Editorial

Welcome to the 30th issue of *Science in School*

As we finalise the contents of this issue, I've been thinking a lot about mentors and teachers. A school reunion is not just an excuse to meet with old friends and classmates, but also an opportunity to revisit the school itself – which invariably seems smaller now than it did even when I was a student.

The school itself, of course, is just a collection of buildings. What makes it a school is the teachers that teach within it, and I count myself lucky to have had some great teachers. Looking back through old notes, I'm amazed how insightful they were, identifying my strengths and interests and encouraging me to pursue them.

October 5th is World Teachers Day, when hopefully even more people will reflect on the influential teachers from their past. Of course, here at *Science in School*, our role is to support the teachers of the present and future, with new teaching activities and insights into the world of science. Curricula and pedagogical techniques change over time, but some simple truths remain. Engaging classes and teachers will remain with students long after they leave the classroom, and learning human skills is as important as acquiring functional skills and facts.

In this issue, we start by looking at how science writing and blogging can help inspire students (p 5), before looking at more hands-on activities. The ESO Astronomy Camp (p 8), for example, combines the majesty of space and the sky above us with the most modern instruments to bring pupils closer to real-life astronomy and teamwork. For a more imaginative lesson, why not start planning our next trip to the Moon (p 36)? First we need to define why we should return; the actual planning will have to wait until issue 31.

Other teachers have taken large projects and scaled them down to size, from modelling particle accelerators like the CERN's LHC in the classroom using a cathode ray tube (p 21), to developing an electrolyser and fuel cell to explore how the hydrogen economy might one day power our cars and homes (p 31). Implementing such innovative teaching activities is what motivates Vasiliki Kioupi, both in her role as a teacher and as a teacher-trainer (p 49).

However, inspiration doesn't come only from big technological projects: the weird and wonderful world of slime moulds has been used to model transport networks, something you can explore with your students while also learning about chemotaxis and phototaxis (p 16). Taking weird to a different level, 'note-by-note' cooking is letting inspired chemists into the kitchen, changing how chefs look at gastronomy (p 44).

As well as getting inspiration from our latest issue, don't forget that the entire *Science in School* archive remains freely available online. Learning and mentorship don't stop when you leave the classroom, but as I reflect on my school days I realise that the best teachers prepare you for that.

Happy Teaching!

Laura Howes
Editor, *Science in School*

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

About *Science in School*

The European journal for science teachers

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

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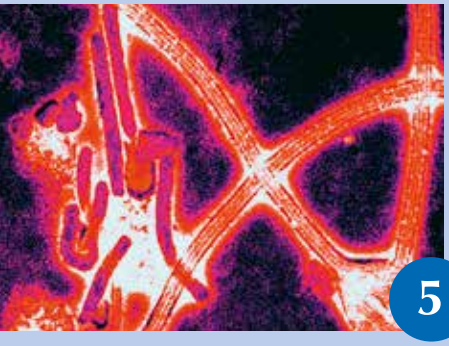
Image courtesy of Thomas W. Geisbert, Boston University School of Medicine



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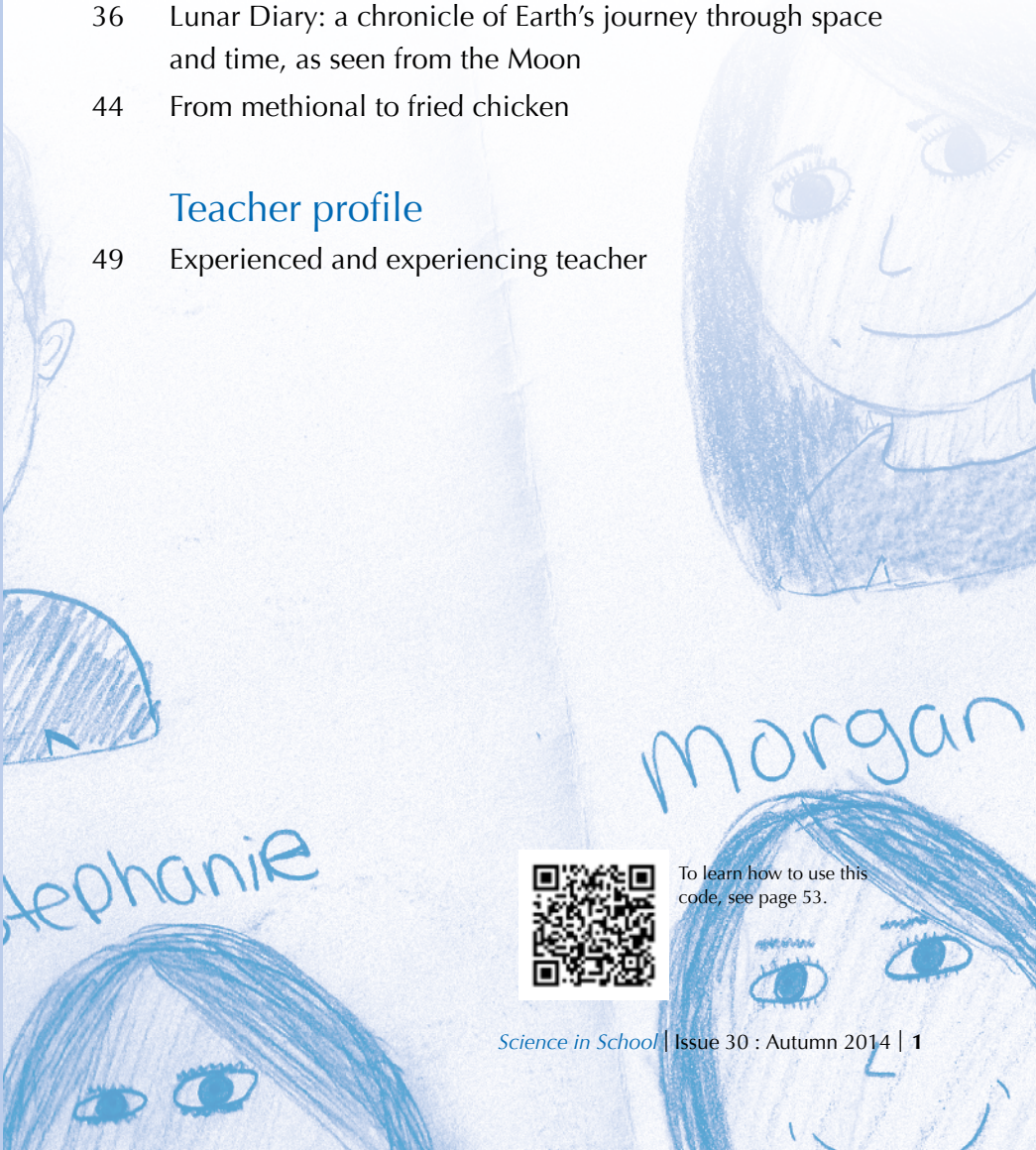

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Reflecting on another three months' worth of advances

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

Image courtesy of konok1a / Fotolia

NEUTRONS FOR SCIENCE

ILL: Neutron diffraction sheds light on photosynthesis

Scientists from ILL and CEA-Grenoble have improved our understanding of the way plants evolved to take advantage of sunlight. Using cold neutron diffraction, they analysed the structure of the thylakoid lipids found in plant leaves where photosynthesis takes place. Thylakoids are light-sensitive membranes that cover an enormous surface area, with several hectares being present in every square metre of leaf. The thylakoids present in plants and algae are remarkable in possessing a unique lipid composition which is not replicated by any other cellular membrane. The conservation of this composition across all plants throughout millennia of evolution has led scientists to speculate as to its role in the structure of thylakoids and its significance for the photosynthetic process.

The experiments' results reveal that lipids do indeed play a central role in determining the structure of photosynthetic membranes. They suggest that the dense lamellar stacking of thylakoid bilayers is due to the presence of hydrogen bonds which stick the membranes together across layers of water – a discovery which opens the door to a deeper understanding of photosynthesis in plants.

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

To learn more, see also the list of ILL-related articles on the *Science in School* website at www.scienceinschool.org/ill

European XFEL: The world's brightest X-rays meet the world's flattest mirrors

Scientists and engineers at European XFEL are working on installing many pieces of equipment in the tunnel systems along the 3.4 km-long complex. Among the most prominent pieces of infrastructure are items that will manipulate and direct the X-rays to the beamlines. Eventually, this will include some unique optical instruments that have been in development through partnerships with industry.

Among these instruments are the flattest mirrors ever built. The X-rays in the tunnels of the European XFEL complex do not run in perfectly straight lines: in order to channel X-rays with different qualities towards the experiment hall, they have to branch off in several places, causing deviations from straight paths. It is at these bends and branches that the world's flattest mirrors have to reflect the world's most intense X-rays.

Each mirror, 90 cm in length and made of silicon, has special mechanisms that help it deal with the high power of the X-rays while reflecting them in a manner that preserves their laser qualities. What can usually be perceived with optical instruments as a flat mirror is actually curved by as much as a 100 km radius. This curvature would be unacceptable for some of the mirrors used for the X-ray laser. So these specialized mirrors have to be flatter than flat. Small piezo-electrical elements are evenly spaced along the mirror's edges to make tiny adjustments, so the mirror will not deviate from flatness by more than a few nanometres. That is the equivalent of a 28 km road not moving up or down by the width of a human hair for its entire length. A mirror prototype was developed and tested early this year, and the vacuum chambers in which the mirrors will sit within the tunnels have likewise been designed and tested.

The tunnels are being prepared for the installation of highly technical components such as these. Items such as supports for the beam pipeline and platforms for the X-ray-generating undulators are being installed throughout the photon tunnels on the Schenefeld end of the facility near the underground experiment hall. The tunnels themselves are in the process of being closed off and brought to operating conditions as installations of technical infrastructure continue into the coming year.

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. See: www.xfel.eu

To learn more, see also the list of European XFEL-related articles on the *Science in School* website at www.scienceinschool.org/xfel

The vacuum chamber for the mirror

The mirror itself

Images courtesy of XFEL

EMBL:
Viruses: from foes to friends

Antibiotic resistance is a growing concern worldwide, but another weapon against bacteria is re-emerging: bateriophages. These very specific viruses attack only bacteria, not humans or animals.

Bacteriophages essentially act like big syringes, injecting their genetic material into a bacterium. After multiplying safely inside the cell, they destroy its cell wall and spread out to infect new cells.

Scientists at EMBL Hamburg have discovered how endolysins, the viral enzymes that degrade the bacterial cell wall, are activated. Using X-ray crystallography techniques, they determined the 3D structures of the inactive and the active forms of the enzymes, and deduced how the enzymes switch from one state to the other. This finding opens the door to engineering targeted bacteriophages that could destroy specific bacterial species and perhaps become an efficient solution to antibiotic resistance.

Read the original article in *PLoS Pathogens*:

Dunne et al. (2014) The CD27L and CTP1L Endolysins Targeting Clostridia Contain a Built-in Trigger and Release Factor. *PLoS Pathogens* **10**(7): e1004228 DOI: 10.1371/journal.ppat.1004228

Read more about this story on the EMBL news portal: http://news.embl.de/science/1407_cdiff/

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

To learn more see also the list of EMBL-related articles on the *Science in School* website: www.scienceinschool.org/embl

Electron microscopy image of the bacteriophages investigated

Image courtesy of Kathryn Cross/IFR

EIROforum

EIROforum combines the resources, facilities and expertise of its member organisations to support European science in reaching its full potential. 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

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

Blog about it! Getting students closer to science

Teen blogger Julia Paoli and her teacher Lali DeRosier discuss how blogging can help science students

By Nina Notman

Last spring, Lali DeRosier was at a science communication conference geared towards teen bloggers. By chance, she learned that Scitable was looking for more school-aged students to join their blog network, Young Voices. Scitable is the education branch of Nature Publishing Group[w1]. "They have three levels of bloggers," she explains. "Professional researchers, undergraduate students who are studying science, and high school students."

Armed with application details, Lali returned from the conference and set about finding volunteers.

Julia Paoli blogs at Viruses 101

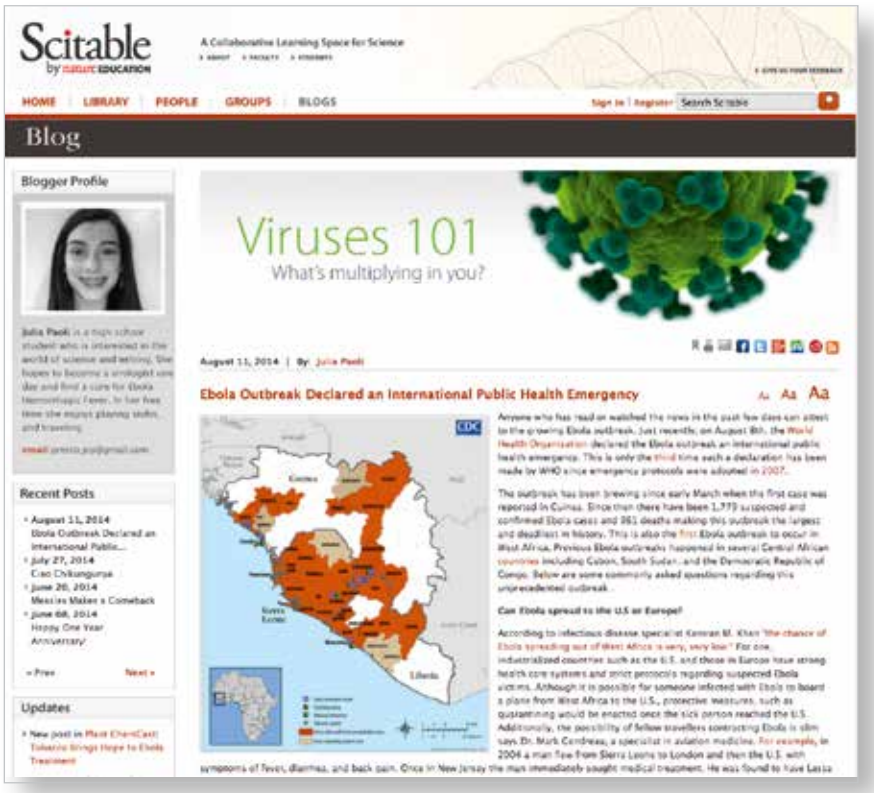
Image courtesy of Julia Paoli

REVIEW

- **All sciences**
- **Ages 16–18**

The article is an excellent testimony about the benefits of blogging for learning and teaching science, namely at pre-university level. It is particularly interesting because the bloggers are students and not, as is more common, the teacher.

Betina da Silva Lopes, Portugal



Scitable now hosts four blogs written by students from Lali's school: Trinity Preparatory School in Florida, USA. At 16 years old, Julia Paoli is the youngest of these bloggers with a blog called Viruses 101[w2]. "Viruses make a really good blog topic because most people are interested in them and there is enough new research for it to be continued week after week," Julia explains.

Behind the blog

Each blog post focuses on a new piece of published research or something that has been in the news related to viruses. Julia often selects the topic herself after scouring the internet for ideas. "I also get ideas thrown at me from my parents, Mrs DeRosier or classmates," she says. "Sometimes my editors at Scitable will tell me something they want me to focus on." For instance, a recent blog entry covered the controversy surrounding the price of two new hepatitis C drugs in the USA. In another, Julia discussed the discovery that viruses coated in silica can survive in environments similar to those on Mars. "Right now I'm working on a piece on smallpox because the editors at Scitable want me to do a piece in conjunction with another blog."

Before writing a post, Julia reads relevant journal articles as well as blog and news articles on the topic. "Occasionally I also reach out to a scientist and email them," she says. When she first started blogging, the Scitable editors would edit her posts before publishing them but now she has more of a free reign.

Julia still gets some help editing her posts, but from her dad, she explains. "I'm very lucky because my dad has a science background and knows what I am writing about."

Blogging as a step into science

The student's view

Blogging has not only allowed Julia to learn more about science but also opened up other opportunities. In February she attended, and blogged about, her first science communication conference: ScienceOnline Together[w3]. Her highlights of the three-day conference include learning about new genres of science communication, such as songs about science and science comics. She also got to try ice cream made using dry ice for the first time.

Julia aims to write two blog posts a month, but it is sometimes hard for her to find time between schoolwork and her other hobbies, such as dancing and violin. It is feedback from readers, she says, that keeps her writing. "People reach out to me from all different walks of life, asking me questions or giving me positive feedback, which really encourages me to write," says Julia. "It makes my day to know that people are reading my work and learning." Julia encourages other teenagers interested in both science and writing to start a blog too.

With two years left to go in high school, Julia sees herself pursuing a career in science. "At this point I don't think I want to go into a writing profession. I like writing but I'd rather do hands-on science. But I don't know yet what field," she says.

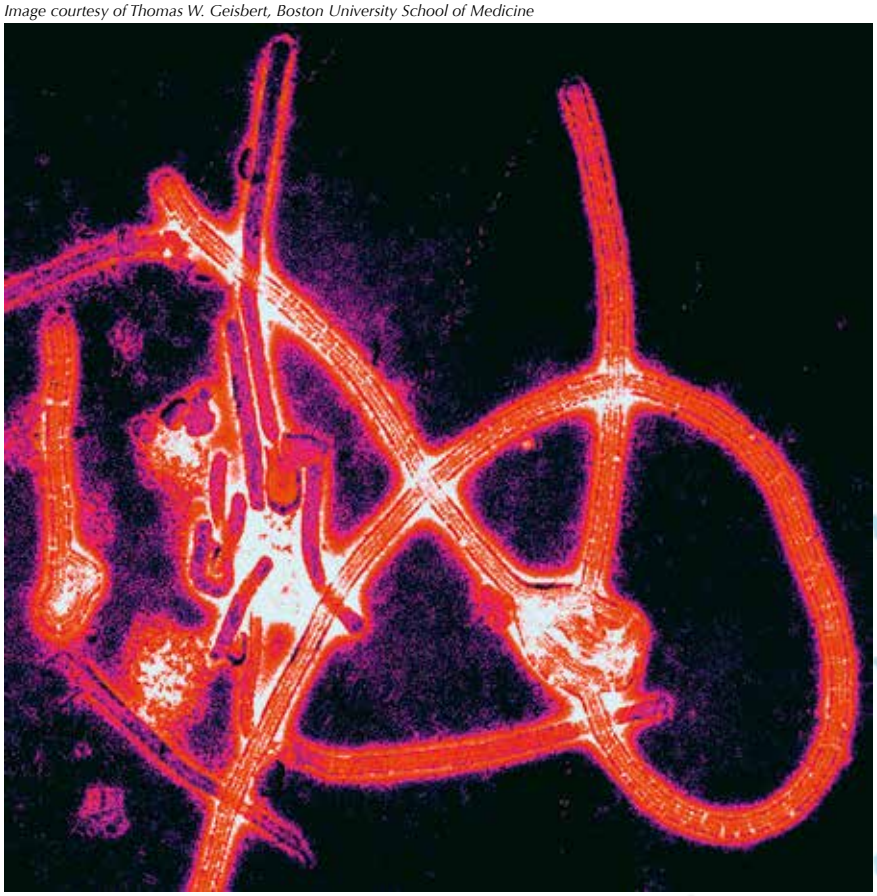
The teacher's view

For Lali, having teen bloggers in her flock has been a very positive experience and hasn't added much extra work. She has organised a couple of meetings with the blogging group to get feedback from them and talk about the process. "But because Scitable is so organised on their end," she adds, "it's not a lot for me. I'm kinda just an all-round cheerleader."

Lali is a big fan of incorporating blogs into the teaching of science. "For both readers and writers, blogs are a really good segue into more formal science writing," she says. "They are a great way to get people involved in very complex science topics in a non-intimidating way."

Blog posts tend to be shorter and the language tends to be more in-

Image courtesy of Thomas W. Geisbert, Boston University School of Medicine



Colour-enhanced electron micrograph of Ebola virus particles. Ebola has recently been in the news and featured on Julia's blog

formal than journal or news articles, Lali explains. "They can be in lots of different voices and styles: they can be serious tone, they can be investigative, and they can be more fun. So it gives a lot of flexibility into what people are interested in reading and what they are interested in writing."

Lali incorporates blog posts, both those written by her students and from other sources, in her classes. "Rather than give my students a dry research article to read", she explains, "I can give them some blog posts about that topic before I introduce the formal research itself." Other blogs she uses include ones hosted by *National Geographic, Discover Magazine* and *Scientific American*.

Working with blogging has also inspired Lali to add new aspects to her teaching. "I am currently working with a graduate student to develop a science writing curriculum to be integrated in our school," she concludes.

Web references

w1 – Scitable is a free science library and personal learning tool from Nature Publishing Group. To visit the blogs homepage, see: www.nature.com/scitable/blogs

w2 – To read Julia's Viruses 101 blog, see: www.nature.com/scitable/blog/viruses101

w3 – ScienceOnline is a nonprofit organisation aimed at those who conduct or communicate science online. The annual ScienceOnline Together conference can be found here: http://together.scienceonline.com/

Resources

Leli also has her own blog where she discusses science, education, and research. See:

http://nerdletestuary.wordpress.com/

Dr Nina Notman is a science writer and editor. After completing her PhD in synthetic organic chemistry at the University of Bristol, UK, she started a career in publishing, managing the peer-review process of a number of the UK's Royal Society of Chemistry journals. She then moved into science journalism, working on the society's flagship magazine, *Chemistry World*. In early 2012, Nina left the magazine and went freelance.

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

Camping under the stars — the ESO Astronomy Camp 2013

On 26 December 2013, after a long and exciting trip, 56 secondary-school students from 18 countries arrived at their destination: the picturesque alpine village of Saint-Barthélemy, Italy, where the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA) was built because of the area's clear skies.

By Cristina Olivotto, Davide Cenadelli, Oana Sandu, and Lars Lindberg Christensen

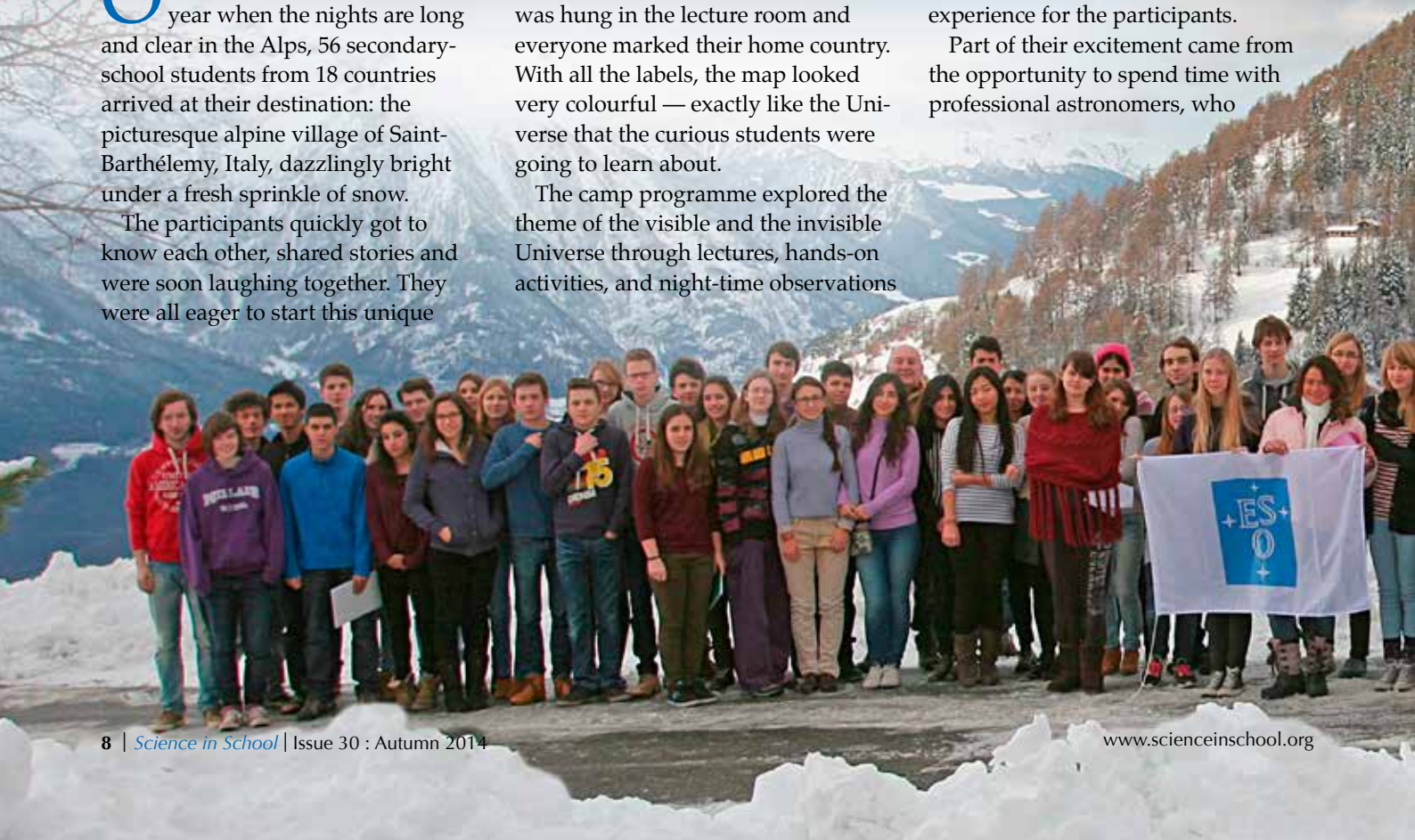
On 26 December 2013, a time of year when the nights are long and clear in the Alps, 56 secondary-school students from 18 countries arrived at their destination: the picturesque alpine village of Saint-Barthélemy, Italy, dazzlingly bright under a fresh sprinkle of snow.

The participants quickly got to know each other, shared stories and were soon laughing together. They were all eager to start this unique week at the first ESO Astronomy Camp[w1], hosted by the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA).

On the first evening, a world map was hung in the lecture room and everyone marked their home country. With all the labels, the map looked very colourful — exactly like the Universe that the curious students were going to learn about.

The camp programme explored the theme of the visible and the invisible Universe through lectures, hands-on activities, and night-time observations with telescopes and instruments at the observatory. Social activities, winter sports, a planetarium show and multicultural tea-time meetings contributed to making the camp a memorable experience for the participants.

Part of their excitement came from the opportunity to spend time with professional astronomers, who



not only shared their knowledge and enthusiasm with the students during the activities but were also so overloaded by questions during meal times that they had little chance to eat the delicious food prepared by the hostel staff!

Looking at the temperature

The programme began with an introduction to visible light and an explanation of how to interpret the light arriving from the stars to calculate their temperatures.

The spectrum of a star is an absorption spectrum: the stellar photosphere – the thin layer where the stellar gas undergoes the transition from opaque to transparent and where light can escape into space – emits light at all wavelengths, but some specific wavelengths are absorbed by the elements at the star's surface. This absorption creates dark lines of missing wavelengths on the spectrum.

In addition, the colour of the star – or, to be more precise, the maximum brightness of the spectrum – depends on the temperature of the stellar photosphere: it shifts towards blue if the star is hotter, and towards red if it is cooler, as explained by the black body laws (see box).

More precisely, the specific wavelengths absorbed by the elements at the surface of the star correspond to the quantity of energy that the electrons in the atoms of those elements need in order to reach a higher level of energy. The energy levels that the electrons occupy change from atom to atom and also depend on the temperature of the gas. Because different stars have similar chemical compositions, the absorbed wavelengths depend mainly on the temperature. So, in a

BACKGROUND

The black body laws state that a hot, dense, and opaque gas emits a continuous spectrum of wavelengths whose maximum brightness moves towards shorter wavelengths when the temperature increases. Because blue light has a shorter wavelength than red light, the colour we see for a star shifts from red for colder stars to orange, yellow, white (when the peak of brightness is in the green, stars actually look white) and finally blue for hotter stars.

Group photo of the participants of the ESO Astronomy camp

Image courtesy of Paolo Calcidese

- Physics
- Astronomy
- Astrophysics
- Spectrometry
- Star classifications
- Ages 14–18

As a teacher, one can sometimes come across opportunities available to 16 years old that make one regrets not being 16 years old anymore.

This article promotes the ESO, European Southern Observatory, Astronomy camp, an amazing occasion that some 16 year old students, from any European country, attended in December 2013. This camp balanced exciting astronomical observations and learning from professional astronomers with a healthy sports and social program.

For teachers, this article is an excellent and complete resource to use during an astrophysics lesson for 16 to 18 years old. For younger students, it provides a good introduction to stars classification. The stimulating part of this article is that it offers an easy-to-follow procedure to calculate the surface temperature of stars by analysing their spectra using real data, which is always an added plus to a lesson. It also exposes some of the challenges faced when calculating these temperatures, a possible extension to the work.

Looking at the web references given in this article, I could see that another ESO astronomy camp is planned for this December 2014. Oh, to be 16 again!

Dr Caroline Neuberg, Fulneck School, UK

REVIEW

first approximation, we can consider that both the colour of a star and the dark lines on its spectrum depend on its temperature. Colour and lines are correlated: blue stars show certain lines and red ones others.

The Harvard Classification

Astronomers understood this crucial correlation in the second half of the 19th century, and established so-called spectral classifications. The most important one, named the Harvard Classification, was created at the beginning of the 20th century and is still in use today with very few changes.

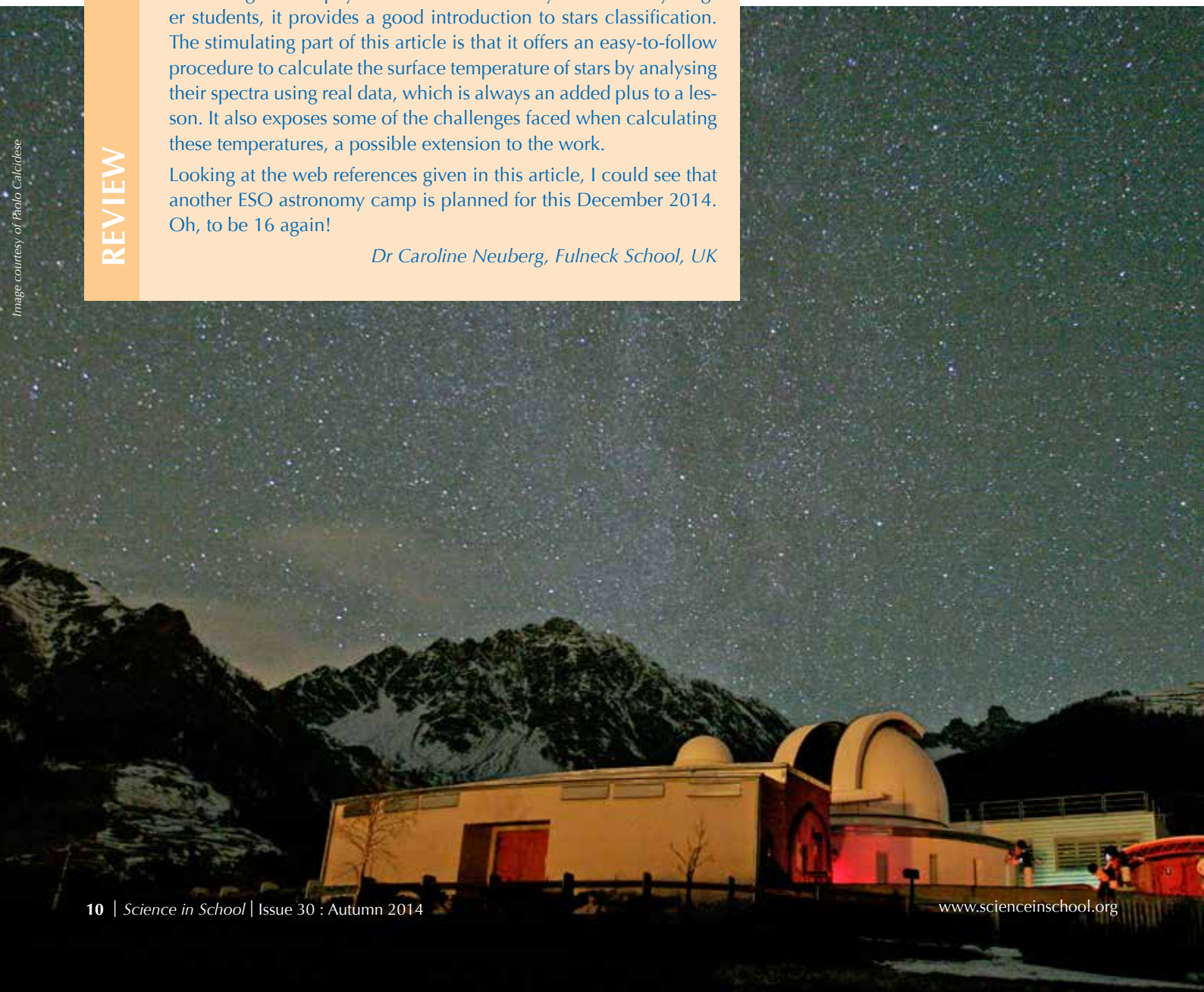


Image courtesy of Paolo Calcidese

The Harvard Classification contains seven major classes: O, B, A, F, G, K and M, in order of decreasing temperature:

- O and B stars are blue;
- A stars are white;
- F and G stars are yellow;
- K stars are orange;
- M stars are red.

Each class is further divided into 10 types, indicated by numbers from 0 to 9, where 0 is the hottest and 9 the coldest. So we have stars that are type A0 (Vega), G2 (Sun) and K5 (Aldebaran), for example.

Image courtesy of Mariona Isern

Participants busy analysing stellar spectra

The observatory of the Aosta Valley

Moreover, stars of the same temperature can have different radii and luminosities. To reflect these variations, a luminosity classification with Roman numerals complements the Harvard Classification:

- Ia are bright supergiants;
- Ib are less bright supergiants;
- II are bright giants;
- III are giants;
- IV are subgiants;
- V are dwarfs.

Physics

The camp was a wonderful experience. Meeting so many people from other cultures with different ways of thinking and the chance to discuss hot topics with them was unique and exciting.

Gabriele, 16, Italy

I am not exaggerating when I say that the night observations were the most exciting part of the camp! We scrutinised stellar spectroscopy together with the observatory staff — one of the most interesting parts of astronomy for me. […] I'm sure what I learned at the ESO Camp will be useful for my future education.

Daniil, 16, Russia

[…] We soon settled into a wonderful routine of astronomy-related lectures and activities interrupted only by meals and winter excursions. […] By the end of the camp I had experienced some of the best days of my life.

Hera, 16, Sweden

Participants solving a mathematical puzzle

Image courtesy of Mariona Isern

Spectral sequence

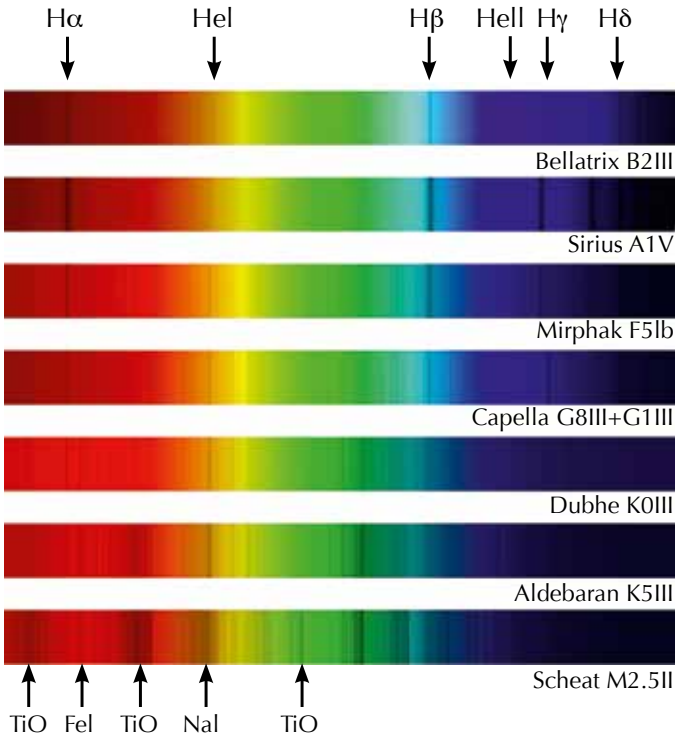


Image courtesy of Davide Cenadelli

Stellar spectra taken by participants of the ESO Astronomy Camp. Below each spectrum, the name, spectral classification and surface temperature of the star are reported. Some major lines and bands are indicated. Note that helium lines are typical of very high temperatures; hydrogen Balmer lines of moderately high ones; neutral sodium lines of low or moderately low temperatures; and molecular bands of the lowest ones.
Colours in this image don't correlate with temperature because they are not corrected for atmospheric extinction and for the charge-coupled device's spectral response.

Luminosity also has a slight impact on spectrums, but this was not explained in detail at the camp.

The correlation between star colour and spectral lines means that each class in the Harvard Classification is characterised by lines that are typical of the temperature of that class:

- very hot stars show helium lines;
- moderately hot stars show hydrogen lines (the so-called Balmer Series, whose lines are indicated by the symbols Hα, Hβ, Hγ, Hδ …);
- moderately cold stars show lines of neutral and ionised metals;
- very cold stars show lines of neutral metals and molecular bands.

And much more…

On the first day, students were asked to choose their favourite star from a photo of the winter sky, and to calculate its temperature and maximum emission based on its tabulated spectra.

In the evening, groups of students were able to operate a spectrograph and a charge-coupled device camera attached to one of the didactical telescopes, and to capture the spectra of several favourite stars, among them Aldebaran, Betelgeuse, Dubhe, Mirphak and Sirius.

These newly observed spectra were then used on the following day to calculate the temperatures of the stars and to classify them. The students proved to be excellent team-workers. You can download the step-by-step explanation of how to implement this activity in your classroom, together with the spectra of several stars, from the *Science in School* website[w2].

Lecture after lecture and activity after activity, the astronomers opened new windows on the Universe by letting the students see it in a different light. Curiosity was in the air, and questions were raised and answered about the infrared, radio, ultraviolet and X-ray Universe.

Several other activities based on healthy competition were used to help foster teamwork. The Antares competition, for example, challenged the students to use absorption lines in spectra to classify a number of famous and less famous stars according to the Harvard Classification scheme. The non-oven microwave technology tournament was another activity that engaged six groups in measuring what direction the specific signal received by an antenna came from.

The camp concluded as the International Space Station passed above our heads, an unforgettable traditional gala dinner and astronomical gifts and awards from ESO. Time flew by but the memory of the camp activities and friendships will last forever. We are already looking forward to next year's camp[w3]!

Acknowledgements

Special thanks go to the camp supervisors Emily, Koen, Lorenzo and Mariona (also for the blog text and photos), and to the camp astronomers for their fantastic lectures and activities: Davide Cenadelli (Observatory of the Aosta Valley), Enzo Bertolini (Observatory of the Aosta Valley), Lars Lindberg Christensen (ESO), Andrea Bernagozzi, Paolo Pellissier and Paolo Recaldini (Observatory of the Aosta Valley), Anna Wolter (ESO/INAF), Juan Fabregat (University of Valencia), Aniello Mennella and Paola Battaglia (University of Milan).

Web references

w1 – To learn more about the first ESO Astronomy Camp, visit its dedicated webpage: www.sterrenlab.com/camps/eso-astronomy-camp-2013/

w2 – You can download the detailed explanation on how to determine the temperature of a star from its spectrum, from the *Science in School* website. See: www.scienceinschool.org/2014/issue30/ESOcamp#w2

w3 – To learn more about the upcoming ESO Astronomy Camp in December 2014, and to register, see: www.sterrenlab.com/camps/eso-astronomy-camp-2014/

Resources

To learn more about the analysis of stars' spectra, read:

Kaler JB (2011) *Stars and their spectra: an introduction to the spectral sequence.* 2nd Ed. Cambridge, UK: Cambridge University Press. ISBN: 9780521899543

Night sky observation

Image courtesy of Julian Durnwalder

Image courtesy of Cigillo83/Wikimedia commons

Map of Italy showing the Val d'Aosta region

Robinson K (2007) *Spectroscopy: the Key to the Stars*. London, UK: Springer. ISBN: 9780387367866

Our eyes are very limited in their ability to show us the Universe. To learn more about how covering the full spectrum of light can change your perception, read:

Christensen LL, Bob Fosbury B, Hurt R (2009) *Hidden universe*. Berlin, Germany: Wiley-VCH. ISBN: 9783527408665

The European Southern Observatory builds and operates a suite of the world's most advanced ground-based astronomical telescopes. See: www.eso.org

Sterrenlab organises science camps and summer schools around the world and offers services in science education and communication. See: www.sterrenlab.com

The Astronomy Observatory of the Aosta Valley hosts some extremely modern equipment that is used for research, teaching, and promotional purposes. See: www.oavda.it/english/osservatorio/index.htm

The Istituto Nazionale di Astrofisica (National Institute for Astrophysics, INAF) is an important Italian institution for research in astronomy and astrophysics. See: www.inaf.it/en?set_language=en

The University of Milan is one of the most important and largest universities in Europe. See: www.unimi.it/ENG/

Image courtesy of Gerri/Wikimedia commons

The Aosta plain

The Polish Astronomical Society (Polskie Towarzystwo Astronomiczne, PTA), with headquarters in Warsaw, brings together professional astronomers. See: www.pta.edu.pl

Urania – Postępy Astronomii is a Polish magazine on astronomy for a lay audience. It is one of the oldest astronomy magazines in the world. See: www.urania.edu.pl

Polish Children's Fund is an independent, non-governmental organisation whose main objective is to help gifted pupils. See: http://fundusz.org/english

Ciência Viva is an open programme to promote science in Portugal. See: www.cienciaviva.pt/home/

The Sociedad Española de Astronomía brings together Spanish astronomers and astrophysicists. See: www.sea-astronomia.es/drupal/

The Université de Genève is a public research university and the second-largest university in Switzerland by number of students. See: www.unige.ch/international/index_en.html

If you found this article interesting you may want to browse the other astronomy-related articles on the *Science in School* website, see: www.scienceinschool.org/astronomy

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Oana Sandu works as community coordinator for ESO's education and Public Outreach Department (ePOD). She is responsible for the promotion of outreach products or events and the social media presence of both ESO and ESA/Hubble. With a degree in communications and public relations and a master's degree in marketing, she worked for two years in a leading PR agency in Eastern Europe.

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Image courtesy of ESA

The Faulkes Telescope, in Hawaii

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

Intelligent slime? A hands-on project to investigate slime moulds

These simple but unusual life forms can be used to develop students' understanding of life and the scientific method

Image courtesy of Frankenstoen/Wikimedia commons

A *plasmodium* in its natural habitat

By Claas Wegner, Friederike Strehlke and Phillip Weber

Moving red or yellow slime might sound like something from a 1950s science fiction movie, but scientists often use slime moulds as model organisms to study cell motility, growth and differentiation (Montag, 2008).

Slime moulds (*Eumycetozoa*) are one of the most diverse genera known to man. Because of their variety, it is hard to classify them and the classification system itself changes every few years. It is not even clear what group of organisms they belong to: their fruiting bodies resemble those of real fungi, but their genetics show they are more closely related to flagellates and amoebae (Hoppe & Kutschera, 2010).

There are more than 1000 species of real slime moulds (subclass *Myxomycetes*), and each organism is

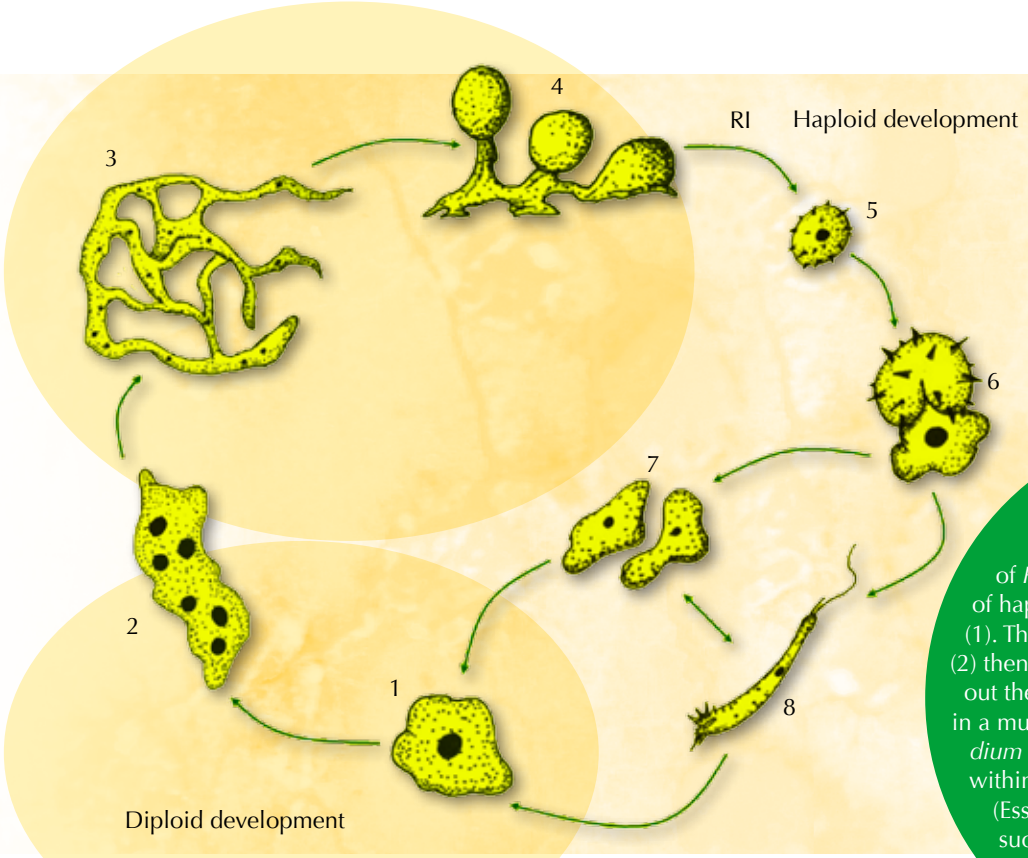


Image courtesy of the authors

Figure 1:
The development of *Physarum*. The vegetative development of *Physarum* starts with the paired fusion of haploid myxamoebae and myxoflagellates (1). The nucleus of the resulting diploid zygote (2) then duplicates mitotically several times without the *plasmodium* multiplying, which results in a multinucleotic *plasmodium* (3). This *plasmodium* then grows into a macroscopic network within three to four days at room temperature (Esser, 2000). Whereas the normal size of such a network is 15x15 cm, *plasmodia* have reportedly exceeded 3 m^2 (Marwan, 2001).

REVIEW

- **Biology**
- **Genetics**
- **Ages 11–19**

The practical activities described in the article allow students to investigate how slimes adapt to use light and how they feed themselves.

The activities could also be used by younger students to consider how the slime finds food. I would use the experiments with students aged 16–19 mainly as an introduction to how science can be used to solve issues faced by modern civilisation. Students could think about what other problems they might be able to solve using the simple ideas described here.

I can see that with a little imagination, the slime can be used in all sorts of ways to extend the students' understanding – for example, as a way of showing how the slimes can solve a maze problem. The practicals experiments are simple enough and cheap enough for the students to design their own practicals to develop their problem-solving skills.

Mike Sands, Longcroft School, UK

made up of just one cell. They are adapted to all sorts of environments and feed on other micro-organisms or detritus.

Physarum polycephalum is the most well known species of *Myxomycetes* and is an easy-to-use organism for demonstrating many basic biological processes.

The macroscopic form of the slime mould, called a *plasmodium*, constantly moves around in search of food; once *Physarum* has found it, it will engulf the particles or micro-organisms, creating food vacuoles that are then digested within the cell (Esser, 1976). This process is called phagocytosis.

If *Physarum*'s environment becomes too dry, it changes into a more resistant form to enable the mould to survive long periods of drought. Once the conditions improve, the mould can redevelop into a normal *plasmodium*. Environmental influences such as constant light or food shortage, however, prompt *Physarum* to develop fruiting bodies. Figure 1 shows the development cycle of a slime mould.

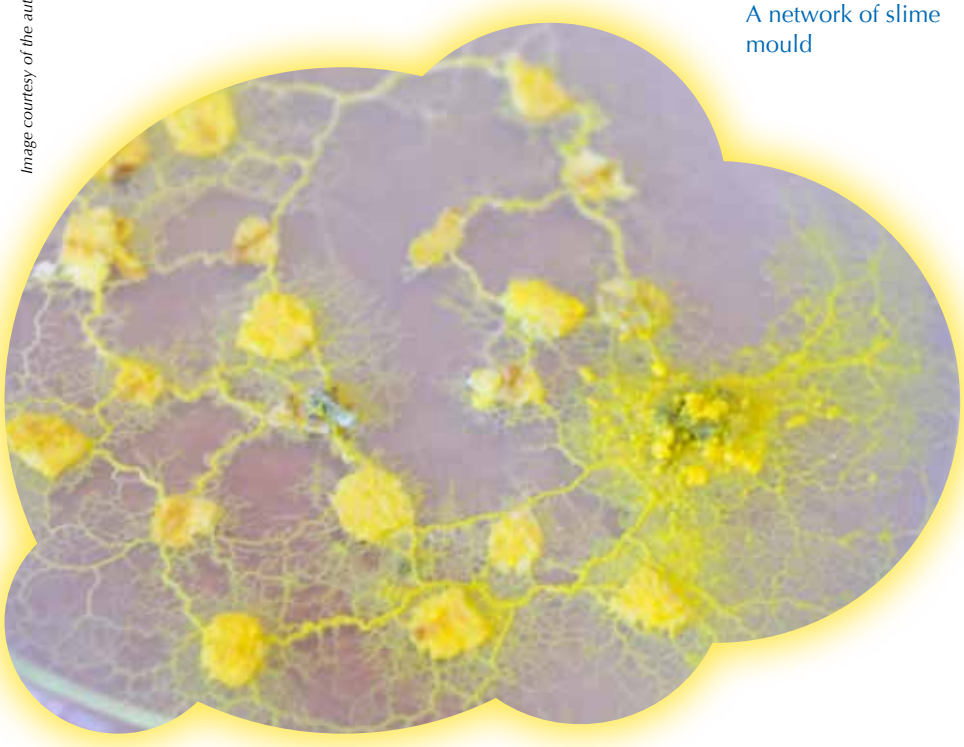
Investigating slime moulds

The project described here spans two lessons for students aged 16–19. The unit's design is derived from the scientific method and has been divided into three phases: the introduction phase (theoretical background), the working phase (practice), and the evaluation and presentation phase.

Begin by showing your students a *Physarum* culture. The students can examine the mould in small groups with magnifying glasses in order to note down its main characteristics. Collect their results as a mind map on the board, with the centre being *Physarum polycephalum*.

You can also show a film depicting the life cycle of the slime mould, for example from YouTube[w1]. Since the video shows the movement of the cell, which appears to be directional, you can ask students how they think the mould could orientate itself. Note down the question and a few answers on the board.

Whenever the students start one of the experiments described over the page, make sure they first note down hypotheses regarding its expected result. For each experiment, the students should note down what they do and the results on their worksheets. This makes for better information retention and keeps them on track. At the end of the unit, collect the results and discuss them in class, finally answering the hypotheses that the students originally suggested. As most of the experiments described above take some time to finish, the evaluation and presentation are done in the second double period.



A network of slime mould

Image courtesy of the authors

Further experiments

Once the principles of chemotaxis and phototaxis have been explored, further experiments to investigate the properties of slime moulds are possible.

Japanese scientists started studying the mould's intelligence in 2000, when they found that it was able to find the shortest way through a maze in search of food quite quickly (Nakagaki et al., 2000). A few years later, scientists even used *Physarum* as a central control unit for a six-legged slime mould robot (Tsuda et al., 2007). Tero et al. (2010) showed that the mould was even able to create an efficient network between several food sources. They arranged 36 food sources around one central source in a pattern resembling the geographic positions of Tokyo and the surrounding cities. *Physarum* built up a network almost identical to the railroads between these cities.

The networking experiment described above, during which the mould imitates a railroad network or something similar, is highly suited as a transfer experiment for classes using the downloadable worksheet called 'Intelligent slime' available from the *Science in School* website[w3].

Put one oat flake into the middle of the Petri dish and let the *plasmodium* engulf it. Then position more flakes around the mould in a specific pattern. These could be special forms or bear a resemblance to the

CLASSROOM ACTIVITY

Slime movement

The results obtained in the chemotaxis and phototaxis experiments described here can be recorded on the worksheet 'Creeping slime'[W2] that you can download from the *Science in School* website.

1/Chemotaxis

Physarum finds food and avoids harmful conditions by moving in response to chemical stimuli – a process known as chemotaxis. In this lesson, small groups of students investigate the effect of chemoattractants and repellents. One half of the class studies the positive type while the other half studies the negative.

Materials

- Sterilised oat flakes
- Petri dishes with agar and cultivated *Physarum polycephalum*
- Distilled water
- White/spirit vinegar

Procedure

Place a chemical stimulus 1.5 cm away from a *plasmodium* in a Petri dish. For positive chemotaxis, use an oat flake; for negative chemotaxis, drop some vinegar onto the flake. Cover the whole plate with a thin film of distilled water and keep it in a dark place for some time at room temperature.

After some time, take the Petri dishes out and measure the distance between the mould and the oat flake.

About what happens

The *plasmodium* will have moved towards the positive stimulus – the oat flake. Thick canals will be visible within the cell, transporting the fresh nutrients to every part of the organism. Meanwhile, in the other experiment, the mould will have moved away from the negative stimulus – the oat flake soaked in vinegar.

The results of the experiment suggest that *Physarum* must have chemoreceptors, as the environment was completely dark. They also show that the mould is able to measure differences in concentration because it moved to the food source directly: if more receptors are activated on one side of the cell, it knows where the concentration is higher. These receptors induce a signal transduction chain in the cell, which ultimately leads to the migration of the cell.

The experiment can be extended into an experiment of choice: the students might dip the oat flakes into different substances and present them to *Physarum* at the same time and at the same distance, and see which oat flake the mould moves towards.

Image courtesy of the authors

2/Phototaxis

Movement in response to light, called phototaxis, is used differently by young and old slime moulds. This experiment can show how, and groups can then discuss why.

Materials

- Torch
- 1 Petri dish with agar and a young (2–3 day old) *Physarum polycephalum*
- 1 Petri dish with agar and an old (1.5 week old) *Physarum polycephalum*

Procedure

Point the beam of a torch onto the edge of a young *Physarum*. It will immediately start retreating from the lit area. If the *Physarum* is then put in the dark, it will move back to its original position. Repeat the experiment with an older *Physarum* – it will move towards the light.

About what happens

The phototactic reaction becomes positive once the *plasmodium* is old enough to build up fruiting bodies (Esser, 1976). The *plasmodium* wants to grow its fruiting bodies in a free spot so that they can reach the wind. Where there is light, there are usually no big plants or obstacles hindering the distribution of spores.

In contrast, younger *Physarum* avoid light because light can also mean more heat, threatening the mould with dehydration.

Image courtesy of the authors

geographic locations of surrounding towns.

After a day or two, *Physarum* will have found the most efficient connections between all those flakes, and the students can make a comparison between them and a railroad network. The process behind this phenomenon is quite simple. Connections with a high flow of cytoplasm become stronger, whereas connections with a low flow become weaker and weaker until they eventually vanish (Tero et al., 2010). Since there is always a high cycling, or cyclosis, between two food sources, these connections will automatically become stronger.

To show the students how the slime mould does this, conduct an experiment on the organism's cyclosis using the downloadable worksheet 'Movement of slime moulds' available from the *Science in School* website[w4].

Students could also build a maze out of cardboard on an agar bed and place negative stimuli (e.g. sterilised oat flakes soaked in vinegar essence) in it and a positive stimulus at the end of it. After some time, *Physarum* will find its way through the maze. Since the underlying processes are all automatic, however, whether these phenomena prove that the mould is intelligent remains to be answered.

Web references

w1 – To watch a short video on The Life of a Slime Mold, see: http://youtu.be/sDdDN_EWpVM

w2 – Download a worksheet to record the evidence of chemotaxis and phototaxis at www.scienceinschool.org/2014/issue30/slime_moulds#w2

w3 – Download a worksheet to record how the slime mould can model networks at www.scienceinschool.org/2014/issue30/slime_moulds#w3

w4 – Download a worksheet to record the evidence of cyclosis at www.scienceinschool.org/2014/issue30/slime_moulds#w4

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Download the article free of charge on the *Science in School* website, see: www.scienceinschool.org/2014/issue30/slime_moulds#references or subscribe to *Nature* today: www.nature.com/subscribe

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Resources

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Build your own particle accelerator

The world's largest particle accelerator, the LHC, is deepening our understanding of what happened just after the Big Bang. Here's how to explore the principles of a particle accelerator in your classroom.

By Julian Merkert, Andrew Brown and Becca Wilson

When students think of a particle accelerator, they are likely to imagine the world's largest – CERN's Large Hadron Collider (LHC). However, not all particle accelerators are used to investigate the origins of the Universe, nor are they in a 27 km circular tunnel that crosses an international border. Much closer to home is the cathode ray tube (CRT) found in old-fashioned computer and television monitors. A CRT is a linear particle accelerator that creates an image on a fluorescent screen by accelerating and deflecting a beam of electrons in a vacuum (figure 1). And although CRTs are many orders of magnitude less powerful than the LHC, the principles of operation are similar (table 1).

The activities described below enable students to control the same parameters in a CRT as scientists do at the LHC: creating a particle beam, changing the path of the particles and altering their speed. All four activities could occupy a class for at least half a day, but they could also be used separately in individual lessons. For all activities, the particle accelerator needs to be set up as outlined in the worksheet that can be downloaded from the *Science in School* website[w1].

Image courtesy of CERN

Particle accelerators like CERN are huge, but smaller ones can be controlled in the classroom

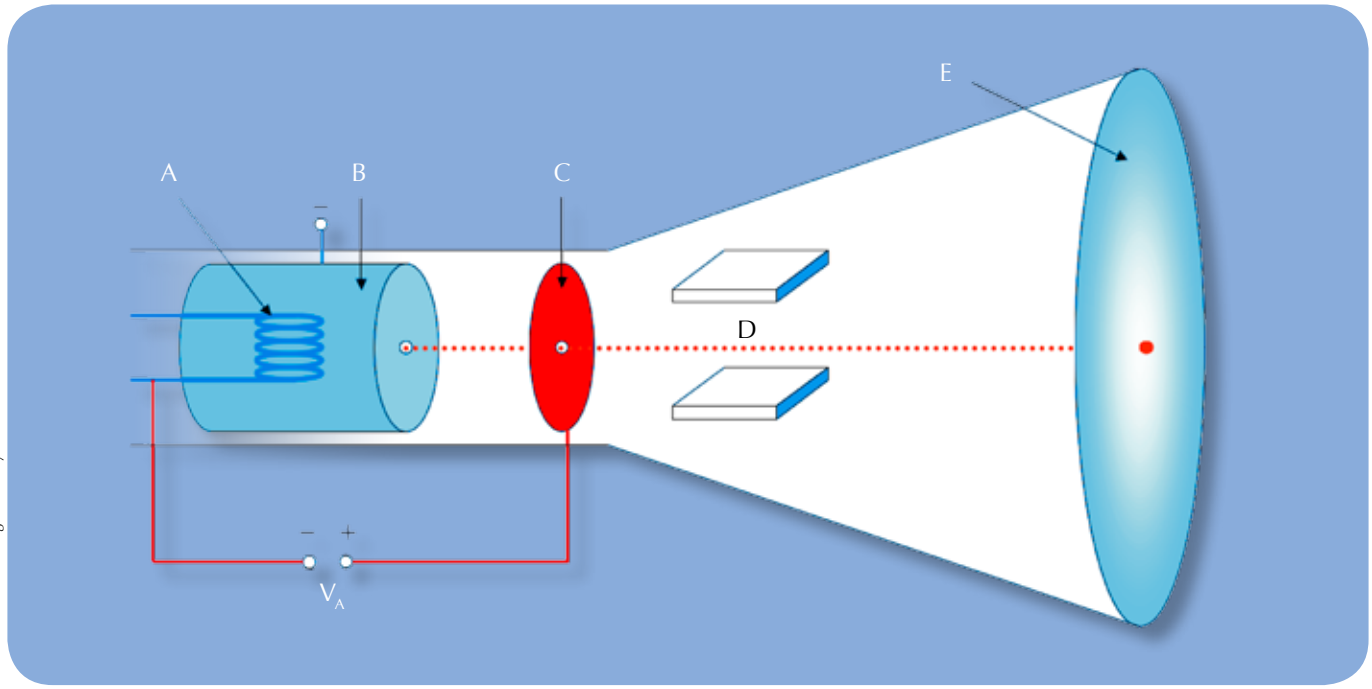


Image courtesy of CERN

Figure 1: The cathode ray tube is a vacuum tube in which electrons are produced by a heated filament (the cathode, A), focused into a beam as they pass through the aperture of the control grid (Wehnelt cylinder, B) and accelerated by the voltage (V_A) between the cathode and the anode (C). The electrons can then be deflected by a magnetic (or in the case of oscilloscopes, an electrical) field (D) before they strike the phosphorescent screen (E), creating an image. The image could be, for example, electrical waveforms (on an oscilloscope), radio wave echoes of aircraft or ships (on a radar screen) or pictures on an old-fashioned television screen or computer monitor.

Characteristic	CRT	LHC
Pressure (For comparison, a vacuum cleaner has pressure of $1–10^{-3}$ atm, and outer space has a pressure of $<10^{-15}$ atm	$10^{-6}–10^{-10}$ atm	$10^{-9}–10^{-15}$ atm
Distance travelled by a particle between collisions	0.1–100 mm	$1–10^{5}$ km
Particle types and source	Electrons produced by thermionic emission at the cathode (a heated filament)	· Protons produced by ionisation of hydrogen atoms · Lead nuclei
Mode of accelerating particles	A potential difference between the anode and cathode	Electronic fields and radio frequencies, synchronised with particle speed
Mode of directing particles	Electrical or magnetic fields	Strong magnetic fields achieved using super-conducting electromagnets (4 T in strength)
Mode of focusing particles	Wehnelt cylinder and anode hole	Quadrupole magnets
Ultimate aim	To cause a beam of particles to form an image on a fluorescent screen	To collide the beam of particles with a second beam and observe the result

Table 1: A comparison of the classroom particle accelerator (the CRT) and CERN's LHC

REVIEW

✔ Physics
✔ Ages 14+

We have all heard about CERN and the particle acceleration experiments conducted there. However, for some it may seem like a place that is very far from the classroom. Despite this physical distance, the project described in this article succeeds in reducing the barrier between the scientists' working place and the students' classroom.

The procedure for setting up the apparatus is very detailed, hence making it accessible to teachers. While ensuring that every part of the project is explained in terms of the physics theories involved, the authors have also compared the LHC with the CRT throughout the article. This makes it extremely interesting, apart from being highly instructive.

This article can give rise to a discussion about the work being done at CERN, linked with the origin of the Universe, the progress we have made so far in the exploration of this theory, and the certainties and uncertainties surrounding it!

Catherine Cutajar, Malta

Producing free particles

Materials

See the list of the necessary materials in the downloadable document[w1].

Procedure

1. On the CRT power supply unit, disconnect the lead that supplies the voltage to the cathode (see the circuit diagram in the attached worksheet).
2. Set the voltage of the auxiliary anode – the anode of the control grid or Wehnelt cylinder – to 10 V.
3. Set the voltage of the anode to 30–50 V.
4. Set the cathode voltage to 200–300 V.
5. Connect the power unit to a source of electricity.
   Can you see a spot on the fluorescent screen?
6. Reconnect the voltage lead to the cathode and repeat the previous step.
   Now can you see a spot?

About what happens

A spot is only visible on the fluorescent screen when the cathode is connected. The metal filament heats up and its electrons escape in the form of thermionic emission. The high positive potential of the anode relative to the cathode pulls the electrons into a narrow beam that strikes the fluorescent screen, appearing as a spot.

When the power is disconnected and the cathode is not heated, the electrons cannot escape from the surface because their thermal energy is lower than the energy that binds them to the metal nuclei, sometimes called the work function. Consequently, no electron beam is observed and no spot appears on the screen.

How does this compare to the LHC? Instead of electrons, the LHC accelerates beams of protons or lead nuclei (table 1). The protons, however, are produced using a similar technique to the CRT – in this case with an ion source known as a *duoplasmatron*. A cathode filament emits electrons into a vacuum chamber containing small amounts of hydrogen gas. The electrons ionise the hydrogen gas, forming a plasma of hydrogen ions (protons) and free electrons. The protons are then confined by magnetic fields and accelerated to become a beam.

Deflecting an electron beam with an electrostatic field

Materials

See the list of the necessary materials in the downloadable document[w1].

Procedure

1. On the power supply unit for the deflection plate, alter the voltage

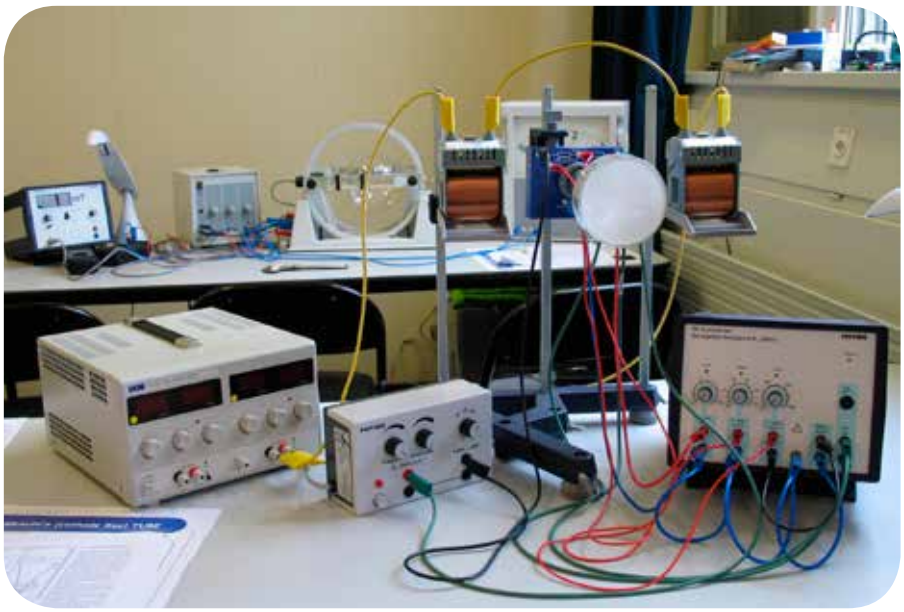


Image courtesy of CERN

Figure 2: The completed CRT setup

Physics

Image courtesy of Jfmeler/ Wikimedia Commons

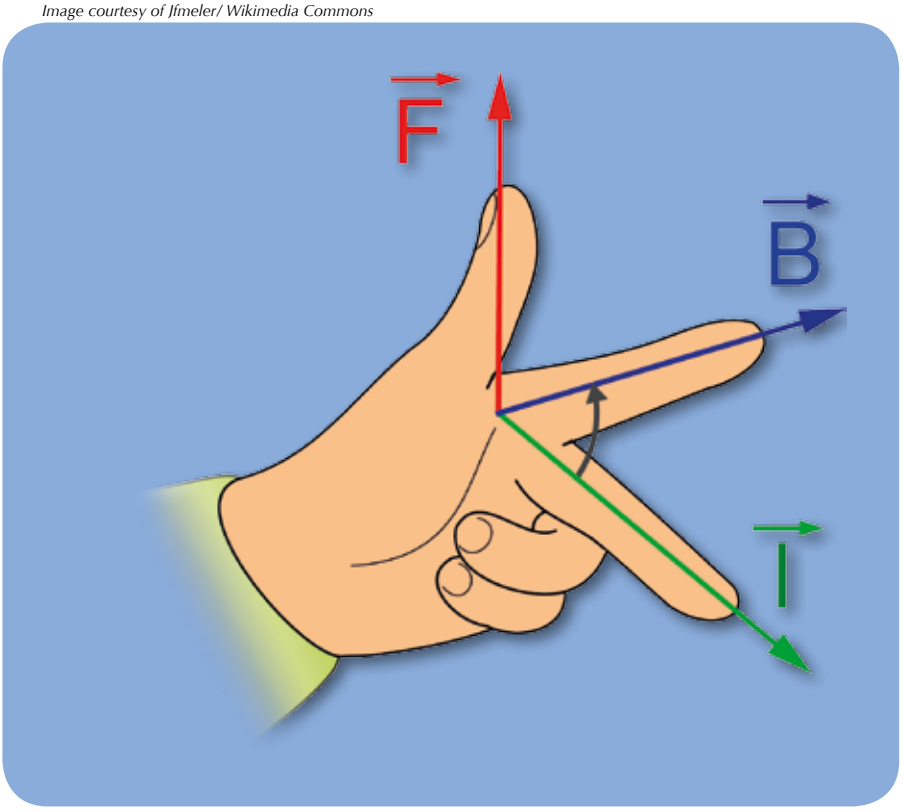


Figure 3: Fleming's left hand rule: using your left hand, your thumb indicates the direction of motion, your first finger represents the magnetic field (north to south) and your second finger shows the current (from positive to negative).

first to the left and then to the right deflection plate (between -80 V and +80 V). What happens to the spot on the screen?

2. Vary the voltage to the auxiliary anode of the control grid. How does the spot on the screen change?

About what happens

When the voltage to the left deflection plate is greater than the voltage to the right plate, the spot will be to the left of the screen and vice versa.

This is because an electrostatic field is created when a potential is applied across the plates. The negatively charged electrons are deflected towards the positive plate, which makes them follow a curved path within the electrostatic field.

Once the electrons leave the electrostatic field, they travel in a straight line towards the screen, at the angle at which they left the field. The greater the potential applied to the plate, the wider the deflection angle of the beam.

Increasing the voltage to the control grid brightens and sharpens the spot on the screen because the potential difference between the control grid and the anode is greater than that between the cathode and the anode. The electrons released by the cathode are repulsed by the control grid and focused towards the anode, resulting in a fine electron beam.

Image courtesy of K. Aainsqatsi/Wikimedia Commons

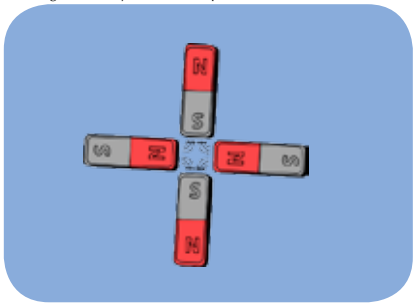


Figure 4: A quadrupole magnet consists of four magnetic poles positioned so the field lines are cancelled at the centre.

Deflecting the beam with magnetism

If you do not have access to a CRT, you could try a comparable demonstration using an old television screen[w2].

Procedure

1. Bring one pole of the bar magnet close to the side of the CRT, beside the path of the beam. What happens to the spot?
2. Power up some electromagnetic coils and bring them close to the side of the CRT. What happens to the spot?

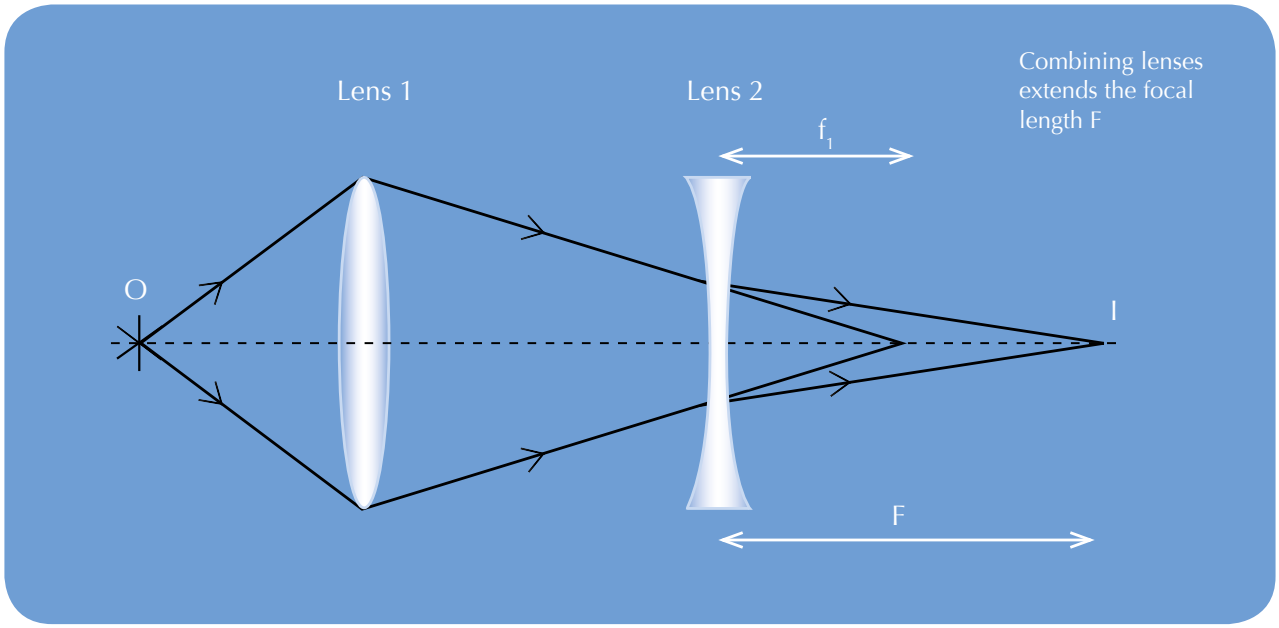
About what happens

When electrons in the beam pass through the magnetic field, they experience a force at right angles both to the direction in which they are travelling and to the magnetic field. This deflects the electron beam. You can work out the direction of force using Fleming's left hand rule (figure 3).

Electromagnets produce a stronger magnetic field so the beam is deflected more than by the bar magnet.

How does this compare to the LHC? The LHC uses superconducting quadrupole magnets to focus the particle beam. A quadrupole magnet consists of four magnetic poles, positioned so that the field lines cancel each other out at the centre (figure 4). When a particle beam passes through the very centre, where there is no magnetic field, it feels no force. The quadrupole magnet, therefore, pushes the beam into a small cross-section, akin to a lens focusing light. However, each quadrupole magnet only focuses the beam in one direction, so to produce a fully focused beam, successive quadrupole magnets at 90° to each other are used.

Image courtesy of Nicola Graf



Optical lenses can be used as an analogue for quadrupole magnets. Just as a series of quadrupole magnets at 90° to each other focuses the electron beam in the LHC, combining two lenses of the same focal length (one converging/focusing and one diverging/defocusing) results in an overall increased focal length.

The total focal length F of a system of two lenses with focal lengths f_1 and f_2 separated by the distance d is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 \cdot f_2}$$

Because the first lens is focusing and the second defocusing, while their focal length is the same, $f_2 = -f_1$. Substituting this into the formula gives:

$$\frac{1}{F} = \frac{d}{f_1^2}$$

The total focal length is increased when two lenses are combined.

Changing the speed of particles

Procedure

1. Alter the voltage of the anode. How does the spot on the screen change?

About what happens

When the anode voltage is low, there is no electron beam. As the voltage is increased, the spot becomes visible and then brighter.

Increasing the potential difference between the anode and the cathode (by increasing the voltage to the anode) increases the velocity of the electrons towards the screen.

How does this compare to the LHC? The first electrostatic accelerator of the LHC (located inside the proton source) accelerates protons using a potential difference of 90 kV. However, these protons do not reach the velocity that the electrons in the CRT reach with a lower potential. This is due to the higher mass of the protons. Proton accelerators like the LHC, therefore, need more energy to accelerate particles to high speed.

Comprehension questions

1. What is the speed of electrons that have been accelerated by a potential difference of 250 V in the CRT?
2. What is the speed of protons that have been accelerated by a potential difference of 90 kV at the first electrostatic accelerator of the LHC?

Answers

1. Kinetic energy of the electrons:

   $E = 250 \text{ eV} = 4 \times 10^{-17} \text{ J}$

   But $E = \frac{1}{2} mv^2$, which can be rearranged to give the speed of the electrons as:

$$v = \sqrt{\frac{2E}{m_e}}$$

$$= 9.38 \times 10^6 \text{ ms}^{-1}$$

Energy of the protons:

$E = 90 \text{ keV} = 1.44 \times 10^{-14} \text{ J}$

Speed of the protons:

$$v = \sqrt{\frac{2E}{m_p}}$$

$$= 4.15 \times 10^6 \text{ ms}^{-1}$$

Web references

w1 – For the list of materials and instructions on how to set up the apparatus, please download the worksheet in either Word or PDF form at www.scienceinschool.org/2014/issue30/accelerator#w1.

w2 – An alternative to activity 3, using an old-fashioned television screen,

Physics

More about CERN

The European Organization for Nuclear Research (CERN)[w3] in Meyrin, Switzerland, is one of the world's most prestigious research centres. It aims to understand fundamental physics – finding out what makes our Universe work, where it came from and where it is going.

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

See all CERN-related articles in *Science in School*: www.scienceinschool.org/cern

is described on the website of the Oxford University physics department. See: www.physics.ox.ac.uk (search for 'cathode ray tube') or use the direct link: http://tinyurl.com/alq4hgl

w3 – Find out more about CERN: www.cern.ch

The CERN education website offers resources for schools and information about CERN's residential courses for teachers. See: https://education.web.cern.ch

w4 – Learn more about EIROforum at www.eiroforum.org

Resources

To learn more about CERN, see:

Hayes E (2012) Accelerating the pace of science: interview with CERN's Rolf Heuer. *Science in School* **25**: 6–12. www.scienceinschool.org/2012/issue25/heuer

Landua R (2008) The LHC: a look inside. *Science in School* **10**: 34–45. www.scienceinschool.org/2008/issue10/lhchow

Landua R, Rau M (2008) The LHC – a step closer to the Big Bang. *Science in School* **10**: 26–33. www.scienceinschool.org/2008/issue10/lhcwhy

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Acknowledgement

These activities were developed in Julian Merkert's thesis during his study at the University of Karlsruhe, Germany, and a two-month stay at CERN. The initial inspiration came from an idea from Prof. Dr Günter Quast at the University of Karlsruhe to "explain particle physics with school experiments".

Andrew Brown is a molecular and cellular biology graduate of the University of Bath, UK. After working for *Science in School*, he returned to the UK and is now at the Royal Institution.

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Dr Rebecca Wilson is a planetary scientist working on public and business engagement projects at the Space Research Centre, University of Leicester, UK. She is a project scientist for the UK's National Space Academy, collaborating with scientists and educators to develop secondary-school revision materials based on space science. She also works for the Space IDEAS Hub, giving small local businesses access to the university's space-derived expertise.

All in the family

Building a hypothetical family portrait can help students to understand genetics.

Image courtesy of © mevans

By Steven M. Autieri

Looking for a way to assess whether your biology students truly understand key genetics terminology, such as dominant and recessive or genotype and phenotype? This activity presents a fun, collaborative and interdisciplinary way to get students excited about the study of human genetics. Students pair up to create a genetic portrait of their imaginary family based on several observable, heritable traits. By actively using their knowledge, students will appreciate the importance and meaning of the study of genetics in its real-life context.

Terminology such as genotype, phenotype, homozygous and heterozygous is prevalent in every biology classroom, yet can be cumbersome and difficult for students to comprehend, especially if it is not taught in a way that promotes active learning and collaboration (Nowak & Plucker, 2002).

A genetics unit usually begins by introducing how certain traits or physical characteristics arise in individuals in different generations of the same family. The assessment activity described here allows students to demonstrate an understanding of concepts such as the difference between dominant and recessive traits and genotypes. They will use this knowledge to construct Punnett squares for heritable traits. Students will then predict the possible outcomes of genetic crosses to make an album of 'family portraits' that accurately depict the phenotypes of parents and offspring.

REVIEW

- Biology
- Maths
- Art
- Ages 11–16

This is an interesting activity that could easily be adapted to a range of age groups and abilities. The author has designed it to help students understand Mendelian genetics – and to help teachers identify which students are having problems and which ones 'get it'. The family portraits that make up the final part of the activity inject cross-curricular possibilities, and it would not be hard to develop extension activities as well. The instructions for students are easy to follow and the evaluation form has been designed to help students and teachers to see how well Mendelian genetics has been understood.

Devon Masarati, UK

Classroom activity

Building connections: examining dominant and recessive traits in humans

To begin the family portrait project, allow students to pair up – ideally with a student of the other gender. However, in single-sex schools, or classes without an even gender split, this may not be possible.

First, the students should complete worksheet one in detail[w1] to help them to determine their own phenotype and possible genotype for severable observable traits. Students start by examining a selection of their own physical features, including everything from the presence of freckles to the ability to roll their tongues. My students expressed a great deal of excitement and surprise to realise that characteristics they rarely consider are actually dominant or recessive traits.

Image courtesy of Steven Autieri

Figure 1: Example of student-generated family portrait displaying phenotypic traits of parents and offspring.

Genetics Family Portrait Evaluation Rubric

Partner 1: _____ Partner 2: _____

Evaluation:

Content	Criteria Assessed	Skill Evaluation	Point Value	Points Earned
Parent/ Child Sheet	The genotype/phenotype of both team members is correctly labelled on the chart.	Chooses and applies appropriate strategies to address subject	15	
Punnett Squares	Genetic crosses are provided for each of the indicated traits. Genotypic and phenotypic percentages are indicated for each cross.		10	
Family Portrait	Provides a sufficient attempt at artistic excellence. The drawing appears to be well thought out and detailed based on the information provided in the chart.	Solves problems and reasons effectively	20	
	Each trait for each child is evident from the drawing or is labelled to guide the reader in determining the phenotype.	Identifies all important elements of the problem	10	
Total			**55**	

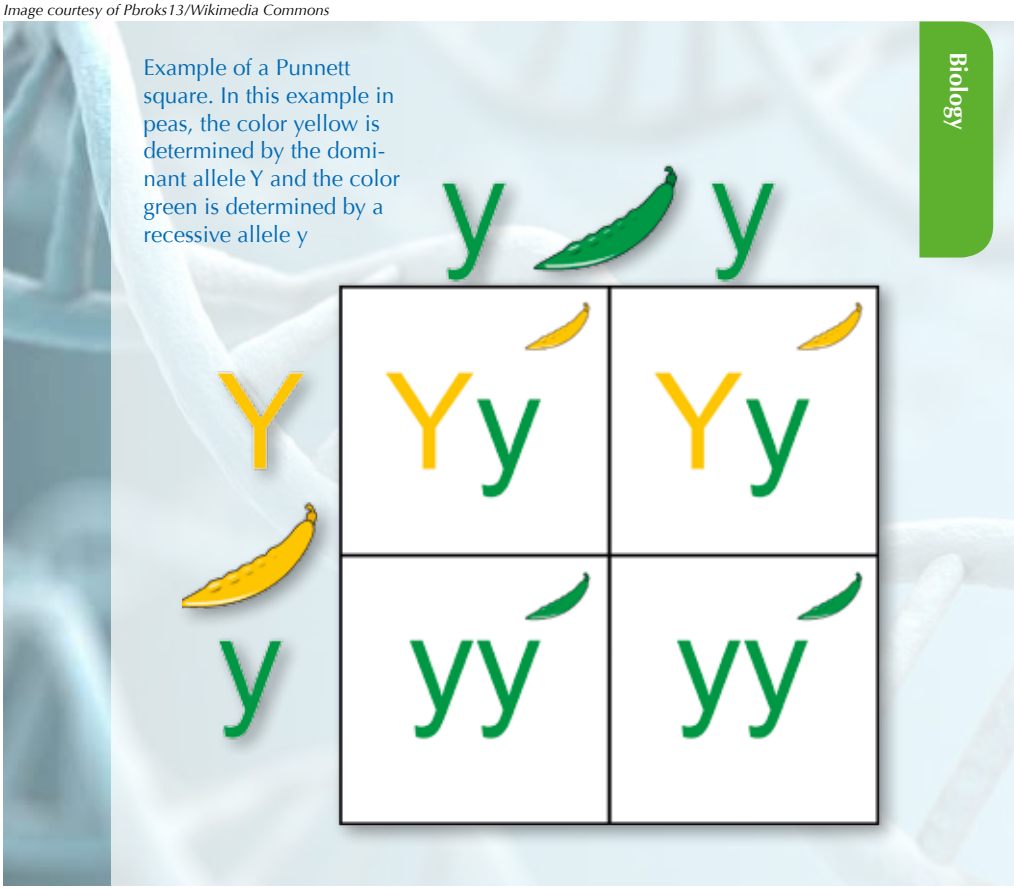
CLASSROOM ACTIVITY

Building a family: using crosses to determine the genotype and phenotype of offspring

Student pairs should then randomly select the gender of up to seven children by tossing a coin or picking marked cards from a bag. To make the activity more realistic, we also included phrases such as 'twin boys' or 'triplet girls' in the bag. Once the genders of children have been selected, the student pairs can construct genetic crosses for their heritable traits. Students should then use worksheet two[w2] to organise the genotypes and phenotypes for their families as they construct their crosses. Remind students that genetics is very complex and that in the real world, relationships cannot be established by considering a small number of traits that may also be affected by environmental factors.

Once the genotypes and phenotypes are determined for each of the possible offspring, the family portraits may be constructed. Students are provided with crayons, coloured pencils, paints and construction paper. The portrait for each child must accurately depict the phenotypes obtained during their genetic crosses. Students can be as imaginative and creative as they would like during this phase of the project (figure 1). Perhaps the most intriguing aspect of this project is its interdisciplinary nature. We were able to incorporate this project into the art teacher's unit on composite sketches and portraits.

Image courtesy of Pbroks13/Wikimedia Commons



Example of a Punnett square. In this example in peas, the color yellow is determined by the dominant allele Y and the color green is determined by a recessive allele y

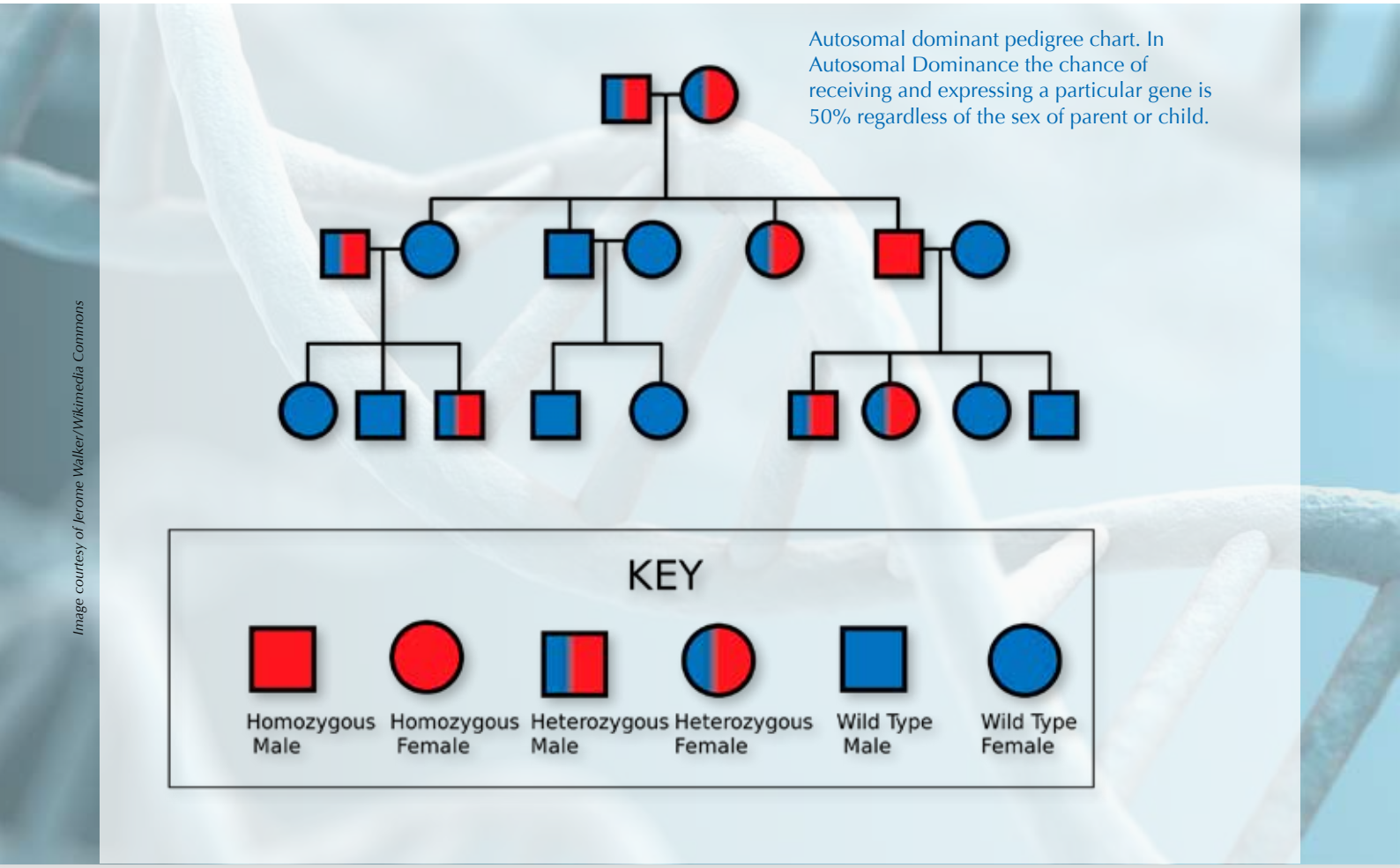
Evaluation

We have provided an evaluation rubric to assist the teacher in gauging whether students have accurately depicted a family portrait, accounting for the genotypes and phenotypes of each parent and all offspring (see box). Students will submit all illustrations and Punnett squares for evaluation as well. One of the hallmarks of this activity is that it provides multiple forms of authentic assessment for students to showcase their learning. Students who are comfortable with working in teams and artistically depicting information reached proficiency with construction of the family portrait. Students who are strong writers were very comfortable and successful completing the worksheets.

It is strongly encouraged that formative assessment occurs throughout the lesson by observing students' knowledge and/or skills, noting their application of new concepts and change in thinking, not just factual recall.

Summary and Conclusion

Biology is a fascinating discipline to motivate students' curiosity and engagement, particularly in the study of genetics. Students often struggle to make integral connections between different concepts and may not see the real-life applications of what they are learning. By providing dynamic assessments that allow students to have conversations and receive real-time feedback on their strengths and weakenesses, we can only increase students' information retention (Van Scotter & Pinkerton, 2008). These balanced assessments also provide students with expectations at the beginning of a project, so they know ahead of time what is important and what characteristics a high-quality assessment product will have.



Autosomal dominant pedigree chart. In Autosomal Dominance the chance of receiving and expressing a particular gene is 50% regardless of the sex of parent or child.

Image courtesy of Jerome Walker/Wikimedia Commons

Web references

w1 –To download worksheet one in Word or PDF format, visit: www.scienceinschool.org/2014/issue30/family_genetics#w1

w2 – To download worksheet two in Word or PDF format, visit: www.scienceinschool.org/2014/issue30/family_genetics#w2

References

Nowak JA, Plucker JA (2002) Do as I Say, Not as I Do? Student assessment in Problem-Based Learning. *Inquiry: Critical Thinking Across the Disciplines* **21**(2): 17–31

Van Scotter P, Pinkerton, KD (2008) Assessing science as inquiry in the classroom. In Luft J, Bell RA, Gess-Newsome J (eds) *Science as inquiry in the secondary setting* pp 107–119. Arlington, VA, USA: NSTA Press. ISBN: 9781933531267

Resources

Family genetics can expose family secrets, and you should always be careful of this when working with your students. The problem becomes even more amplified with the use of genetic testing services, for example see: http://tinyurl.com/nd7mnku

If you found this article interesting please browse the other teaching activity articles on the *Science in School* website: www.scienceinschool.org/teaching

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

A classroom hydrogen economy

Could hydrogen be the best alternative for fossil fuels? This demonstration shows how a hydrogen economy might work in practice.

By Mario Mitov and Yolina Hubenova

Chemistry

Physics

While fossil fuel resources are slowly being exhausted, the growing population of our planet is consuming ever more and more energy. We now know that the use of traditional carbon-containing fuels has seriously worsened environmental pollution, which makes the development of environmentally friendly energy production increasingly important.

One of the most plausible scenarios for the production of so-called 'green' energy is the hydrogen economy. Hydrogen has a higher energy density by weight than traditional fossil fuels and it also releases fewer greenhouse emissions. When hydrogen is burned directly or oxidised in fuel cells to obtain heat and electricity, the only product is water.

Although some companies have been developing new engines based on the internal combustion of hydrogen, fuel cells are the main energy converters on which the concept of the hydrogen economy is based.

Fuel cells were first invented in the first half of the 19th century, when

REVIEW

- Biology
- Chemistry
- Age 15+

This article describes a practical activity to explain the concept of the hydrogen economy, which could be used to introduce the applications of oxidation-reduction reactions. Although the activity requires materials not normally included in standard school equipment, it would be possible to obtain them quite easily.

Chemistry is sometimes seen as contributing to pollution and damage to the environment, but this text shows that it can also have a very important role in protecting the environment.

Finally, this article could also be used as a starting point to think about the advantages and disadvantages of the energy sources currently used by our society and the need to find alternatives to fossil fuel resources.

Mireia Güell Serra, Spain

British physicist William Grove suggested that if water could be split into hydrogen and oxygen by electricity, then combining the two elements could generate electricity. However, as fossil fuels became dominant, fuel cells fell by the wayside.

In the 1960s, NASA used alkaline hydrogen fuel cells in their Apollo space vehicles and later in the space shuttles to produce both electricity and water. Now the technology may get another boost.

The production and use of fuel cells are still quite limited, mainly because production and storage of hydrogen are very expensive, as are the catalysts used in the most efficient fuel cells. However, as technology improves and fossil fuels become more expensive, fuel cells are expected to replace existing energy sources and converters.

Demonstrating the principle

To explore how fuel cells work, we have developed a low-cost fuel cell for use in the classroom. The resulting electrolyser and fuel cell can be used as part of a setup to demonstrate how hydrogen might be produced and used.

The following criteria for the models were chosen:

1. Materials must be accessible and cheap;
2. The whole construction should be comparatively easy to allow others to observe the phenomena and processes;
3. The prototypes should be safe to make.

Here we describe the materials and procedures required for constructing a water electrolyser and hydrogen fuel-cell prototype for the classroom.

Figure 1: Connection of the electrolyser electrodes to a solar panel

Image courtesy of Mario Mitov

CLASSROOM ACTIVITY

Classroom activity

Materials and reagents

- Plastic syringes (50 ml)
- Graphite rods or pencil leads
- Carbon gas-diffusion electrodes pressed on Ni-mesh
- Small flexible piping with valves
- T-shaped glass connector
- Plastic vessel (bottle) for the electrolyte
- Laboratory stand with clamps
- Aluminium or copper foil
- Grease-proof paper
- Hot-plate
- Glass vessels (400 ml beakers)
- Isolated copper wires with connectors
- Drill
- Silicon paste
- 6–12 V DC power source (solar panel or 9 V battery)
- End consumer (low-powered electromotor with fan, LED)
- Set of resistors
- Two multimeters, or a voltmeter and an ammeter
- 1 M H_2SO_4
- 2 M HNO_3 (for etching)
- $PdCl_2$ solution prepared by dissolving 1 g of the salt in 50 ml of 0.5 M HCl. Heat to 50°C and then dilute to 100 ml with distilled water.
- 1 M KOH or NaOH
- Gloves and goggles

Procedures

*The steps marked with asterisks should be performed by the teacher for safety.

Constructing the electrolyser

1. *Remove the plungers and needles from two syringes.
2. *Remove the rubber gaskets from the plungers and make a hole for a graphite rod electrode in each of the rubber gaskets.
3. Push the graphite rods into these holes and insert the rubber gaskets back into the syringes.
4. *Drill holes into the sides of both syringes about 1 cm from the bottom. The holes should be about 1 mm bigger than the outer diameter of your T-shape connector.
5. Attach 1 cm lengths of hose to both edges of the T-shape connector.
6. Connect the syringes with the T-shape connector.
7. Use the hose to connect the electrolyte container with the free edge of the T-shape connector.
8. Connect the thin flexible tubes to the narrow ends of the syringes.
9. *Pour 1M H_2SO_4 into the electrolyte container until the electrolyte fills both syringes.
10. Connect both electrodes by copper wires to the power source (figure 1).

Constructing the fuel cell

1. *Remove the plungers and needles of two syringes.
2. *Cut two pieces from the gas-diffusion electrodes to completely cover the flange of the syringes.
3. *Place a piece of aluminium or copper foil on a hot-plate, put grease-proof paper on it, and then place the shaped gas-diffusion electrode on the paper.
4. *Press the flange of a syringe onto the gas-diffusion electrode – due to the high temperature, the plastic will melt and the electrode will stick to the syringe.
5. *Drill a hole through one side of the flange and the sealed gas-diffusion electrode.
6. Push a metal screw through the hole.
7. Remove the insulation from one end of a piece of copper wire, make several loops around the screw and tighten it with a nut.
8. Isolate the bolt with silicon paste.
9. Repeat steps 3 to 8 to make the second electrode.
10. *Etch the electrodes by immersing them in 2 M HNO_3 for 5 minutes, then wash with water.
11. *Pour the solution of $PdCl_2$ into the 400 ml beaker and immerse the prepared electrodes in it for 5 minutes. Based on the reactivity series of metals, a thin catalytic layer of elemental palladium is deposited on the gas-diffusion electrodes when palladium ions come into contact with the carbon and nickel mesh.

12. *Pour 100 ml 1 M NaOH (or KOH) into another beaker and place both syringes with sealed electrodes in it (figure 2).
13. Connect these syringes to the two thin hoses from the electrolyser.

Image courtesy of Mario Mitov

Figure 2: Construction of the fuel cell

Image courtesy of Mario Mitov

Figure 3: Demonstration of the stoichiometry of the water decomposition

After collecting some quantity of hydrogen and oxygen, stop the gas production and open the valves to allow the gases to pass to the electrodes of the fuel cell (figure 4).

Image courtesy of Mario Mitov

Figure 4: a) Opening the valves to allow the gases to pass to the electrodes of the fuel cell; b) electricity generation by the fuel cell

Image courtesy of Mario Mitov

Students can then measure the electrical parameters of the fuel cell by using the circuit described in figure 5. The current, *I*, is calculated according to Ohm's law:

$I = V/R$

Figure 5: Electric scheme for fuel cell testing

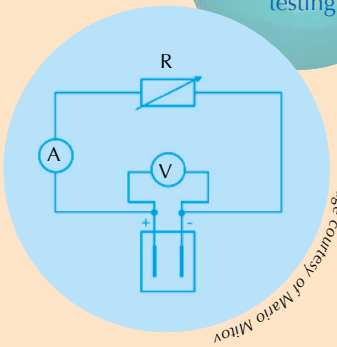

Image courtesy of Mario Mitov

Instead of a resistor, a light emitting diode (LED) or low-power electromotor can also be used.

An important advantage of this system is that each of the basic modules can be replaced by other devices. For example, a special wind turbine can be used instead of a solar panel to generate the electricity that is necessary to supply the water electrolyser. Or, instead of a water electrolyser as a source of gaseous hydrogen and oxygen, gas generation by chemical reaction (figure 6) can be used.

Image courtesy of Mario Mitov

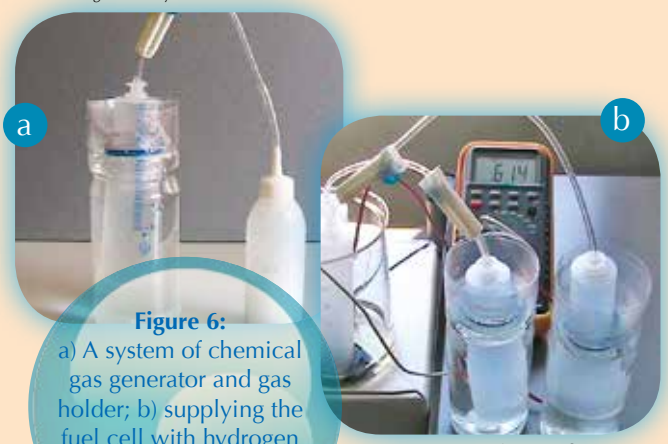

Image courtesy of Mario Mitov

Figure 6: a) A system of chemical gas generator and gas holder; b) supplying the fuel cell with hydrogen and oxygen collected in gas holders

Other versions of a fuel cell, using liquid fuel (for example, ethanol instead of hydrogen), can be also developed.

Both the electrolyser and the fuel cell in the proposed ecological energy system could be replaced by our DeMi Cell, which works on the principle of reversible fuel cells[w1]. Because DeMi Cells use non-dangerous salt electrolytes, they more easily satisfy safety requirements.

With some basic theoretical background, students from different educational stages are able to develop prototypes of advanced and sophisticated technologies (figure 7).

Image courtesy of Mario Mitov

Figure 7: Prototypes of water electrolyser, fuel cell and gas holders

A practical demonstration

Linking together the electrolyser and fuel cell with a solar panel, as shown in figure 1, can demonstrate how solar energy can be stored as hydrogen and then converted back into electricity. The electricity needed to power the water electrolysis can be generated by shining an artificial light source onto the solar panel, after which the evolved gases are collected above the electrolyte in the separated parts of the electrolyser (syringes). Valves stop the gases passing from the electrolyser to the fuel cells until it is needed.

The syringes also help to show that the volume of the gas from the anode is twice the volume of the gas from the cathode: 2 moles of hydrogen and 1 mole of oxygen are produced from 2 moles of water (figure 3):

(−) $4\ H_2O + 4\ e^- \rightarrow 2\ H_2 + 4\ OH^-$

(+) $4\ OH^- \rightarrow 2\ H_2O + O_2 + 4\ e^-$

Summary $2\ H_2O \rightarrow 2\ H_2 + O_2$

Web reference

w1 – For more information on the DeMi cell, see: www.eef-bg.org/demi.html

Resources

Lex Solar provide kits with fuel cells and other renewable energy sources for school. See: www.lexsolar.de

This book provides an introduction to the topic of fuel cells and the hydrogen economy:

Cook B (2001) *An Introduction to Fuel Cells and Hydrogen Technology*. Vancouver, Canada: Heliocentris

For more information on Mario Mitov's work, you can read

Mitov M, Kondev I, Petrov Y, Bliznakov S, Popov A (2003) Fuel cells – Achievements and Perspectives. *Khimiya* **12:** 455–466 (only available in Russian)

Mitov M, Petrov Y, Manev S (2005) Demonstrational Fuel Cells. *Khimiya* **14:** 440–445 (only available in Russian)

Another type of fuel cell is the microbial fuel cell, which brews electricity instead of beer. You can read about how to use one of these in the classroom in

Madden D (2010) The microbial fuel cell: electricity from yeast. *Science in School* **14**: 32–35

www.scienceinschool.org/2010/issue14/fuelcell

For a complete list of all teaching activities published in Science in School, see: www.scienceinschool.org/teaching

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Mario Mitov graduated as a chemical engineer in electrochemical production and power sources at the University of Chemical Engineering and Metallurgy, Sofia, Bulgaria, in 1985 and began his professional career at the Department of Chemistry at South-West University, Blagoevgrad, Bulgaria, in 1987. Currently, Prof. Mitov delivers lectures on general and inorganic chemistry, physicochemistry and electrochemistry at the same university. His research interests focus on the characterisation of nanomaterials as potential electrodes for rechargeable batteries and fuel cells and on the investigation of bio-electrochemical systems such as microbial fuel cells and microbial electrolysis cells.

Yolina Hubenova received her MSc in biotechnology – gene and cell engineering) from St. Kliment Ohridski University of Sofia and completed three years specialisation in medical biology at the Medical University Plovdiv. In 2005, Yolina Hubenova was awarded the postgraduate academic degree Dr.rer.nat. in Neurobiochemistry by the Friedrich Wilhelm University Bonn. In 2013, she successfully defended her second dissertation, earning her a Doctor of Science from the St. Kliment Ohridski University of Sofia. She now works at the Department of Biochemistry and Microbiology of Paisii Hilendarski University of Plovdiv, Bulgaria. Yolina delivers lectures on ecological biochemistry, clinical biochemistry and protein engineering at the same university. Her research interests are in the field of bio-electrochemical systems development and the extracellular electron transfer in biofuel cells.

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

Lunar Diary: a chronicle of Earth's journey through space and time, as seen from the Moon

Clues to the history of the Earth, the Milky Way and the Universe are hidden on the lunar surface.

By Erin Tranfield

The Moon has been Earth's constant companion for approximately 4.5 billion years. Together they have travelled around the Sun and the Milky Way galaxy. They formed together, have evolved together and experience a shared history. What makes the Moon so scientifically interesting is that, compared with Earth, it is a very simple place. It lacks the protective atmosphere of Earth, has no wind or rain, and its surface is not remodeled by tectonic activity. Because of this, the ancient surface of the Moon bears the marks and the chemical history of its journey alongside Earth and preserves evidence of the earliest geological history. The Moon can tell us the story of the formation of the inner Solar System planets and is a diary of the journey of the Earth and Moon. It can tell us about the places our planet has been, and about the fellow travellers we have met along the way.

In this two-part series, I will first introduce why scientists wish to return to the Moon, what scientific questions remain and why it is important to find the answers. The second article (in the next issue) will focus on the challenges of returning to the Moon and obtaining these answers.

This image was taken by Galileo as it flew by the Earth–Moon system in 1992.

Image courtesy of NASA

Humankind landed on the Moon six times between 1969 and 1972. In 1972, your students were not born, cell phones did not exist, computers were the size of a room, and the scientific knowledge and technical abilities were rudimentary compared to today. Science and technology have come very far since humans stood on the Moon, and lunar exploration is now approached differently.

Image courtesy of Ben Schumin/Wikimedia commons

A mobile cell phone from 2002

Image in the public domain/Wikimedia

Modern mobile phone

Image in the public domain/Wikimedia

Computer in the 1960s, from the North American Aerospace Defense Command

Image courtesy of Aido2002/Wikimedia commons

Recent computer from 2006

Map showing the landing sites of the Apollo, Luna, and Surveyor missions

Image courtesy of NASA

Twelve men walked on the Moon during the six Apollo missions[w1]. With them, they brought back 382 kg of lunar material[w2]. The Soviet Union also had a very active lunar exploration program and although they did not send humans, they did send robots to the lunar surface[w3]. Among a number of robotic surface missions, three Soviet Luna missions returned a total of 300 g of lunar material[w2,w4]. The samples from the Apollo missions are stored at a special facility in Houston, Texas, USA, while the Luna samples are stored at the Verndasky Institute in Russia. These samples are still studied by scientists to this day, and continue to produce new and unexpected scientific results.

Although we have been to the Moon, we have barely scratched the surface in terms of exploring it or understanding what it has to tell us about ourselves. As aliens landing on a dune in the Sahara desert could never say they had explored or understood Africa, so is the extent of our exploration of the Moon today.

History of the Earth and Solar System

The formation of the Moon is still a matter of scientific debate. The leading scientific theory is that a large body called Theia slammed into Earth, destroying Theia and causing massive destruction of Earth[w5]. A large cloud of debris was ejected, and over time it collected together to form the Moon. However, there are inconsistencies in this model and computer simulations do not yield Earth and the Moon as we know them today. Detailed chemical analysis of lunar samples from new locations would give scientists more information about the composition of the Moon and would expand our growing understanding of how the Moon was formed (see Herwartz et al., 2014, for evidence of Theia in lunar soil samples).

To establish the age of lunar samples, scientists rely on the analysis of

Image courtesy of the US Army Cold Regions Research and Engineering Laboratory

Researchers with the ERDC Cold Regions Research and Engineering Laboratory (CRREL) use a trencher to prepare an area of the Pegasus White Ice Runway, McMurdo Station, Antarctica, to install temperature probes.

the ratio of different parent–daughter isotopes[w6]. By extension, this method can also be used to identify the age of the specific terrains and craters from which the samples were taken[w7]. When scientists combine this information with the number of craters in a given terrain, they can estimate how many meteorite impacts have happened over time. From this information, the ages of cratered surfaces elsewhere on the Moon and throughout the inner Solar System can be inferred. As scientists learn more about the impact history of the Moon, more precise deductions can be made about the impact history of Earth that has been erased over time by our environment (e.g. by wind, rain and plate tectonics).

NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) Mission confirmed that there is water ice, as well as frozen gases (such as methane, ammonia, hydrogen gas, carbon dioxide and carbon monoxide) in permanently shadowed regions of the lunar poles[w8]. Lunar ice is a mixture of all the ice delivered to its surface dur-

Image in the public domain/Wikimedia commons

US Air Force firefighters in suits with an outer aluminized shell go through a decontamination line during an emergency management exercise.

ing impacts, and analysis of this ice could be useful in understanding the origins of water on Earth. In addition, lunar ice is thought to be a trap and a good place to look for frozen gases and reactions that may have formed pre-biotic chemistry. Some theories suggest that the early precursors of life on Earth may have been delivered by or formed during icy impacts[w9], so the analysis of the lunar ice could also help researchers to understand the very early origins of life on Earth.

Travel beyond the Moon and into space

The Moon can also be used as a testing location for missions to Mars and other planetary bodies. Much has been learned in remote environments on Earth and in the International Space Station (ISS) but the Moon represents a greater level of difficulty than what has been previously achieved. Mars will be an even bigger challenge than the Moon; any challenges must first be overcome on the Moon, which is closer to Earth, before we can hope to succeed on other distant planetary bodies. The Moon can be the testing grounds for:

- **building a base on another planet**. We can use the experience from remote bases such as Arctic and Antarctica research stations, but there is much to learn about building a habitat off our planet. To explore this further with your students, please refer to a lesson on space habitats[w10].
- **developing and implementing procedures to use the natural resources on the lunar surface** to reduce what must be brought from Earth (known as in situ resource utilisation (ISRU)). Local resources could supply material needed for building habitats, shielding astronauts from radiation, supplying raw material for life-support systems and even for fuel for planetary exploration. Their use is actively being tested by

European Space Agency astronaut Frank De Winne, Expedition 21 commander, exercises on the Combined Operational Load Bearing External Resistance Treadmill (COLBERT) in the Harmony node of the International Space Station.

Image courtesy of NASA

REVIEW

- Physics
- Astrophysics
- Geography
- Biology
- Ages 10–19

This article (part 1 of 2) gives an overview of how the Moon has formed, our visits to the Moon's surface, and their scientific benefits. When travelling into space, e.g. to Mars and beyond, the Moon seems to be an important testing area for the preparation of the journeys – some of these challenges are summarised in the article and will be discussed in part 2.

This article would be useful not only for physics, but also for geography, different languages and biology.

Comprehension questions could include:

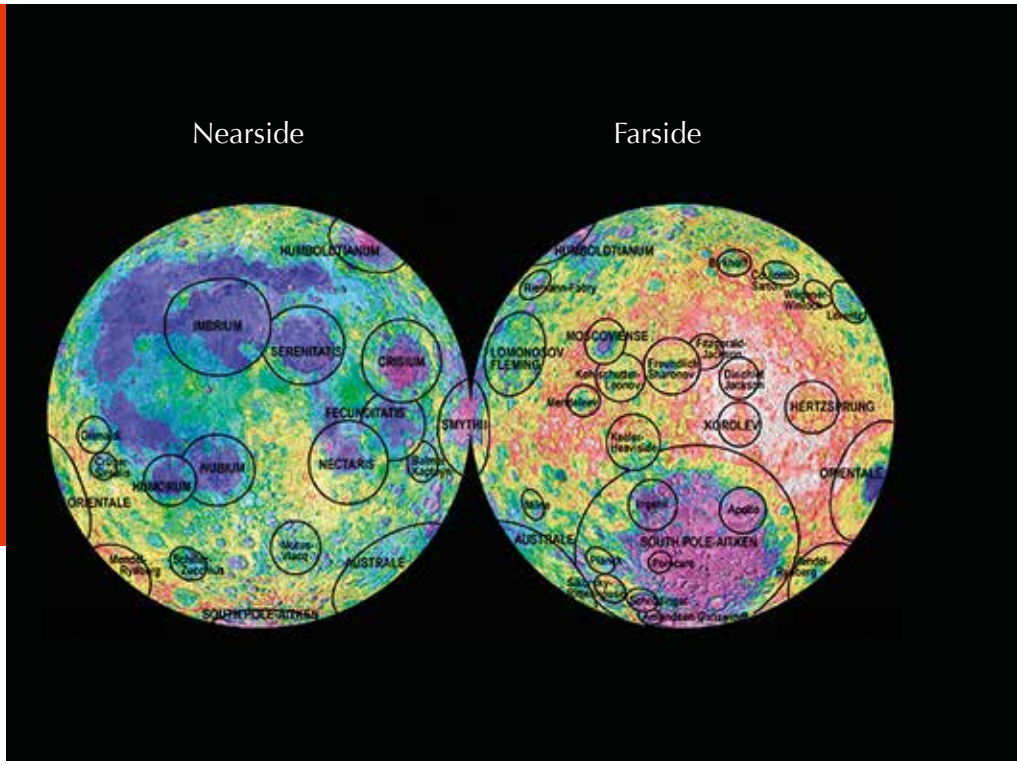
- How was the Moon formed?
- Why did humankind visit the Moon? How often have they visited, and which nationalities were involved?
- What are the differences between the Moon's surface and atmosphere and Earth's?
- Why could the Moon become important for further planetary explorations?

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

Earth science

Image courtesy of LPI (Paul Spudis and David Kring)

Lunar Impact Basins
The most energetic impact events on the lunar surface produced immense impact basins of more than 300 km in diameter. The colour-coded topography ranges from 8 kilometers below a global mean (black to dark purple) to 8 kilometers above a global mean (white). The largest and deepest basin is the South Pole-Aitken Basin. The youngest and best preserved basin is the Orientale Basin. This inventory of basins is based on Apollo-era analyses. New efforts to detect other basins are underway.



space agencies[w11] and this work will feed knowledge to the lunar and planetary missions.

- **dealing with health and equipment hazards** such as radiation and lunar dust. Experience from industries such as nuclear power plants and mining will help us, but would need to be adapted before being implemented on the lunar surface. Water is believed to be a good radiation shield, but how do we get water on the Moon? It is too heavy to carry there in large quantities, so it would need to be harvested or made on the Moon.
- **operating missions with limited food and water** – submarine, polar and ISS missions can help inform us, and efforts should be made to grow food on the Moon.
- **equipping a habitat with the right tools** – submarine, polar and ISS

Image in the public domain/Wikimedia commons

The helm of the Ohio-class guided-missile submarine, USS Florida (SSGN-728), in March 2010

Image in the public domain/Wikimedia commons

Russian space suit 'Sokol'

missions can help us create equipment lists, and a workshop on the Moon may be needed to build and repair small pieces of equipment. Furthermore, three levels of redundancy must be built in for life-support equipment to ensure astronaut safety.

- **dealing with medical emergencies far from medical personnel** – submarine, polar and ISS missions have taught us a lot, but questions remain about treating infections, dealing with minor surgeries or even a sore tooth. A partial solution could be to have a doctor as part of the crew.
- **studying the psychology of living in an extreme environment** away from family, friends and modern conveniences. Much has been learned from isolated missions, but there are discussions of how to realistically test this psychological stress. Simulation participants know it is just a simulation and it will end. How will people feel watching Earth shrink into a tiny speck as they spend months travelling in a tiny capsule to Mars? There may not be a way to accurately simulate such an experience.

The Moon could also become a staging post for planetary exploration. Lunar resources could be used to generate fuel and consumables such as oxygen. The base on the Moon could become a collecting point for Earth resources and Moon-made resources from which missions to other planets could be prepared. The reduced lunar gravity makes launching planetary exploration missions from the lunar surface much less energy-demanding when compared to launches from Earth. Desert and polar missions can be used as a test location, but the best place to test this is on the Moon.

There are many scientific and exploration reasons to return to the Moon. In the next decade, many different space agencies, countries and the private sector have planned robotic missions. The next challenge is to determine how we get there and how

Barringer Meteor Crater in Arizona, USA

Image in the public domain, courtesy of the U.S. Geological Survey

Detailed and annotated artist's conception of the spiral structure of the Milky Way with two major stellar arms and a bar. This version of the image has been updated to include the most recent mapping of the shape of the central bulge deduced from survey data from ESO's VISTA telescope at the Paranal Observatory.

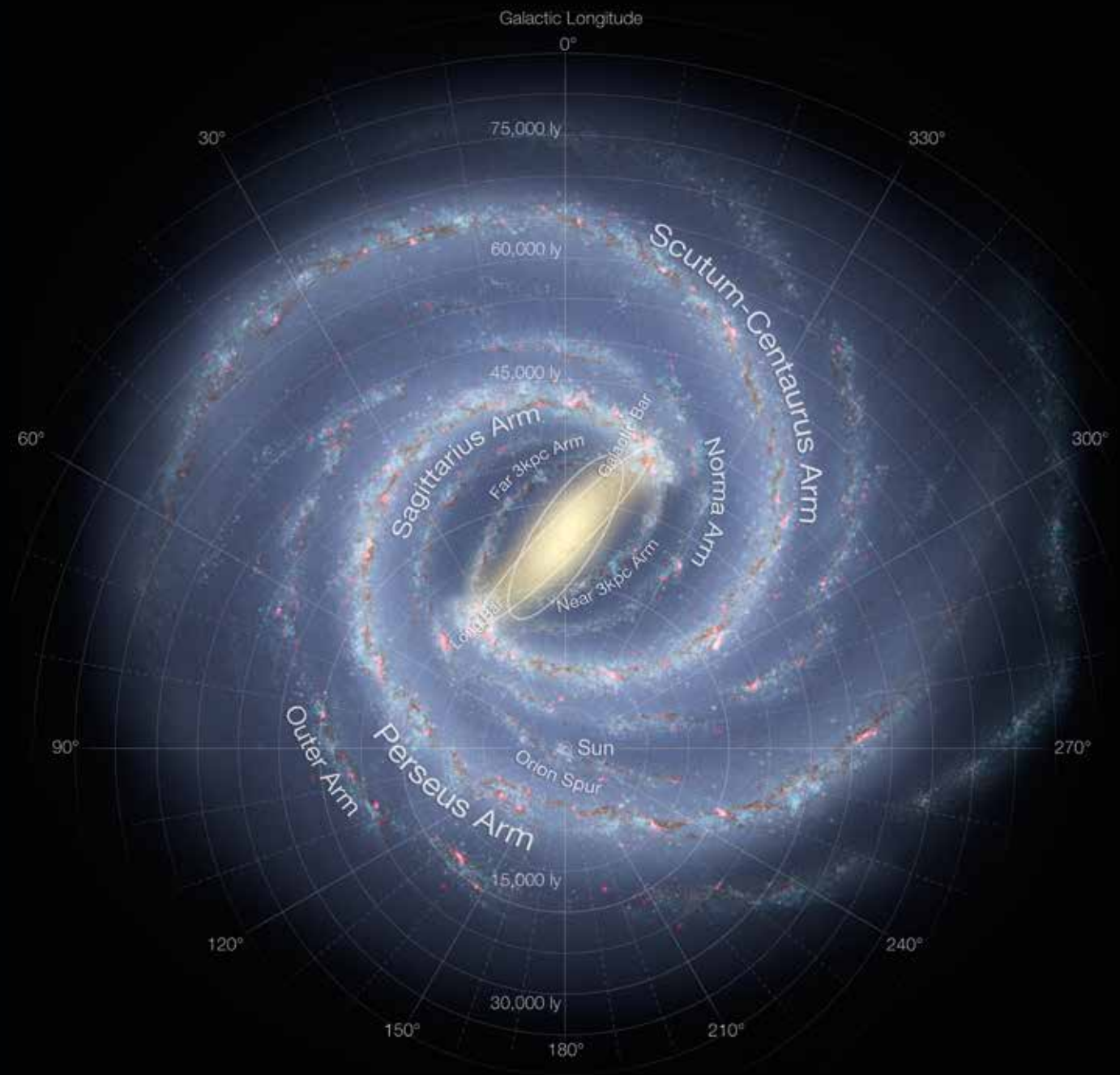


Image courtesy of NASA/JPL-Caltech/ESO/R. Hurt

we return samples and knowledge. Stay tuned to the next issue of *Science in School* for some ideas.

Acknowledgements

Thank you to James Carpenter at the European Space Agency for valuable feedback on the article.

Reference

Herwartz D, Pack A, Friedrichs B, Bischoff A (2014) A study reporting isotopic traces of Theia: Identification of the giant impactor Theia in lunar rocks. *Science* **344**(6188): 1146–1150

Web references

w1 – NASA has provided a brief overview of the Apollo programme and its missions to Mars. See: http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo.html

w2 – To find out what happened to the lunar samples brought back by the Apollo missions, see: http://curator.jsc.nasa.gov/lunar/index.cfm

w3 – Compare the goals of the various missions sent to, or around, the Moon: www.lpi.usra.edu/lunar/missions/

w4 – The Lunar and Planetary Institute of the Universities Space Research Association provides a summary of the Luna missions launched by the Soviet Union. See: www.lpi.usra.edu/lunar/missions/luna/

w5 – In an article entitled 'How did the Moon form?', a short video explains one possible theory. See: www.universetoday.com/19718/formation-of-the-moon/

w6 – To learn more about parent-daughter isotopes, see: http://eesc.columbia.edu/courses/ees/lithosphere/labs/lab12/radioisotope_tutorial.html

w7 – For more information about the impact craters on the Moon and what we can learn from them, see: www.lpi.usra.edu/education/explore/shaping_the_planets/impact_cratering.shtml

w8 – NASA have a website dedicated to LCROSS. To read more about this satellite, see: www.lcross.arc.nasa.gov/observation.htm

w9 – The origin of life on Earth has been linked to impacts of ice comets. To read more about this, see: www.redorbit.com/news/space/1112948254/icy-comet-impacts-provide-building-blocks-life-091613/

w10 – Want to build a space habitat in your classroom? Check out this article from a previous issue: Tranfield E (2011) Building a space habitat in the classroom. *Science in School* **19**: 43–49. www.scienceinschool.org/2011/issue19/habitat

w11 – Read more about NASA's effort to develop In-situ Resource Utilisation procedures: http://isru.msfc.nasa.gov/

Resources

For more information on how astronomers estimate the age of Mars by crater counting, see this article from a previous issue: de Pablo MA, Centeno JD (2014) Glaciers on Mars: looking for the ice. *Science in School* **28**: 12–17. www.scienceinschool.org/2014/issue28/mars_glaciers

In 'Ice on the Moon', NASA reseachers explain the origin of ice on the moon and why it is so interesting: http://nssdc.gsfc.nasa.gov/planetary/ice/ice_moon.html

To browse through the full list of space science-related articles on the *Science in School* website, visit: www.scienceinschool.org/space

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

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

From methional to fried chicken

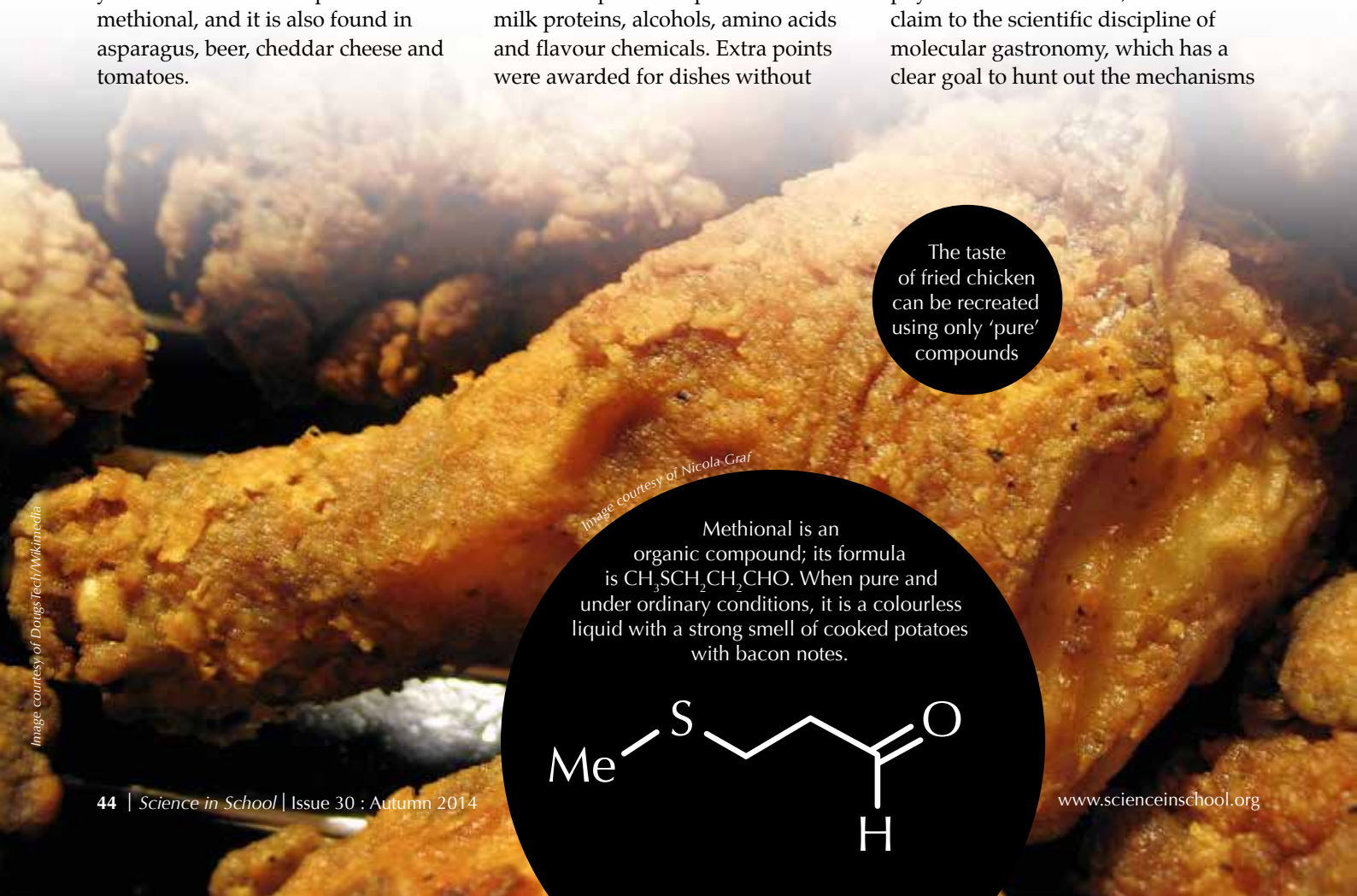
Methional played centre stage at the recent Second International Contest for Note by Note Cooking. The challenge: to make dishes containing only methional and 'pure' compounds such as milk proteins, alcohols, amino acids and flavour chemicals, and, ideally, no plant tissues, meat, fish or eggs.

By Emma Davis

Drain a pan of boiled potatoes and the steam that rushes past your face brings with it an unmistakeable earthy smell, with an underlying hint of bacon. The chemical hitting your nose's odour receptors is called methional, and it is also found in asparagus, beer, cheddar cheese and tomatoes.

The simple, sulfur-containing derivative from the amino acid methionine played centre stage at the recent Second International Contest for Note by Note Cooking[w1] in Paris, France. The challenge: to make up to three dishes, all containing only methional and other 'pure' compounds such as milk proteins, alcohols, amino acids and flavour chemicals. Extra points were awarded for dishes without plant tissues, meat, fish and eggs.

The contest was organised by Hervé This[w2], a physical chemist from the French National Institute for Agricultural Research, who came up with the concept of 'note by note' cooking. In 1988, together with the late Oxford physicist Nicholas Kurti, Dr This laid claim to the scientific discipline of molecular gastronomy, which has a clear goal to hunt out the mechanisms



The taste of fried chicken can be recreated using only 'pure' compounds

Image courtesy of Nicola Graf

Methional is an organic compound; its formula is $CH_3SCH_2CH_2CHO$. When pure and under ordinary conditions, it is a colourless liquid with a strong smell of cooked potatoes with bacon notes.

Image courtesy of DougsTech/Wikimedia

REVIEW

- Physics
- Food technology
- Chemistry
- Biology
- Ages 14–18

Odours play an important part in memory and can be strongly linked to experiences. This is due to the olfactory receptors. This is the key idea in making 'foods' that bring the gastronomic experience without the primary animal and plant protein present. This article could be used to stimulate discussion on the world food shortage and how alternatives could be manufactured. How would the manufacturers ensure that nutritional guidelines are met? Students could investigate food labels, research the key chemicals that produce particular flavours, and study how flavourings are manufactured for foods – for example, how are potato crisp flavours made? The concepts and science of molecular gastronomy could be discussed, as some chefs are now using scientific techniques to advance food preparation and presentation.

Dr Shelley Goodman, UK

Image in the public domain/NIH

underlying cooking, tasting and eating food. Chemistry and physics are at its core.

The field spawned a generation of inventive chefs who brought lab equipment, from rotary evaporators to water baths, into the kitchen. Liquid nitrogen hit the culinary scene, as did a host of tricks with gelling agents, producing soft gel pearls with a liquid core packed full of flavour.

'Note by note' cuisine?

Initially intended to improve food, 'note by note' cuisine soon morphed to acquire the ambitious goal of making dishes entirely from compounds, Hervé This says. "I don't want to recreate anything. The proposal with 'note by note' is to create new food." He equates the approach with using a synthesiser to make music. "With a synthesiser you can make any music. With 'note by note' cuisine you can make any food."

Dr This envisages a time when we will routinely assemble food from ingredients taken from jars and bottles in our kitchens. "'Note by note' will be the future," he insists. "If the public wants and needs it, it will happen."

Importantly, he sees 'note by note' as a solution to the inevitable food crisis that lies ahead as the world's population continues to expand.

One of the key advantages of this type is cuisine is its ability to cut transport needs. Dr This takes the example of tomatoes. When fresh, the fruit is heavy and water-laden. Why transport the water, asks Dr This. Instead, necessary nutrients and flavours could be extracted at the farm site and reintroduced when the tomatoes are needed. He compares this process to transporting cheese instead of milk, or wine instead of grapes.

Dr This is almost evangelical about 'note by note' cuisine, and has been busy touring the USA and Europe to spread the word. "The contest is one

Image courtesy of the Dublin Institute of Technology/Wikimedia

Hervé This at Dublin Institute of Technology, with a student demonstrating how to achieve a greater volume when whipping egg whites.

Turning juices and other liquids into pearls using soft gels is a popular technique in molecular gastronomy

Image in public domain/Wikimedia

Cheddar cheese is another food that contains methional

Image in the public domain/Jon Sullivan

of many pieces to implement 'note by note' cooking for everybody," he says. This year, it was a "big success".

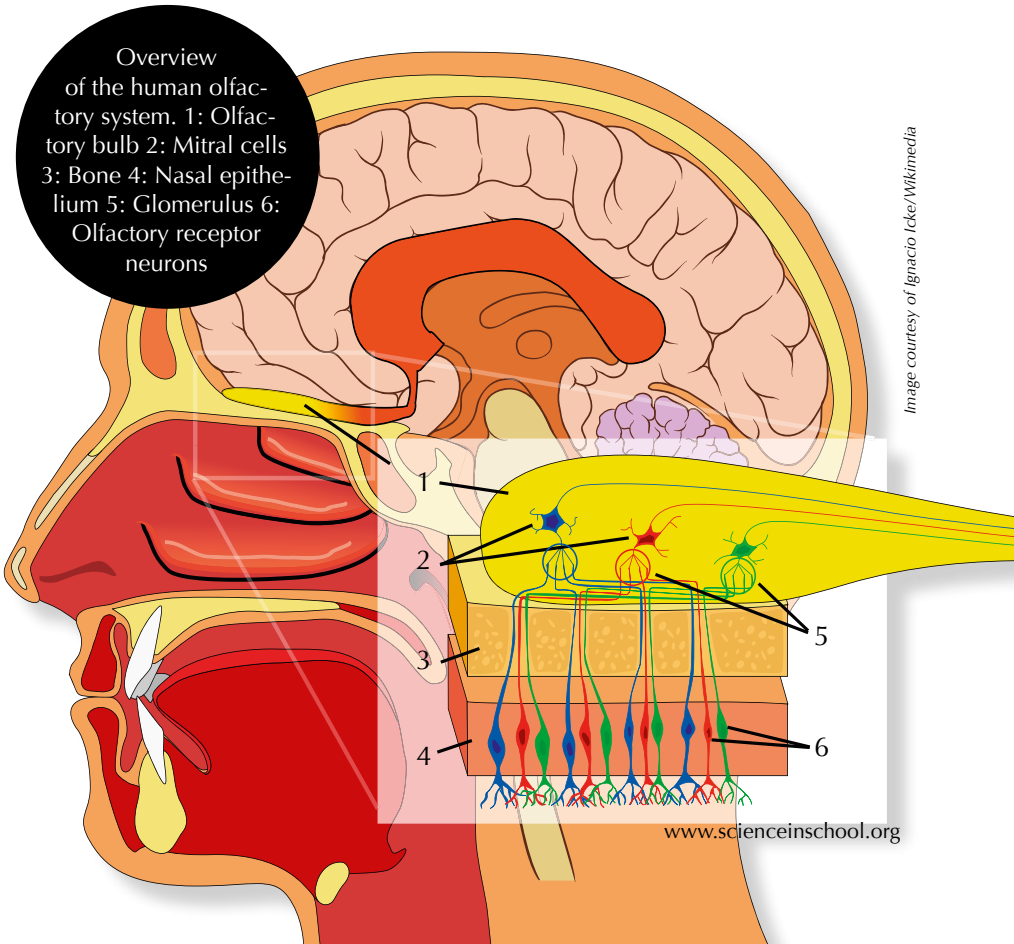
Seventy-three contestants battled it out for five prizes in different categories. An undergraduate team studying molecular gastronomy at the Dublin Institute of Technology, Ireland, won the student prize with its novel roast chicken creation[w3]. This was developed in response to a specific challenge to make a dish that is neither extraordinary nor extravagant yet evokes memories. Their creation consisted of a wafer or tuile of roast chicken, with a smattering of accompaniments. They made powdered 'potato' by mixing a methional solution in oil with maltodextrin, citric acid and salt, and turned it into a potato meringue. This sat alongside rosemary caviar made from sodium alginate, and a roasted carrot tuile made by mixing powdered carrot with maltodextrin, sugar, a gel and water. The resulting gel layer was then dehydrated until it became crispy.

Next year's contest will focus on plant protein, Dr This says. With demand for meat soaring across the globe, creating foods from plant proteins will become increasingly important, he says.

For Dr This, part of the challenge is to persuade companies to sell ingredients such as methional directly to the public. As it happens, methional can already be purchased from lab suppliers for industry use. One, Sigma Aldrich, bills methional as being "toothsome" and able to complement many savoury flavours. At very low levels it can add an "appetising, cooked quality to fruits like apple, pineapple and pear".

So how does methional hit our senses?

Only about one fifth of flavour perception comes from the tongue's taste buds; most of the rest comes

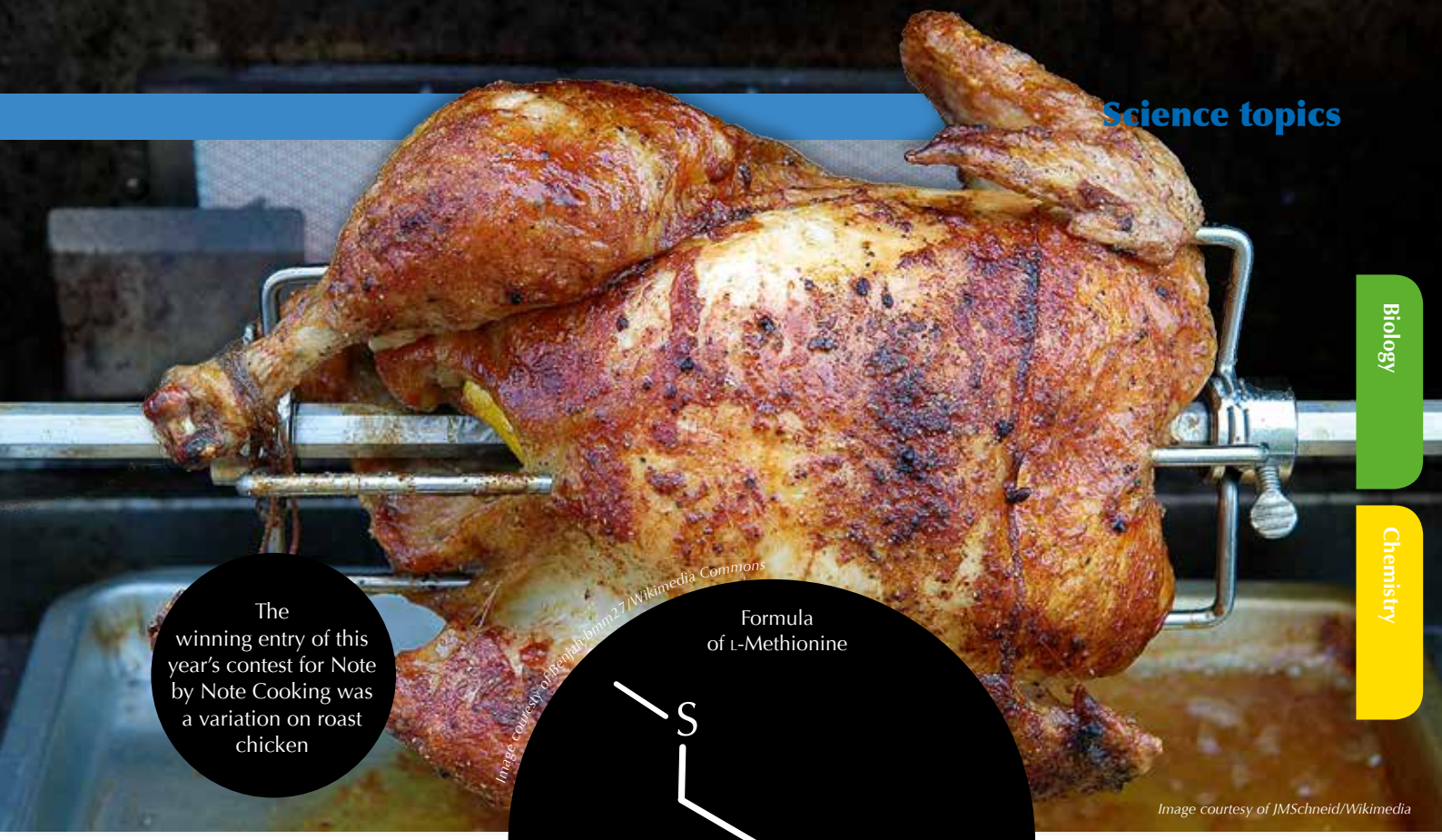


Overview of the human olfactory system. 1: Olfactory bulb 2: Mitral cells 3: Bone 4: Nasal epithelium 5: Glomerulus 6: Olfactory receptor neurons

Image courtesy of Ignacio Icke/Wikimedia

Biology

Chemistry

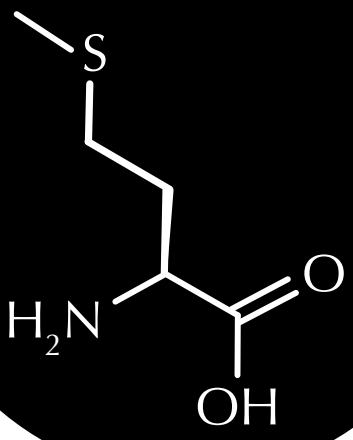


The winning entry of this year's contest for Note by Note Cooking was a variation on roast chicken

Image courtesy of JMSchneid/Wikimedia

Image courtesy of Benjah-bmm27/Wikimedia Commons

Formula of L-Methionine



from smell. When we chew food, our mouths pump volatile molecules to the nose where they are met by hundreds of different odour receptors.

Each receptor consists of a protein specially designed to create a pocket for odour molecules to sit in. When a molecule activates a receptor, it triggers an electrical signal that travels to the brain.

In 2004, US scientists Richard Axel and Linda Buck[w4] were awarded a Nobel prize in physiology or medicine for their discovery of odour receptors and the organisation of the olfactory system. They discovered a large family of about 1000 different genes that produce an equivalent number of types of olfactory receptors. These receptors are found in receptor cells.

Each receptor cell contains only one type of odour receptor and each receptor can detect only a limited number of smells. The cells send signals directly to a region of the brain called the olfactory bulb, and on to other parts. Information from different receptors combines to create an odour pattern.

Image in the public domain/Wikimedia

Laboratories' centrifuges are making a noteworthy entrance into restaurants' kitchens.

Image in the public domain/Wikimedia

Rotary evaporator used in the preparation of distillates and extracts in the kitchen of a restaurant

The 'potatoes' in the winning meal were a bit different to these

Image courtesy of umami/Flickr

Gordon Shepherd, a neuroscientist at Yale School of Medicine, USA, has worked on the olfactory bulb since the 1960s. He calls the process of how the brain creates flavour 'neurogastronomy'. "Much of our brain power is actually used to create flavours and everything that goes with the flavours – memories, emotions and the language that we use to describe the flavours," he says. He works on 'odour images' in the brain, which are processed at the highest level, where perception occurs.

"The more we understand about how the brain creates flavour, the more it will help us to understand how to encourage healthy diets," he says.

Web references

w1 – To read more about the 2nd International Contest for Note by Note Cooking in Paris, France, see: http://molecular-gastronomy-international.blogspot.de/2013/12/the-second-international-contest-for.html

w2 – Hervé This has gathered his work and all sorts of information related to molecular gastronomy online, including material for teachers and ready-made lesson plans on this blog: https://sites.google.com/site/travauxdehervethis/
He also has several other blogs where he writes about:
- the science behind our usual cooking: http://gastronomie-moleculaire.blogspot.de/
- science in general: http://hervethis.blogspot.de/

w3 – This article from *New Scientist* provides a good explanation of 'note by note' cooking, and mentions the winners of this year's contest: www.newscientist.com/article/mg22229722.900-chemical-cuisine-poised-to-shake-up-food-chain.html?full=true#.U_3G2WO1S6Y

w4 – To learn more about the Nobel Prize awarded to Richard Axel and Linda Buck, see: www.nobelprize.org/nobel_prizes/medicine/laureates/2004/press.html

Resource

The AgroParisTech's International Centre for Molecular Gastronomy was opened in June 2014; its director is Hervé This. See: www.agroparistech.fr/-Centre-international-de-.html

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Emma Davies has a BSc in chemistry and a PhD in food science. Before embarking on a freelance career, Emma worked for the Royal Society of Chemistry, where she was features editor of *Chemistry World*.

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

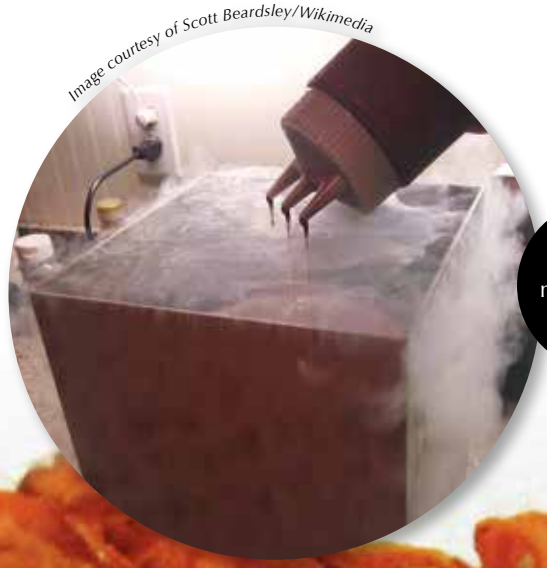


Image courtesy of Scott Beardsley/Wikimedia

Liquid nitrogen ice cream

Image courtesy of libsciterp/Flickr

Methional is part of the reason why the smell of cooked bacon is so attractive

Experienced and experiencing teacher

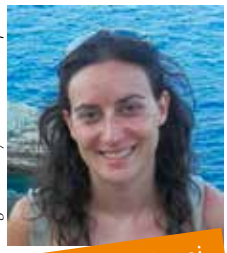


Image courtesy of Vasiliki Kioupi

Vasiliki Kioupi

Vasiliki Kioupi has always run science experiments with her students. Now she is also testing various pedagogical methods in her classroom and is moving towards teaching the teachers.

Image courtesy of Vasiliki Kioupi

Environmental education group – sustainable transportation "take the underground to go to school" campaign

By Isabelle Kling

Most teachers do experiments *with* their students, not *on* them – unless, like Vasiliki Kioupi, they spent the past year working for the Varvakeio Model Experimental School (VMES)[w1] in Athens, Greece. With her large smile and enthusiastic eyes, Vasiliki has never used a scalpel on anybody in her classroom; instead, she used the school as a testing ground for various pedagogical methods, such as enquiry-based learning or the story-telling teaching model.

"These methods are still new in Greece, so the feedback we give to the science advisors goes to the Greek ministry of education, and is then hopefully used to improve the national curriculum," she explains.

Enquiry-based learning

Vasiliki initially trained as a biologist, then earned a master's degree in science education before embarking on her career as a biology, chemistry and physics teacher. As a scientist, she believes in observing her surroundings, asking questions and learning from her own experiments – so the

enquiry-based learning method has always been a natural fit for her lessons.

Even before her time at the VMES, Vasiliki set up interactive lesson plans in which students were encouraged to actively investigate scientific concepts. As a biology teacher, she put a lot of emphasis on genetics and turned towards the worldwide web to find interesting information that could be used to motivate her students: web-based biological databases offer free access to some very comprehensive and important sets of data. From DNA to proteins, from sequences to structures and interactions – it is all there, provided you know how and where to look. Despite their availability, these tools were – and still are – not being used by Greek teachers, so Vasiliki found herself isolated.

In 2012, she turned to the European Learning Laboratory for the Life Sciences (ELLS)[w2] Teacher Training programme at EMBL in Heidelberg, Germany, to learn more about bioinformatics and how she could use it in her classroom. There Vasiliki was told about the latest techniques for genome analysis, what databases[w3] store what kind of information and, most importantly, how she could find and use them to demonstrate important concepts to her students.

Following that training, Vasiliki set up a two-month project in her classroom to investigate the structure and function of DNA. "Using web-based databases is an incredibly motivating and effective tool to demonstrate genetics concepts. My students were able to compare sequences and understand how DNA folds, replicates and translates, using real scientific data," Vasiliki explains. "They felt like true scientists and were instinctively more motivated by the lessons because they were using real data."

Vasiliki was also teaching chemistry and physics, so she set up other projects in these subjects, including an experiment to investigate the production of sustainable energy. During a year-long project, her classroom built an electricity plant based only on solar and wind energy. The electricity that they produced was used to power a station that recorded the temperature and humidity of the air.

In the first half of 2014, Vasiliki also got her students involved in the E-CLIC Competition[w4]. This European initiative aims to promote landscape preservation among younger citizens, to enable them to get involved in policy development and to assess the impact of these policies. Her environmental education group submitted a proposal on how to make their school more environmentally friendly and use its resources in a more sustainable way. The results of the competition are due soon.

Such enquiry-centred projects are very popular with students because they feel involved and can get something tangible out of it. "It is also very rewarding for the teacher. Part of why I like my job so much is because I can create a special relationship with the students and I get this immediate feedback on what I do. It can be good, or sometimes not so good, but you immediately feel how things are going and you can adapt," says Vasiliki. "It pushes you to be at your best all the time."

Story-telling teaching model

Such human interactions influence progress on more than one level.

Project on DNA structure and function: students visiting an interactive science to collect initial data

Image courtesy of Vasiliki Kioupi

REVIEW

- Biology
- Maths
- Ages 14–18

The article was very interesting. I found a lot of analogies between the system used here and the old Nuffield Learning approach used in the UK.

Dr Terry Myers, Banbridge Academy, Northern Ireland

Science doesn't develop on its own, independent of any context: it is done by people, and very often influenced by the society in which they exist. Understanding this human aspect is important, so the VMES team started testing the story-telling teaching model in 2014.

Students watch videos on important scientific discoveries that are presented in a narrative: the focus is put on the scientists that made the discovery, how they thought and approached their research subject, what method they used, and how their societal background influenced their decisions. Following the screening, students answer questions, carry out activities and perform research on the worldwide web to complement their understanding of both the scientific concept and the context in which it was discovered.

One of these videos, for example, tells the story of the Scottish physician James Lind, who discovered the cure for scurvy. Lind was the first person to conduct a clinical trial to test various hypotheses on the treatment of the disease that afflicted mostly sailors in his time. The corresponding educational activity first asks the students to identify and research the most important facts about the discovery and the disease itself. They are then asked to design and conduct their own experiment to find a solution to a real-life problem similar to the one that Lind faced.

Image courtesy of Vasiliki Kioupi

Preparing for the regional contest "Experiments in Biology, Chemistry and Physics"

Collaborations

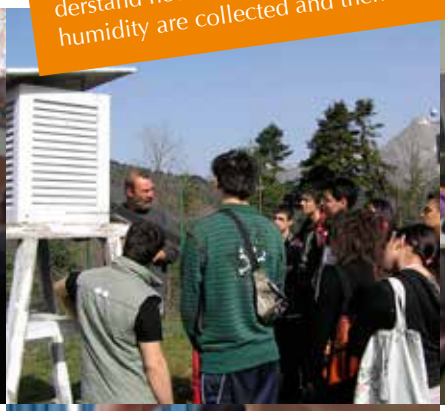
A large part of these new teaching methods relies on collaborations between students: they need to work in a team to solve problems and overcome challenges. Similarly, collaborations between like-minded teachers, or schools, can provide real added value to the lesson and the scope of the students' observations and analyses. Some projects, for example monitoring the environment in a specific area, can become much more comprehensive and interesting if several groups collect and share data and schools establish collaborations with research institutes. For this reason, Vasiliki is now taking on a new role as a teacher trainer and counsellor in Athens.

Image courtesy of Vasiliki Kioupi

Environmental education group: interpreting environmental data

With a focus on the environment and sustainable development, she will set up projects with and for colleagues in and outside the classroom. After careful evaluation, successful projects will be communicated to a wider audience through a network that Vasiliki will co-ordinate. By being responsible for different schools over a wide area of Athens, she also hopes to be able to set up collaborative initiatives, such as a sea-water monitoring project. By using what she has learnt as a science teacher over the years, she is communicating science to an even wider audience – essentially building an even bigger 'classroom'.

Project on sustainable energy production: finding alternatives to power conventional electrical appliances



Visiting a meteorological station to understand how data on temperature and humidity are collected and then used

Building DNA models, on the biology course

Images courtesy of Vasiliki Kioupi

Project on DNA structure and function, laboratory work

Web references

w1 – The Varvakeio Model Experimental School has a website dedicated to its middle school: http://gym-peir-athin.att.sch.gr/, and another one for its high school: http://varvakeion.blogspot.gr/ (in Greek only)

w2 – For more information on the European Learning Laboratory for the Life Sciences (ELLS), see: http://emblog.embl.de/ells/

w3 – The European Bioinformatics Institute (EBI) hosts several important biological databases. You can visit them at: www.ebi.ac.uk/

w4 – Find out more about the E-CLIC Competition on its website: www.e-clicproject.eu/

Resources

Vasiliki Kioupi has a blog full of interesting information, dedicated to science teachers and students: www.vkioupi.wordpress.com (in Greek only)

Vasiliki is the current ELLS Visiting Teacher and is collaborating with the EMBL ELLS to co-organise an ELLS LearningLAB in Athens. Keep an eye on the ELLS LearningLABs announcement page to stay informed about next ELLS courses and registration deadlines. See: http://emblog.embl.de/ells/events/learninglabs

This article explains how you can do bioinformatics with just a pen and paper:

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

Check out this article to find a detailed lesson plan using a biological online database:

Tenorio G (2014) Using biological databases to teach evolution and biochemistry. *Science in School* **29**: 30–34. www.scienceinschool.org/2014/issue29/online_bioinf

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Isabelle Kling trained as a biochemist and a science communicator, then went on to set up various science communication projects in Canada and in Europe. She is now one of the editors of *Science in School* at EMBL.

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

Project on DNA structure and function: evaluation using ICTs

Image courtesy of Vasiliki Kioupi

Publisher: EIROforum, www.eiroforum.org

Editor-in-chief : Dr Eleanor Hayes (currently on leave), European Molecular Biology Laboratory, Germany

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

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

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

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

ISSN:

Print version: 1818-0353

Online version: 1818-0361

Cover images:

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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.

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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