An international effort

When Stefan Pfister hops on his bike to cycle to the DKFZ, it is already dark outside. If you imagine a researcher sitting over a microscope in his white coat or pottering around with test tubes, you would be right sometimes. On this particular evening, however, Stefan's research tools are restricted to a computer and a telephone, as a teleconference is on the agenda. He and his laboratory colleagues in other countries will discuss their recent research findings. By doing this, they can learn from one another and can make quicker progress with their research. It goes without saying that such an international collaboration will take place in English.

Stefan and his team at the DKFZ are interested in the genetic composition of cancerous cells. "The genetic make-up contains all the information on the tasks of such a cell, its appearance and when it should act," the scientist explains. The genetic information contained within DNA is located in the core of almost every cell. One can imagine it as being like a book that is written using only four letters. "Cancerous cells have such a book – but they always have some spelling mistakes," explains Stefan. "By means of special devices called DNA sequencers, we can read these books and look more closely at single chapters, the so-called genes."

In the DKFZ, ten sequencers stand in a room of their own. "We use these to examine not only the cancerous cells but also healthy cells," Stefan explains. "Afterwards we can compare them on the computer and see how a cancer cell differs from a healthy cell – in other words, find the spelling mistake in the text. If we can then understand which chapters have been changed, we can perhaps develop new and better medication against cancer."

Image courtesy of Rhoda Baer Wikimedia Commons

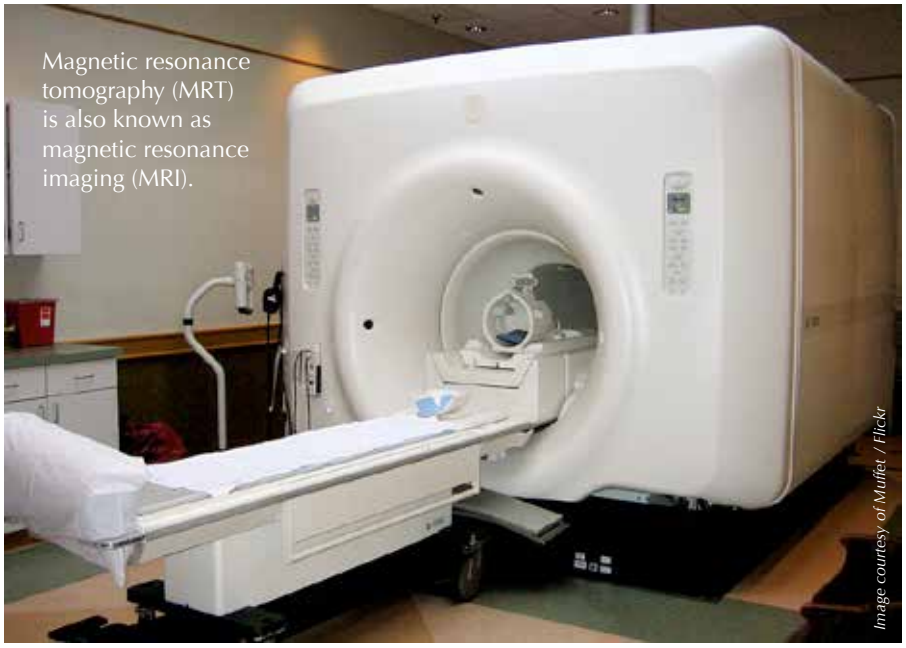
A radiation therapist prepares a patient (lying on back) for radiation treatment

Image courtesy of Beige Alert / Flickr

A DNA sequencer, showing the capillary array and blocks and syringes.

Image courtesy of Bobjgalindo Wikimedia Commons

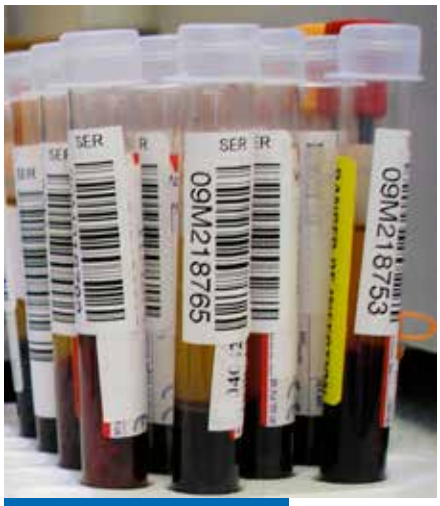
MRI image of a brain with a tumor



Magnetic resonance tomography (MRT) is also known as magnetic resonance imaging (MRI).

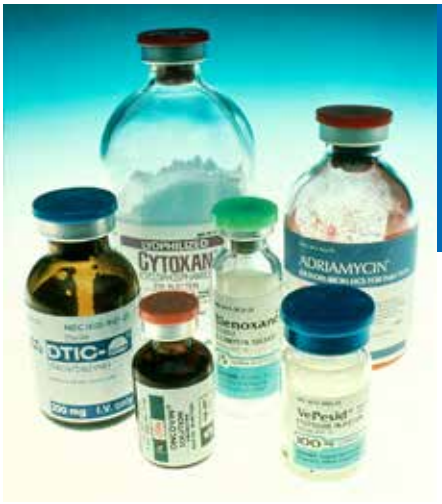
Image courtesy of Mufiet / Flickr

Image courtesy of GrahamColm Wikimedia Commons



Human blood samples

Image courtesy of National Cancer Institute Wikimedia Commons



Six bottles of different types of cancer drugs. Clockwise from center: Blenoxane (bleomycin), Oncovin (vincristine), DTIC-Dome (dacarbazine), Cytoxan (cyclophosphamide), Adriamycin (doxorubicin), and VePesid (etoposide).

Traces in the cerebrospinal fluid

Currently Stefan and his colleagues are examining, among other things, the cerebrospinal fluid. "This is a fluid located in the brain, but also found in a canal in the spinal cord," explains Stefan. "When somebody has a tumour, in most cases single cancerous cells also float in the cerebrospinal fluid – even when the tumour is very small." Because the fluid can be extracted from the spine with a needle, researchers can search for traces of such cancerous cells, or, to be more specific, damaged genetic material. If they detect cell damage in the cerebrospinal fluid, then it is obvious that the patient has a brain tumour. Applying this method will enable researchers to detect whether a tumour has disappeared during treatment. For example, should the doctors locate cancer cells in the cerebrospinal fluid, they could then treat the patient for a longer period and more intensively. "We now want to find out if that works," says Stefan.

Some children are already benefiting from Stefan's research. An especially malignant form of brain tumour, for example, can be separated into one of three different classifications. As a result, some patients can now be healed with less intensive therapy, because it is known that their tumours respond very well to therapy. Stefan has won many awards for this discovery, but they are not so important to him. What matters far more, he says, are the benefits that his small patients can reap. "I am so pleased every time we discover something that can help them."

This article was adapted from an article that first appeared in Einblick, published for children by the DKFZ

*Names have been changed

Resource

If you found this article interesting, you may like to explore the other scientists portraits published in *Science in School* ? See: www.scienceinschool.org/scientists

To learn how to use this code, see page 57.

Image courtesy of DKFZ

How to fossilize your hamster

By Mike O'Hare

Reviewed by Michalis Hadjimarcou , Cyprus

How to fossilize your hamster is a great book to have even if you don't have a hamster that needs fossilization. It includes an amazing collection of do-it-yourself experiments from Mike O'Hare and *New Scientist* magazine that are easy and fun to try. The experiments investigate a wide range of phenomena observed by both scientists and lay people in everyday life, but probably neither of the two groups ever found the time or the means to search for a scientific explanation to them.

The book is everyone's chance to find out the answers to some of life's more everyday conundrums: what causes the hugely unpleasant experience of accidentally chewing aluminium foil caught in food when you have a metal cavity filling; why uncooked spaghetti almost always breaks into more than two pieces; and many more interesting observations and phenomena.

Most experiments do not require any special equipment and can be easily performed using materials found at home or purchased cheaply at the local supermarket. Where appropriate, simple drawings of the described experiments are included to help with the correct equipment setup and experimental procedure, as well as to make understanding of the scientific interpretation easier. And if the experiment does not provide the anticipated results, the reader has the opportunity to troubleshoot through the *New Scientist* website.

Almost all of the experiments are suitable for the secondary-school science classroom, in less than one teaching period, either by the teacher as a demonstration or by the students as small projects. There are experiments suitable for all science disciplines and at all levels, as well as for interdisciplinary approaches. In fact, many can be performed in any classroom and by any teacher, and many could substantially benefit primary-school students as well, enhancing their curiosity and enthusiasm.

The experiments are designed to allow students not only to observe and have fun experimenting but also to learn some real science. In the classroom, upon presentation of the problem or phenomenon, the students could suggest their own theories to explain what is observed. The experimental procedures will help them to collect useful information for the formulation of scientifically acceptable interpretations. The end products can be checked against the book's interpretations, which are based on solid scientific knowledge.

Not all phenomena investigated in *How to fossilize your hamster* will be of interest to all readers and not all the science will be understood by everyone. But surely, everyone with at least a minimal interest in science will find enough attention-grabbing experiments to make it worth having this book.

Details

Publisher: Holt Paperbacks
Publication year: 2008 (First Edition)
ISBN: 9780805087703

To learn how to use this code, see page 57.

Podcasts 'The Elements' and 'The Compounds'

By *Chemistry World*, the magazine of the Royal Society of Chemistry

Reviewed by Tim Harrison, Bristol University, UK

'The Elements' and 'The Compounds' are two series of professionally produced podcasts, each lasting between 5 and 7 minutes. Whether you or your students are interested in the chemistry alone or wish to improve your scientific English, or if you have auditory learners among your students, these resources should be of interest to you. The chemistry podcasts are freely downloadable from the website of the UK's *Chemistry World* magazine, a publication of the Royal Society of Chemistry. Both come with a transcript that would be useful in its own right.

In 'The Elements' podcast, a leading British scientist or author tells the story behind each of the elements. The resource is presented as a clickable periodic table. The informative articles explain the history behind the discovery of each element, its common reactions and uses.

In 'The Compounds' resource, around 150 important or interesting compounds or groups of compounds are explored. For ease they are listed in alphabetical order on the web page. Examples run from everyday laboratory reagents such as acetone (propanone), chloroform (trichloromethane) and sulfuric acid through to important pharmaceutical compounds such as the bronchodilator salbutamol (marketed as Ventolin), thalidomide and penicillin. A number of other curious compounds are also there, including tetrahydrocannabinol, ricin and Kevlar. For more biologically inclined colleagues, there are articles on several vitamins, haemoglobin, cholesterol and DNA.

Check back monthly as this is an ongoing project with new material being uploaded regularly. The latest podcasts are also listed separately at the start of the web page.

Links to podcasts

www.rsc.org/chemistryworld/podcasts

To learn how to use this code, see page 57.

Blog: Ciência para Todos/ Science for All

By Haidi D. Fiedler Nome & Faruk Nome, Florianópolis, Brazil

Reviewed by Tim Harrison, University of Bristol, UK

The 'Science for All' blog, associated e-book and printed book contain a collection of short essays on a series of topics designed to appeal to young students. All three resources are free of charge. Written by academic scientists from around the world, the articles include topics as diverse as biofuels, fireworks, enzymes, fireflies, organic phosphates, animal intelligence and rubber. The texts used in the books are extracted from the first 60 articles of the project. The use of colour pictures and photographs make the essays more fun to read than some standard school texts. Photos of the authors are included to help students appreciate that science is an active discipline pursued by real people.

The blog, from INCT Catálise, is an expanding collection of more than 75 texts written mainly by academics who wish to share their individual interests and experiences. The articles are written in English and Portuguese, with many articles also translated into Spanish and a few also in French and German. Accompanying short videos, in which animations are added to orated text, will appeal to younger secondary-school students. Recently submitted articles include work on the fragrance of roses, reactive oxygen species, calcium ions as chemical messengers, and the biology and practical applications of duckweed.

Both the printed book and the blog should be listed on the web-based resources of science departments in schools and colleges and brought to the attention of science-curious students such as those who attend science clubs. The texts are not designed to support particular curricula but instead to broaden them. There may even be a place for them in modern language departments as the short pieces are presented in at least two, and more often three, languages. There is nothing to prevent teachers from taking some of the articles or their associated videos and turning them into comprehension exercises should they so wish.

Details

The electronic versions of the book may be downloaded from www.ccell11.com/2013/03/this-blog-now-is-book.html#ING

The blog can be found at: www.scienceforall-inctbrasil.blogspot.com

To learn how to use this code, see page 57.

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At the end of each article in this issue, you may notice a square black and white pattern. With the aid of a smart phone, this QR code will lead you straight to the online version of the article. All you need to do is download a free QR code reader app (such as BeeTagg or i-Nigma) for your smart phone and scan the code with your phone's camera. To find a suitable app for your phone, see: http://tinyurl.com/byk4wg

Hint: the apps work better in good light conditions, and with a steady hand. You may also want to try holding your camera at different distances from the code.

You can then use all the live links to the references and resources, download the PDF, send the article to your friends, leave comments, and much more.

Safety note

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

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

Unless the context dictates otherwise, it is assumed that:

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

Credits

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

EFDA-JET
The Joint European Torus (JET) investigates the potential of fusion as a safe, clean, and virtually limitless energy source for future generations. It can create the conditions (100-200 million °C) in the plasma sufficient for fusion of deuterium and tritium nuclei to occur – and it has observed fusion power to a maximum of 16 MW. As a joint venture, JET is collectively used by more than 40 European fusion laboratories. The European Fusion Development Agreement (EFDA) provides the platform to exploit JET, with more than 350 scientists and engineers from all over Europe currently contributing to the JET programme. See: www.efda.org/jet

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

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

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

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

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

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