Autumn 2009 Issue 13

SCIENCE in SCHOOL

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Alan Leshner: at the interface of science and society

The CoRoT satellite: the search for Earth-like planets

Highlighting the best in science teaching and research

Editorial

Welcome to the thirteenth issue of *Science in School*

Health and disease are themes that run through this issue of *Science in School*. In our feature article, Alan Leshner describes his varied career, including his involvement in a major campaign to show that schizophrenia is a brain disease and not a result of environment. In contrast to this concern with the public awareness of mental illness, Sabine Hentze deals with illness on a personal scale – counselling patients and families affected by genetic diseases.

Teacher Gianluca Farusi encourages his students to eat healthily with a colourful chemistry experiment to test the antioxidant content of different foods; Holger Maul, Nele Freerksen and I show why a simple vitamin – folic acid – is such an essential component of a healthy diet; and immunologist Ana de Barros investigates the roles of white blood cells in preventing cerebral malaria.

Saving life is certainly a worthy aim, but the quest to *find* life – beyond the limits of our planet – has seized the imagination of science fiction writers and scientists alike. Malcolm Fridlund introduces the search for extra-solar planets and extra-terrestrial life, and explains how this could tell us about the evolution of life on Earth.

The history of life is an ambitious enough topic, but some astronomers have gone further – probing the history of the Universe itself. Ana Lopes and Henri Boffin describe the search for the first light in the Universe – the first dawn.

Back on Earth, the dawn of understanding on a student's face can be deeply satisfying. Jean-Yves Guichot's project enabled his students to understand the nature of research by working side-by-side with research scientists; he offers advice for setting up a similar project.

Rather than developing a project *for* their students, Ludwig Eidenberger and Harald Gollner developed a project *with* two of them. They describe their activities to demonstrate the unusual thermodynamic properties of latex – including a thermal engine and a 'refrigerator'. Thermodynamics is also one of the many phenomena that can be investigated using Bernhard Sturm's science dramas. Why not try out his ideas for enacting redox reactions, radical polymerisation or the effect of heat on water?

Water is the crux of Giuseppe Zaccai's research: he and his co-workers tested the assumption that biological reactions *in vitro* actually reflect the reality in the living cell. Scientists can heave a sigh of relief – it seems water does indeed behave similarly in the cell and in the test tube.

As if that were not enough choice of topics, we have more articles online – interviews with veterinarian Sarah Baillie and Italian teacher Alessandro Berton, a collection of online astronomy resources, and reviews of books and websites. From now on, these categories of articles will be online only, so don't miss out – visit our website (www.scienceinschool.org).

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About *Science in School*

Science in School promotes inspiring science teaching by encouraging communication between teachers, scientists and everyone else involved in European science education.

The journal addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge scientific research. It covers not only biology, physics and chemistry, but also earth sciences, maths, engineering and medicine, focusing on interdisciplinary work. The contents include teaching materials; cutting-edge science; interviews with young scientists and inspiring teachers; reviews of books and other resources; and European events for teachers.

Science in School is published quarterly, both online and in print. The website is freely available, with articles in many European languages. The English-language print version is distributed free of charge within Europe.

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Translators

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See: **www.scienceinschool.org/2009/issue13**

Science on Stage: heading for a country near you

How better to inspire thousands of schoolchildren across Europe than by motivating and educating their teachers? As Eleanor Hayes explains, that is the idea behind Science on Stage – a network of local, national and international events for teachers.

Initially launched in 1999 as Physics on Stage, it was the brainchild of EIROforum[w1], the publisher of *Science in School*, and received financial support from the European Commission. In 2005, the initiative was broadened to cover all sciences and renamed Science on Stage, but the format remained essentially unchanged. National representatives organised competitions, science fairs and festivals, to identify innovative teachers and teaching activities, encourage the improvement of national education systems and establish a European community of science teachers keen to share and exchange their best teaching ideas. The size of the national activities varied – some were quite small, while the Spanish Ciencia en Acción event[w2] involved several thousand people. A number of lucky teachers from each country were then selected to attend the international festival hosted by one of the EIROforum organisations – a chance to exchange teaching ideas with 500 colleagues from more than 27 countries, attend lectures by leading scientists, take part in workshops, visit world-class research facilities and enjoy the on-stage science shows.

Most importantly, participants from the international festival then took the ideas and experience back to their own countries to share with their colleagues – sending ripples of inspiration across Europe. One of the collaborations that emerged was between the UK and Malta: chemistry teacher Tim Harrison has made several trips to this Mediterranean archipelago to perform dramatic chemistry shows in front of thousands of school students and their teachers. Didier Robbes from the University of Caen, France, found Italian partners to set up an education company based on his electromagnetism project. And there has been much activity at the national level too: Science on Stage Belgium and Science on Stage Austria eV, for example, have presented their activities at a range of conferences and events, both for teachers and the general public (see Furtado & Rau, 2009).

In 2008, the contract with the European Commission – and thus the financial support – ran out, but the enthusiasm and commitment of the national organisers continued. In some countries, the national events had gained so much momentum that it was clear they would continue, even without the lure of an international festival. Nonetheless, it was recognised that the international festival – with the chance to swap ideas and experience with teachers from across Europe – was an intrinsic part of Science on Stage.

The German national organisers[w3] took the initiative, therefore, to plan an international Science on Stage festival in October 2008, with substantial sponsorship from THINK ING[w4]. Two hundred and fifty European teachers flocked to Berlin to share their teaching projects and experiments, discuss innovative methods in workshops and round tables, attend scientific talks and stage performances, and visit Berlin's research institutes. Thus was born the idea that the national organisers should pass the Science on Stage flame from one to the other, competing to host the international festival every two years.

With this in mind, representatives from 18 European countries met on 22–23 October 2009 in Berlin to establish Science on Stage Europe[w5], and to decide which country should have the

Images courtesy of Wolfgang Gollub

honour – and the responsibility – of hosting the next international festival. The national organisers from Austria, Malta and Poland made excellent bids, but the final vote went to Denmark. With generous financial support from the Danish Education Ministry, the fourth Science on Stage international festival will take place on 16–19 April 2011 in Copenhagen.

If you would like to take part in your national event – and maybe even be selected to attend the international festival – why not contact your national organisers? Between now and October 2010, an exciting range of activities will take place to select 400 of Europe's best science teachers to spend Easter 2011 in Copenhagen.

References

Furtado S, Rau M (2009) Science on Stage: recent activities. *Science in School* **12**: 10-13. www.scienceinschool.org/2009/issue12/sos

Web references

w1 – EIROforum – the publisher of *Science in School* – is a partnership of seven European inter-governmental research organisations. For more information, see: www.eiroforum.org

w2 – Ciencia en Acción is the Spanish Science on Stage organisation. See: www.cienciaenaccion.org

w3 – To learn more about Science on Stage Germany, see: www.science-on-stage.de

w4 – THINK ING is an initiative of the German Association of Metal and Electrical Industry Employers. To learn more, see: www.think-ing.de

w5 – To learn more about Science on Stage and find your national contact, see the Science on Stage Europe website: www.science-on-stage.eu

Resources

Teaching materials, photographs and much more information about previous festivals is available here: www.science-on-stage.net

For more information about previous Science on Stage activities, see the following *Science in School* articles:

Capellas M (2007) Science teaching flies high at Science on Stage 2. *Science in School* **5**: 10-11. www.scienceinschool.org/2007/issue5/sos

Furtado S (2009) Science on Stage: recent international events. *Science in School* **11**: 11-14. www.scienceinschool.org/2009/issue11/sos

Hayes E (2007) Awards, rewards – and onwards! *Science in School* **5**: 12-14. www.scienceinschool.org/2007/issue5/sosprize

Hayes E (2008) Science on Stage: recent activities. *Science in School* **10**: 4-7. www.scienceinschool.org/2008/issue10/sos

Riggulsford M, Warmbein B (2006) Space balloons, mousetraps and earthquakes: it's Science on Stage! *Science in School* **1**: 8-11. www.scienceinschool.org/2006/issue1/spaceballoons

Warmbein B (2006) Science teachers take centre stage. *Science in School* **1**: 6-7. www.scienceinschool.org/2006/issue1/centrestage

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Dr Eleanor Hayes is the Editor-in-Chief of *Science in School*.

Particle physics close up: CERN high-school teachers programme

Every year, CERN invites a group of high-school teachers to Geneva, Switzerland, to learn about particle physics – and how to teach it at school.

BACKGROUND

Apply for next year's programme

The next HST programme will take place from 4 to 24 July 2010. For more information, including details of how to apply, see the HST programme website[w4].

You may also be interested in taking part in one of CERN's three-day national teacher programmes[w5]; each one is targeted at teachers from a particular CERN member state and is run in the mother tongue of the participants.

Even though the school holidays were in full swing, some 40 high-school teachers came to CERN to take part in the high-school teachers (HST) programme organised by the CERN education group. Far from considering this as a piece of holiday fun, the teachers got their hands dirty and put in some serious hours of learning.

The three-week HST programme hosts dozens of teachers from around the world, offering a deeper insight into particle physics through a variety of lectures, visits and workshops. The programme's ambitious overall aim is to help these teachers inspire their students to follow careers in science. In the second week, they split up into working groups to evaluate CERN's existing educational tools or create new ones[w1]. "This year, one of the groups is reviewing some of the CERN visits' service itineraries," says HST programme manager Mick Storr. "From their perspective as teachers they can give us a valuable insight into the quality of our tools and thus help us improve them. Another group is sifting through the video archives on the CERN website and drawing up a league table of CERN videos highlighting those which provide the most educational benefit."

In so doing, the teachers are not only working for CERN and their colleagues, but also fulfilling their mission as teachers by working for the benefit of their students. One participant, Juliana Mitrevski, has shown devotion beyond the call of duty. She's from Australia, where schools are not on holiday at the moment, and has set up a blog[w2] to enable her students to carry on learning even while she's at CERN: "I record what I do every day on the blog and describe the lectures I've attended," she explains. Juliana hopes her light-hearted, avant-garde approach will have the desired effect of triggering her students' interest: "I've included a link to the video of the LHC rap[w3] and set up an HST programme group for my students on Facebook," she says.

Beyond the strictly educational and scientific aspects, the participants also

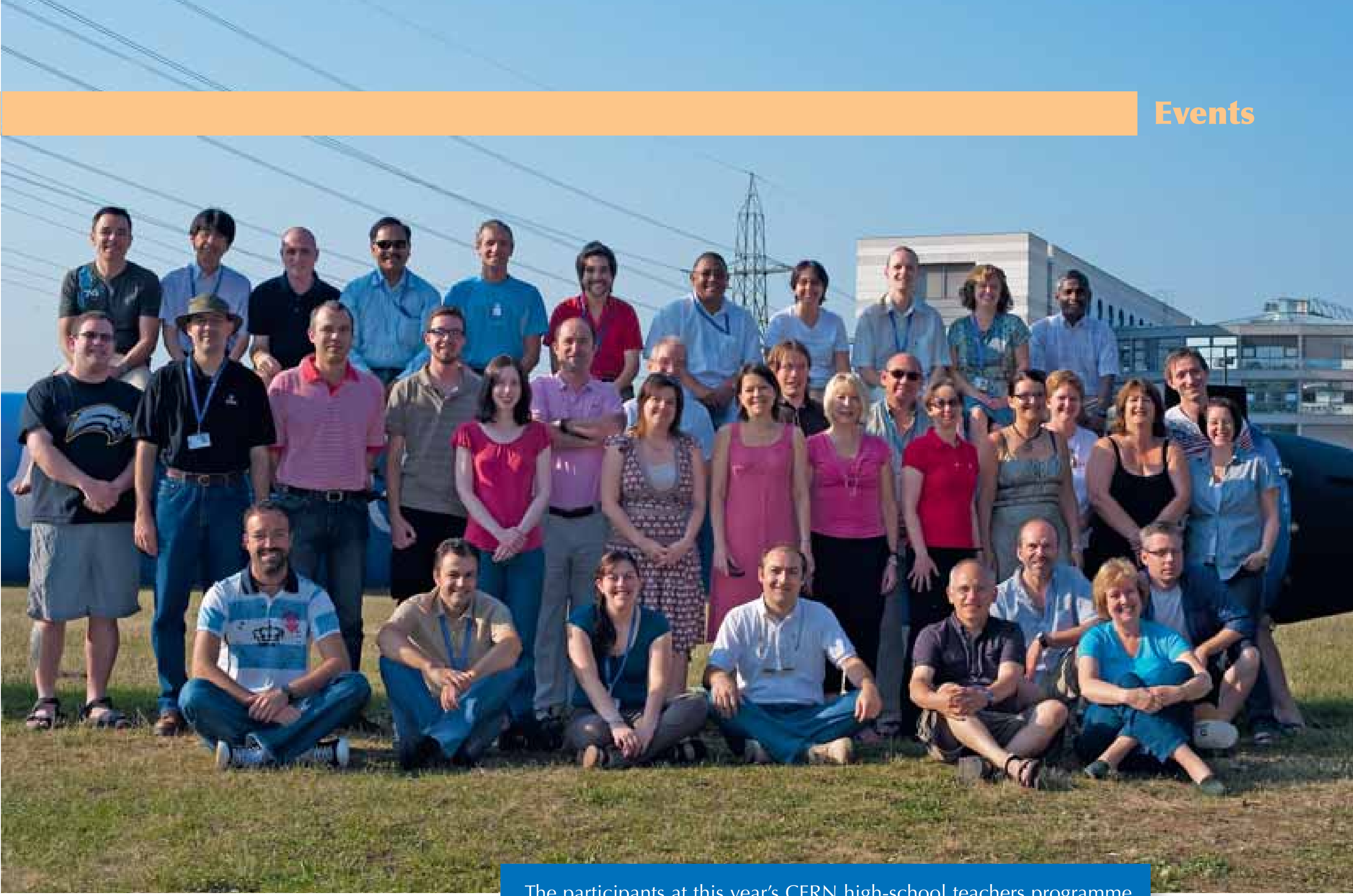

Image courtesy of CERN

The participants at this year's CERN high-school teachers programme

appreciate the social side of this international programme. "When you're working with people from 23 different countries, it's a real cultural melting pot and a great opportunity to compare teaching methods," notes Polish teacher Małzgorzata Karulak. "After three weeks together, the teachers grow very close and it's sad to think we'll all be returning home soon," says Terrence Baine, a Canadian teaching in Norway, who is attending the programme for the second time as part of his research for a PhD in Physics Education. "I've kept in touch with the good friends I made during last year's programme and I'm sure it'll be the same for those attending this year."

Web references

w1 – To download the educational resources created by the HST participants, see: http://teachers.web.cern.ch/teachers/materials/default.htm

w2 – Juliana Mitrevski's blog can be seen here: http://julianaatcern.blogspot.com

w3 – A video of the LHC rap can be viewed here: www.youtube.com/watch?v=j50ZssEojtM

w4 – For more information about the HST programme, see: http://teachers.web.cern.ch/teachers

w5 – The CERN education website offers information, not only about the HST programme, but also about other teacher programmes and educational resources for schools. See: http://education.web.cern.ch/education/Welcome.html

Resources

To read other *Science in School* articles about CERN, see: www.scienceinschool.org/cern

If you found this article interesting, you might like to browse previously published event reports in *Science in School*. See: www.scienceinschool.org/eventreports

The original version of this article was first published in CERN's newsletter, *The Bulletin*.

Dikranos – Fabian's plane with reverse gear

Discoveries in Paris: the European Union Contest for Young Scientists

On 11-16 September 2009, the annual European Union Contest for Young Scientists (EUCYS) took place in Paris, France. **Marlene Rau**, a member of this year's jury, reports.

© European Communities, 1995-2009

Fabian Gaffner, first-prize winner from Switzerland

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Liam McCarthy and John C. O'Callaghan, first-prize winners from Ireland

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Polish first-prize winners Aleksander Kubica and Wiktor Pilewski

Palais de la découverte – the palace of discovery: for six days, it was buzzing with young people from across Europe and beyond, bringing along their scientific discoveries, their enthusiasm, inventiveness and creativity. For them it was an opportunity to meet fellow science enthusiasts from 37 other countries, make friends and discover the world of science – and of course, their host city, Paris.

A total of 132 talented young scientists had come together to compete in EUCYS 09[w1]. All of them first-prize winners of their national contests, they came to present a wide variety of projects, either individually or as a team.

The international jury had a tough decision to make: the topics ranged from butterfly ecology, nanotechnology and biofuel generation; through a cappuccino logo printer, new solutions to mathematical problems, Alzheimer's disease or cancer research, and algorithms for 3D imaging; to the exploration of galaxies, the physics of medieval trebuchets, or a study of the ideal personality traits to become a neurosurgeon.

It was not only the topics that varied so greatly: the contestants came from different backgrounds and age groups (14 to 20) and had access to different levels of resources – some had the best possible while others had virtually none. Some had even patented their inventions already. Most of

EUCYS contestants discover Paris with their student hosts

Image courtesy of EUCYS09

Image courtesy of EUCYS09

EUCYS contestants enjoying a cruise on the River Seine

the contestants faced the additional challenge of presenting their project in a foreign language – English – the standard of which also varied greatly between the young scientists. In the face of all this variety, the jury's task was to assess not only each project's scientific soundness, originality and creativity, but also the students themselves and the structure of their presentation. And that was no easy task – after all, they were all winners in their own countries.

Yet the fact that there was a generous total of €51 500 in ten main prizes from the European Commission, plus 19 sponsored travel prizes to a range of scientific institutes and events to be distributed – including six one-week placements at the EIROforum[w2] organisations and a visit to the Nobel Prize Awarding Ceremony – ensured that all of the most worthy projects were rewarded.

After many interviews with the contestants and heated debates among the jury, the decision was made: the three first prizes went to Fabian Gafner from Switzerland (19), who built a model airplane which can fly backwards; Liam McCarthy (14) and John O'Callaghan (15) from Ireland, who developed a simple method to determine the number of somatic cells in milk, which will help farmers in their daily work; and Aleksander Kubica (20) and Wiktor Pilewski (20) from Poland, who studied the properties of spiral zone plates – a cutting-edge science topic in optical physics. Details of these and all other projects, as well a video of the contest, are available online[w3].

Above all, it was the contestants' scientific spirit that counted: "Everybody wants to win – some want it more, some want it less – but it's not the most important thing. We didn't do our research for this or any other competition – but because we're interested in the subject and we wanted to investigate it!" as one participant put it wisely.

Of course even the most dedicated scientist needs an occasional break; the contestants were taken up the Eiffel Tower and on a cruise along the River Seine, visited a number of science museums, and had the opportunity to meet eminent scientists both at a round-table discussion and in lectures. Even after three exhausting days, packed with new experiences, the contestants were alert enough to quiz the EIROforum evening lecturers, Jacopo Lucci from the European Molecular Biology Laboratory[w4] and Paula Stella Teixeira from the European Southern Observatory[w5], after their talks.

To supplement the official programme, a number of student hosts from the Université Paris XI had organised further tourist trips for the contestants and introduced them to the Montmartre nightlife – a highlight of the youngsters' stay in Paris.

EUCYS is a great experience for everyone involved – why not tell your students about it? Encourage them to develop their ideas and enter your national competition – and with a bit of luck, we'll meet them at EUCYS 2010 in Lisbon, Portugal.

Web references

w1 – To find out more about the European Union Contest for Young Scientists, see: http://ec.europa.eu/research/youngscientists and www.eucys09.fr

w2 – Learn more about EIROforum, the publisher of *Science in School*, here: www.eiroforum.org

w3 – For the full information on all winners and projects, and to watch the official EUCYS09 video, see the EUCYS09 website (www.eucys09.fr) or http://tinyurl.com/ybdwj9b for the winners,

http://tinyurl.com/y9t8gyw
for the projects, and
http://tinyurl.com/ydnmvsa
for the video

w4 – You can find out more about the European Molecular Biology Laboratory here: www.embl.org

w5 – To find out more about the European Southern Observatory, see: www.eso.org

Resources

To find out more about the national competitions and to contact your national organiser, see: http://ec.europa.eu/research/youngscientists/index_en.cfm?pg=organisers

For a flavour of the EUCYS spirit and its contestants, watch a fun video of their Seine cruise with interviews: www.youtube.com/watch?v=sOSkI8MJLBM

Read what it's like to be a EUCYS contestant in the blog of Courtney Williams from the UK, the lucky 2009 winner of an EIROforum special prize visit to CERN, the European Organization for Nuclear Research, in Geneva, Switzerland: www.butrousfoundation.com/ysjournal/?q=node/108

If you enjoyed this article, you might also like to read other event reports in *Science in School*. See: www.scienceinschool.org/eventreports

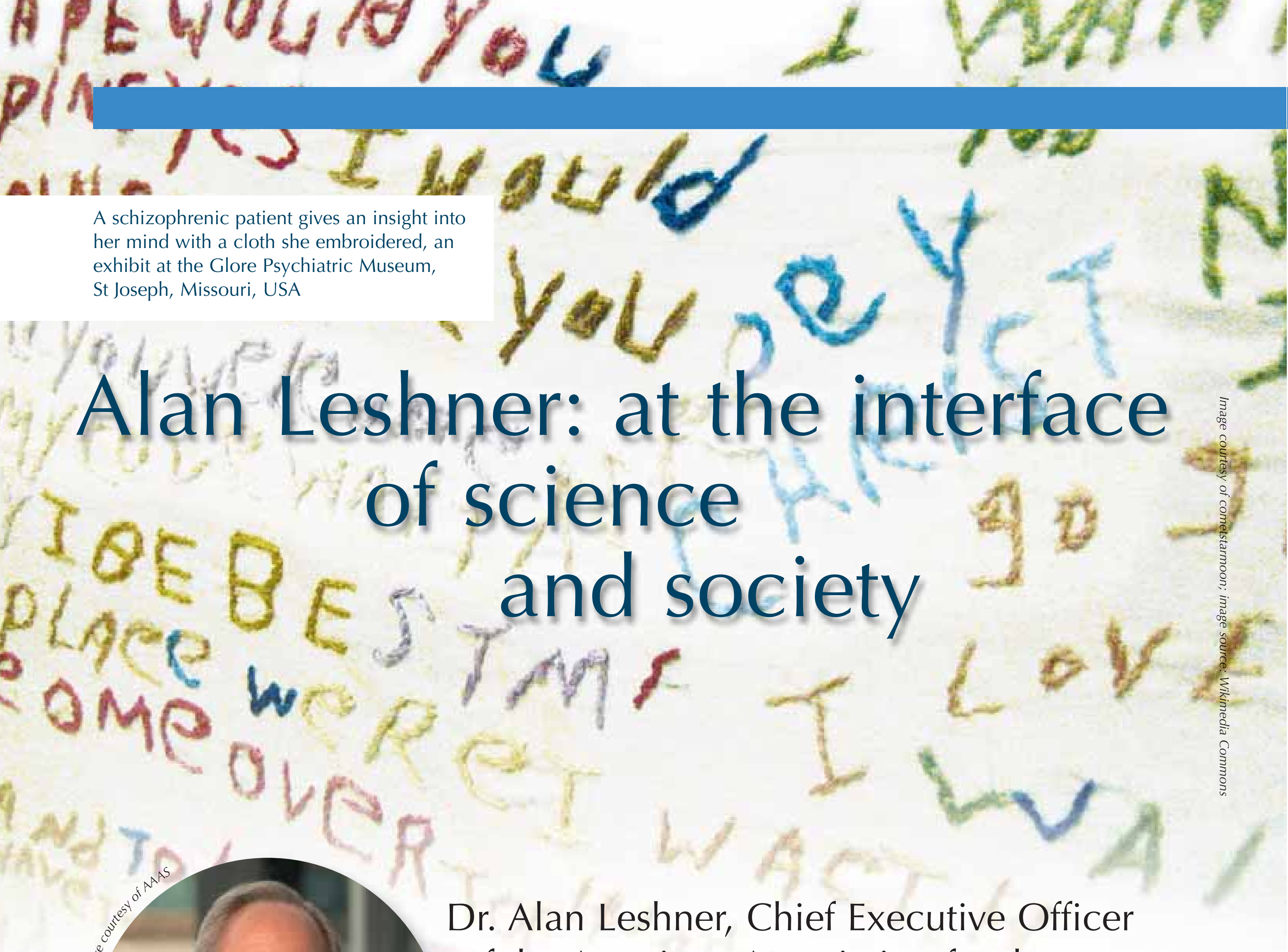

Image courtesy of EUCYS09

Question session during the round-table discussion at La Cité des Sciences with scientists Jean Dalibard, Pascle Cossart, Wendelin Werner and Claudie Haigneré



Image courtesy of Inger Gram Torhild

Philip Cardona from Malta with his cappuccino logo printer



A schizophrenic patient gives an insight into her mind with a cloth she embroidered, an exhibit at the Glore Psychiatric Museum, St Joseph, Missouri, USA

Image courtesy of cometstarmoon; image source: Wikimedia Commons

Alan Leshner: at the interface of science and society

Image courtesy of AAAS

Dr Alan Leshner

Dr. Alan Leshner, Chief Executive Officer of the American Association for the Advancement of Science (AAAS) and Executive Publisher of the renowned *Science* magazine, tells **Marlene Rau** and **Sonia Furtado** about his varied career and shares his views on science education issues.

Alan Leshner started his career as a neuroscientist at a time when neuroscience still fell under the umbrella of psychology. "Like many people," he says, "I became a scientist because of an individual mentor. I was always genuinely interested in science and thought I would become a physician. But at university I started to do some research with one of my psychology professors, and I fell in love with the process of research and scientific inquiry. So instead of enrolling in medical school after my degree, I did neuroscience. There was no such thing as a neuroscientist back then, though: in the late 1960s, if you were interested in the brain, or in the relationship between biology and behaviour, you went into psychology. However, I was part of a first generation of doctoral students who were trained in both psychology and physiology – and in my case, endocrinology, too."

When asked to point out the most interesting aspect of his scientific research, Dr Leshner is reticent – he'd rather talk of the wider scope of his research than focus on a particular detail: "I spent twelve years as a bench scientist, so there is no single thing that stands out, but – like many people – I am interested in grand, overarching questions about the nature of the relationship between biology and behaviour. What I did was approach that through an unusual question. While most people asked 'how does the brain come to generate a mind?', I was interested in how other biological systems can modify

REVIEW

This article on an atypical career in science can be used to discuss science and society issues in class, including: Are teachers paid enough or too much? Do you think it matters if people don't know what is and isn't science? What are the important scientific issues that have moral, political or economic ramifications?

Halina Stanley, France

or affect behaviour, and became interested in hormones. Not in the traditional area of interest at the time – sex hormones and sexual behaviour – I was interested in the role of hormones in controlling what were then called regulatory behaviours: eating, exercising and things like that. Later I became interested in how hormones could affect social behaviours and mood; specifically in the role of the hormones of the adrenal gland on aggressive versus submissive behaviour, and in what came to be called premenstrual tension and how hormones could be involved in that."

Author of a textbook on hormones and behaviour (Leshner, 1978), Dr Leshner doesn't think current knowledge of behaviour can provide any great insights into how to manage a classroom, but he does believe it could be a very useful resource to help get youngsters interested in science. "There is a whole body of literature on the biology of behaviour that I think would be both very exciting and very stimulating to young people", he says.

"Unsurprisingly, many young people are very interested in their own hormones and their effects. In addition to that, most people are intrigued by their mind and their own behaviour. If you can give them insights into the phenomena that relate to them, that's a very good way to engage people with science generally. I'm fond of saying most people are interested in their brains because they're interested in their minds. This makes studying the brain fascinating, because people think it will give them insight into their minds, into their self, into their individuality."

What about the difference between mind and brain? Regardless of what people may think, scientists are certain there is none. Dr Leshner states: "Within the scientific community it's not a question anymore. It may be one in the broader society, but scientists agree that your mind is not floating around outside your body or in your liver – it's in your head. You don't have a separate mind and brain. That doesn't mean you don't have a mind or you don't experience your own consciousness, but the mechanism that generates it is in the mush inside that hard thing that sits above your shoulders. It's very hard for people to accept that, but that's what we've learned over the course of the last fifty years."

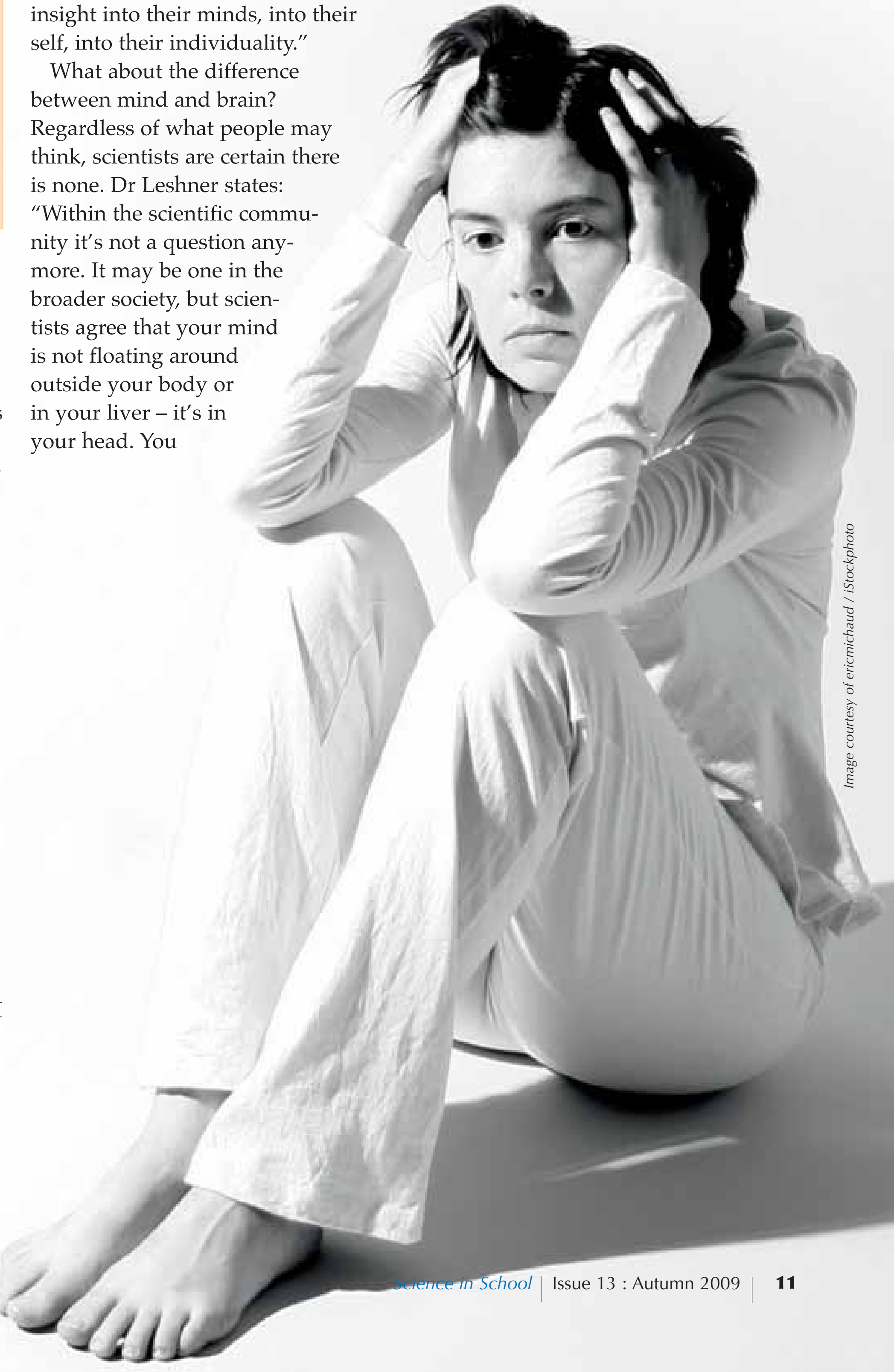


Image courtesy of ericmichaud / iStockphoto

Image courtesy of 1001nights / iStockphoto

Although he is still interested in these matters, Dr Leshner's career has moved away from the lab bench. How did he go from researching behaviour to working in science policy? "Well, I was asked," he replies. "I've always been interested in the relationship between biology and things like mental disorders, mood and emotion. So although my research was very focused, I was always interested in the kind of broader questions that might interest society at large. I was asked to go to the National Science Foundation[w1] for a year, in one of their rotating programme officer positions. Those are jobs where you give out grants, and I did that in a programme called 'psychobiology'. While I was there, I got involved in other projects that were more policy-related, and they asked me to stay for another year to work on a big science policy report called 'The five year outlook on science and technology'. I liked it, and they asked me to stay another year. I kept my appointment at Bucknell University[w2], so I kept my lab going during that time. Then, by accident, I was invited to a meeting about a new science education commission that the National Science Board[w3] was establishing at the National Science Foundation. There they asked me if I would come and work on the staff, and I became deputy director of that commission. So I spent a couple of years working on science education at elementary- and secondary-school levels. I had eight jobs in nine years at the National Science Foundation," Alan Leshner admits. "But they were good," he adds. "Each one was better than the one before.

"After that, I was asked to become the deputy director of the National Institute of Mental Health[w4], at the National Institutes of Health. I did that for a couple of years, and then the director left and I became the acting director of the institute for another couple of years. Then I was asked if I wanted to become the director of the National Institute on Drug Abuse (NIDA)[w5], also at the National Institutes of Health. I thought: 'Oh, that's an interesting challenge. There is no science behind the way in which society deals with drug abuse and addiction, and I could do something about that.' So I was the NIDA director for almost eight years. But because everything comes full circle, I was eventually asked if I wanted to come back to my broader scientific roots and work at AAAS[w6] and *Science* magazine[w7]. I figured I had done about as much as I could do in drug abuse, and maybe I would be able to have a broader effect on the science–society relationship by coming to AAAS, so that's how I got here. Actually my whole career is an accident. I was lucky: my parents didn't think it was essential that I have a plan."

His latent interest in the interface between science and society was sparked into action during his time at the National Institute of Mental Health, Dr Leshner says. "At the time, Public domain image; image source: Wikimedia Commons

American Academy of Arts and Sciences building, Cambridge, Massachusetts, USA

universities and high schools were teaching that diseases like schizophrenia were caused by early parental experience. You know, we had words like 'refrigerator parents' or 'schizophrenogenic mothers' – mothers that induced schizophrenia. I was in a room with four people when we decided we needed to tell the world that schizophrenia was a brain disease. So we mounted a major public information campaign, along with a patient group called 'The national alliance for mental illness'. We successfully used science to change public understanding of mental illness, so that now if you say 'schizophrenogenic mothers', everybody laughs. If you say your mother made you schizophrenic, people think it's a joke; everybody knows it's a brain disease. Well, we had to tell people, using the science."

At AAAS, Alan Leshner now looks beyond his initial field of interest, to more general tensions between science and society. "The link between science and the rest of society is a little fragile these days," he says. "It's fragile in part because people don't understand what is and isn't science, and in part because science is encroaching on areas of core human values, like who we are. There are other kinds of issues that have political or economic ramifications, like what to do about global warming. We have a lot of work to do, getting science and society on the same page and going in the same direction."

"I was lucky: my parents didn't think it was essential that I have a plan"

Nevertheless, Leshner has pretty clear ideas as to how that link can be strengthened: "I believe in public engagement with science: that is in dialogue, communication, bringing scientists and the rest of the public together to work on common issues, listening to each other. One of the hardest things is to get scientists to listen to the public, but every time they do, they benefit tremendously from it."

Dr Leshner believes that educating the public is of paramount importance, preferably from an early age, but that the challenges faced by current educational systems are still very similar to those he encountered while in the science education commission at the National Science Foundation. "I think the issues were actually the same back then as they are today, and that's very discouraging. We have not made tremendous progress. For instance, we still can't get agreement on the standards and objectives for what we want taught at the different pre-college levels in science, mathematics and technology.

"And I believe that the single biggest problem is that in the US, we don't pay science teachers enough to keep them in the business. The best and brightest science teachers frequently get discouraged, both by the bureaucracy of our educational systems and by the terrible pay.

"Therefore, after teaching for a while, they feel as if they need to move to other fields. I believe that until the nations of the world recognise and respect teachers for the very important and difficult jobs that they do, we'll never really solve the so-called science education problems. I actually think if we were to pay teachers reasonably, teaching in secondary or even elementary schools would be viewed as an extremely productive career choice for scientists. There is nothing that says all scientists have to work at the bench. Scientific training can be used in a wide variety of ways, and teaching is among the most noble things you can do in the world. So I would applaud people who choose to use their science education to become teachers. I just think it's very difficult to get them to do that."

The man who once said "People still respect science and technology, but they have no idea what science is" believes school could play a fundamental role in changing this state of

Image courtesy of Eraxion / iStockphoto

affairs. "You can't teach science in a vacuum, but if you don't focus on the nature of the enterprise, you get lost in the details. So you have to find a way to do both. One such way is to start with a societal issue such as global warming and then ask 'How did science teach us about it?' How do we know Earth is warming? It's not just that the graph shows it. It's a whole process by which we've made those advances in understanding.

"You can either teach the graph, or you can teach the process of generating and understanding the graph – and of understanding a bad graph – you know, what makes something true or false for science. Then people could discriminate better between what is and isn't science. The assertion that astrology or homoeopathy or creationism are scientific should be dependent on one's ability to prove that they use scientific methodology, that the results are reproducible and that the findings are observable: all of the normal criteria that make something scientific. The fact that three scientists believe something doesn't make it scientific."

Finally, after holding so many different positions and being involved in so many different areas, what would Alan Leshner like to do next? "Oh, I sort of like this. I think representing the scientific community is a noble thing to do, and anything that I can do to help keep the relationship between science and the rest of society smooth is very rewarding. My main interest is that interface between science and the rest of society, and what better way to work on that than to be the head of an organisation whose mission is to advance science and serve society?"

References

Leshner A (1978) *An Introduction to Behavioral Endocrinology*. Oxford, UK: Oxford University Press. ISBN: 9780195022667

Web references

w1 – For more information on the US National Science Foundation, see: www.nsf.gov

w2 – To learn more about Bucknell University, USA, see: www.bucknell.edu

w3 – Find out more about the US National Science Board on their website: www.nsf.gov/nsb

w4 – Learn more about the National Institute for Mental Health at the US National Institutes of Health here: www.nimh.nih.gov

w5 – For more information on the US National Institute on Drug Abuse (NIDA), see: www.nida.nih.gov

The NIDA also provides teaching material for neuroscience and drug abuse education in English and Spanish: www.drugabuse.gov/parent-teacher.html

w6 – Find out more about the American Association for the Advancement of Science (AAAS) here: www.aaas.org

w7 – You can find the website of the *Science* magazine here: www.sciencemag.org

Resources

For an article on the role of one particular hormone, oxyntomodulin, on eating behaviour, see:

Wynne K, Bloom S (2007) Oxyntomodulin: a new therapy for obesity? *Science in School* **6**: 25-29. www.scienceinschool.org/2007/issue6/oxyntomodulin

To find out more about Euroscience, the European counterpart of AAAS, and its activities, see: www.euroscience.org

If you enjoyed this article, you might also like to read other feature articles in *Science in School*. See: www.scienceinschool.org/features

Sonia Furtado was born in London and moved to Portugal at the age of three. While studying for a degree in zoology at the University of Lisbon, she worked at Lisbon Zoo's education department: there, she discovered that what she really enjoys is telling people about science. She went on to do an MSc in Science Communication at Imperial College London, and is now working in the press office at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany.

Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been the editor of *Science in School*.

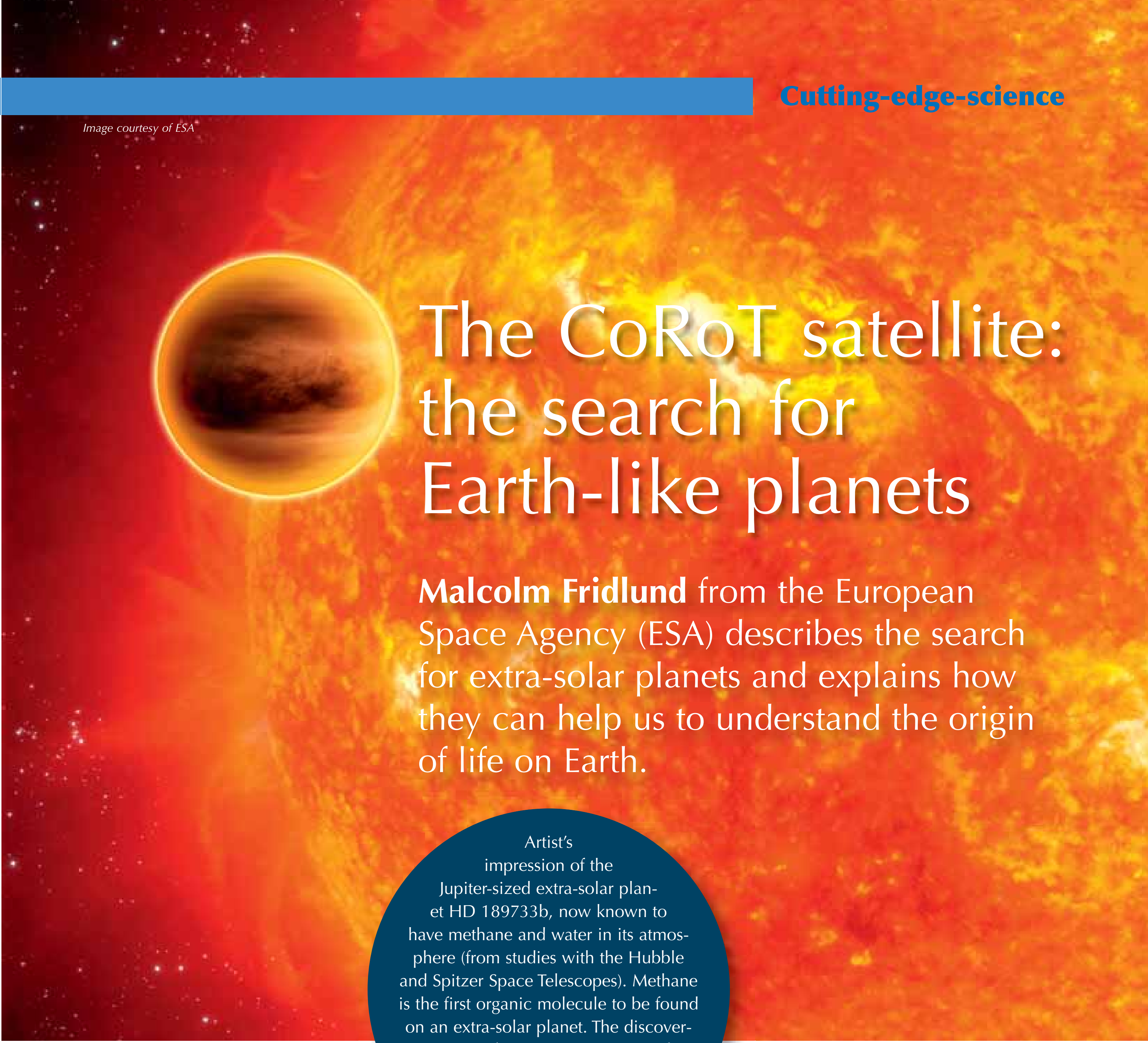


Image courtesy of ESA

The CoRoT satellite: the search for Earth-like planets

Malcolm Fridlund from the European Space Agency (ESA) describes the search for extra-solar planets and explains how they can help us to understand the origin of life on Earth.

Artist's impression of the Jupiter-sized extra-solar planet HD 189733b, now known to have methane and water in its atmosphere (from studies with the Hubble and Spitzer Space Telescopes). Methane is the first organic molecule to be found on an extra-solar planet. The discoveries come from spectroscopic studies of light from the parent star that has passed through the planet's atmosphere

CoRoT

On 27 December 2006, the French space agency CNES (Centre National d'Etudes Spatiales), ESA[w1] and their partners[w2] launched the CoRoT satellite to search for small Earth-like planets outside our Solar System (extra-solar planets, or exoplanets) and detect 'starquakes'. The satellite's name is derived from Convection (Co), Rotation (Ro) and planetary Transits (T), and its scientific objectives are to study the rotation of stars and the convection – the upwelling of hot gas – from the stellar interior, and to detect planets that pass between Earth and the stellar surface (a planetary transit).

All three phenomena can be studied by measuring the changes in the light emission of the observed stars. The convection from the interior of a star causes the intensity of the light it emits to increase or decrease by a few parts per million. Areas of intense magnetic activity inhibit convection, forming areas of reduced surface temperature which are visible as darker

REVIEW

This article on the search for exoplanets can trigger scientific discussions on what life is, and why we are interested in studying the physical and chemical characteristics of celestial bodies. It can also be used as a basis for philosophical and social discussions about the relationship of humans with possible alien life forms.

Marco Nicolini, Italy

BACKGROUND

As we go to press

CoRoT first caught sight of a planet transiting the star CoRoT-7, to the left of Orion in the constellation of Monoceros (the Unicorn), about 500 light-years away, in Spring 2008. However, confirming the planet's nature took months with large ground-based telescopes, so its discovery wasn't officially announced until 3 February 2009.

To measure the planet's mass and density, astronomers then used the High Accuracy Radial velocity Planet Searcher (HARPS) spectrograph attached to the 3.6 m telescope at the European Southern Observatory's[w4] La Silla Observatory in Chile, performing the longest set of observations (70 hours) on this machine so far. On 16 September 2009, the results were finally announced.

The planet, known as CoRoT-7b, is about the mass of Earth, which puts it among the lightest known exoplanets. With a diameter less than twice that of Earth, it is also the smallest exoplanet measured so far.

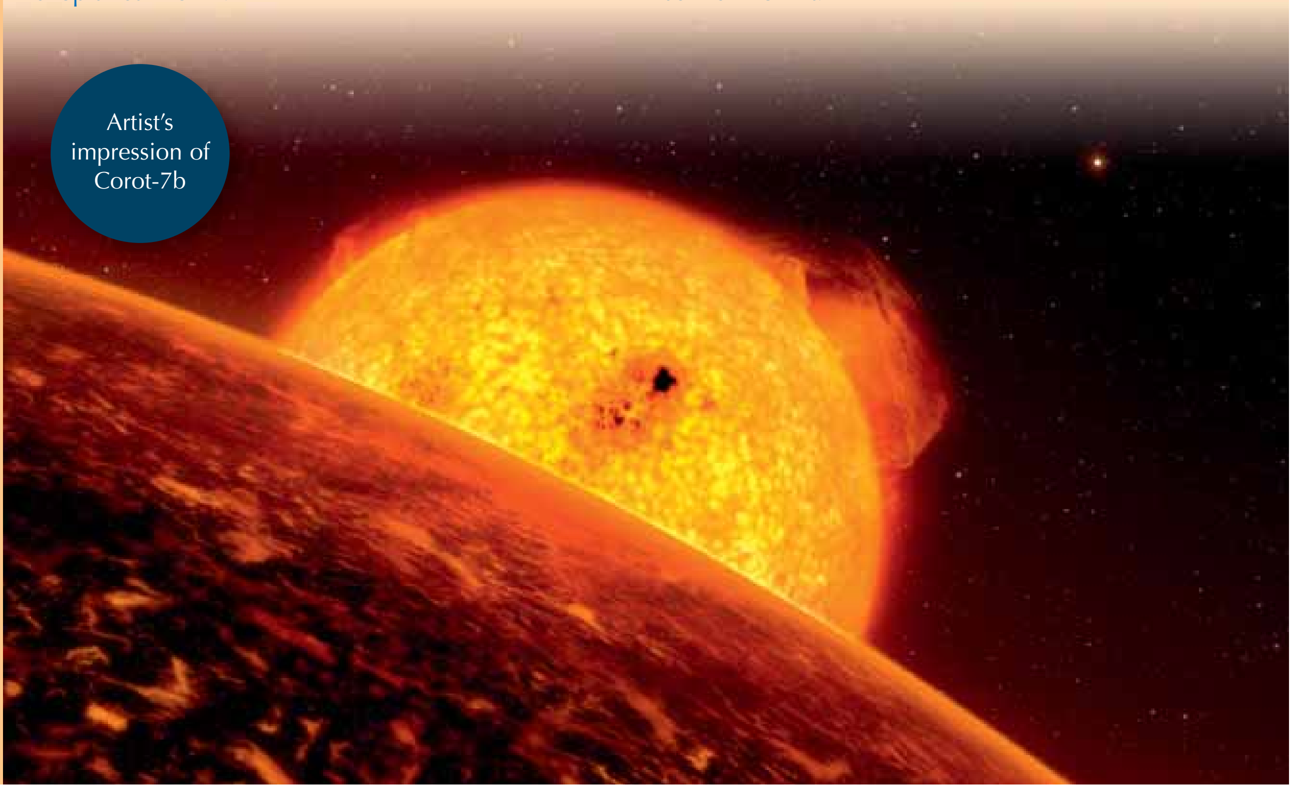
Every 20.4 hours, CoRoT-7b eclipses a small fraction (one part in 3000) of the light of its star for a little over one hour. Orbiting its star at a speed of more than 750 000 km/h, more than seven times faster than Earth's motion around the Sun, it is the fastest-orbiting exoplanet known.

And not only that: it is only 2.5 million km away from its host star, or 23 times closer than Mercury is to the Sun, which also makes it the closest known planet to its host star. It is so close that it must experience extreme conditions, which make it uninhabitable to life as we know it: the probable temperature on its 'day face' is above 2000 degrees Celsius, but minus 200 degrees Celsius on its 'night face'.

The calculated density is close to that of Earth, suggesting that the planet's composition is similarly rocky. Theoretical models suggest that the planet may have lava or boiling oceans on its surface.

The astronomers found from their dataset that CoRoT-7 hosts another exoplanet slightly further away from the star than CoRoT-7b. Designated CoRoT-7c, it circles its host star in 3 days and 17 hours and has a mass about eight times that of Earth. Unlike CoRoT-7b, this sister planet does not pass between its star and Earth, so astronomers cannot measure its radius and thus its density.

The finding brings astronomers ever closer to discovering inhabitable extra-solar planets, but such planets would need to be further from their star to support life as we know it.



Artist's impression of Corot-7b

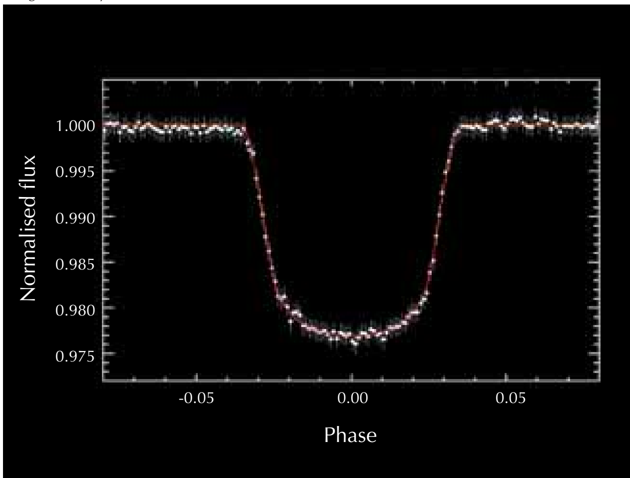
Image courtesy of ESO / L. Calcada

starspots. As the star rotates, its light output changes by a very small amount, depending on the number of starspots on the hemisphere that has rotated into view – so monitoring the starspots tells us how fast the star is rotating. Finally, when a planet in orbit around a star passes between the CoRoT satellite and the star, it can be detected as a small dip occurring periodically in the star's light output.

Planetary transits are used to detect exoplanets, while the convection and rotation measurements are used to characterise the star around which the discovered planets orbit. CoRoT will also be used for astroseismology: detecting acoustical waves generated deep inside a star that send ripples across its surface, known as 'star-quakes'. The exact nature of the ripples allows astronomers to calculate the star's precise mass, age and chemical composition. In this article, however, we will concentrate on the search for exoplanets.

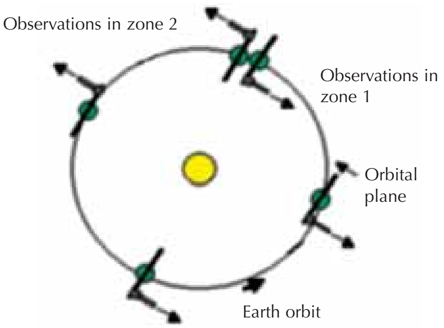
Measuring these phenomena requires a space telescope with a very precise photometer (or light meter). Unlike the larger Hubble Space Telescope (launched in 1990), CoRoT – which measures only 30 cm in diameter – was designed specifically for this purpose. The only instrument on board is a camera that takes one picture every 32 seconds. The on-board computer then measures the light (changes) from each star, and, over time, produces a light curve. The spacecraft is directed at the same spot in the sky for up to 150 days at a time, simultaneously observing up to 12 000 stars. The longer it remains pointed towards the same stars, the more transits it can see (see diagram above).

Image courtesy of ESA



This plot shows the transit of the first exoplanet discovered by CoRoT: CoRoT-Exo-1b. The transit results in a decrease in the luminosity of the Sun-like parent star when the planet passes in front of it every 1.51 days. It is a very hot Jupiter-like giant planet, similar to Jupiter also in mass (as determined by spectroscopic observations from the ground) and 1.49 +/- 0.08 times Jupiter's radius

Image courtesy of ESA



CoRoT is pointed in the same direction for more than 150 days at a time, before the Earth's movement around the Sun leads to the unwanted effect of the Sun's rays entering the telescope. CoRoT then turns 180 degrees around its long axis and points in the other direction

CoRoT can detect planets that are close to their star – taking up to 50-75 days to circle it (i.e. this is the length of their 'year') – and can find planets as small as our own Earth. The shape of the light curve (see diagram above) tells us how the planet is moving, how the outer layers of the star behave, and also the size of the planet. Once a planet has been detected by CoRoT, astronomers can observe the star and its planetary system with other types of instruments on very large telescopes on the ground, and learn more about it.

Already, the CoRoT satellite has found several large planets. It is now also beginning to pick up what we think are small planets. This should enable us to find out how common our own type of planet is in the Universe.

Extraterrestrial life

Why is it important important to know how common Earth-like (i.e. small and rocky) planets are? Firstly, because we would like to know whether our planet is unique. Furthermore, finding Earth-like planets outside our Solar System may help us to understand how life arose on Earth about 3.5 billion years ago.

Based on a hypothesis made more than 30 years ago, scientists assume that all types of 'life' work the same as that on Earth, and that alien life forms would have the same sort of metabolism as ours. Therefore, researchers base their search on what happened on Earth. Although the process by which life on Earth first emerged is still not known, it is believed to be linked to the presence of liquid water on a hard, rocky planetary surface. So if there are any other Earth-like planets, have any of them evolved life?

Finding an extra-solar planet as small as Earth is difficult. How much harder would it be to observe life forms at such distances? It would be particularly difficult if they were just bacteria, which were the only living organisms on Earth for the first few billion years and still outnumber other species by a million to one today in terms of individuals, and possibly also species number.

The key is to find a planet with its atmosphere out of chemical equilibrium. A planet's atmosphere (like almost everything else) tends towards a state of equilibrium (in which every chemical reaction proceeds at the same speed as its reverse process). Life, however, changes its environment: for instance, all the free oxygen (O_2) in our atmosphere has been produced by living organisms - plants and other organisms take up carbon dioxide and process it to oxygen, which is then released. Oxygen is so reactive that, if all life were to disappear from Earth, the free oxygen in our atmosphere would disappear in less than 4 million years (a short period given the billions of years of Earth's history).

A similar chemical disequilibrium occurred when life originated on Earth and bacteria produced an overabundance of methane. What happened to the methane-producing bacteria and their world? We don't actually know, but it is believed that new organisms evolved which produced oxygen instead: the oxygen was poisonous for the methane producers, and most of them died out.

The gas composition and other conditions such as temperature and pressure tell you what the equilibrium should be (in the case of Earth, similar to the atmosphere of Mars). So if we could analyse the chemical equilibrium of an exoplanet's atmosphere, we might determine if there is life as we know it, and maybe even to what stage evolution has progressed (methane or oxygen producers).

The atmospheres of two very large and hot exoplanets have been studied with photometric measurements by the Hubble and Spitzer space telescopes as well as ground-based telescopes, and water and methane have been detected on one (see image on page 15). This is another step towards proper comparative planetology, comparing the planets in our Solar System with those in other systems. With the aid of telescopes like CoRoT, designed specifically to find small rocky planets similar to Earth, we can expect – within the next few years – to find other stars that are circled by planets very similar to our own.

Image courtesy of ESA / CNES

Artist's impression of the CoRoT satellite in its orbit at 900 km altitude over Earth's poles

However, current technology is not sufficient to analyse the atmospheres of such smaller planets. The light we receive from an exoplanet is extremely feeble, and very large telescope apertures are needed: of all the photons radiated by an exoplanet, only a few photons per square metre arrive on Earth. Furthermore, our atmosphere contains so much oxygen and methane that there are already many 'oxygen photons' and 'methane photons' (photons with methane or oxygen signatures, respectively). The few 'oxygen photons' and 'methane photons' from an exoplanet would have to compete with all of these, making it impossible to detect them. Therefore we need to go into space – with large telescopes – which is both very difficult and very expensive. Scientists are developing the next generation of instruments to be technically able to carry out the necessary observations to tell us if these planets have also produced life and, if so, what happened to it.

Ultimately, we hope to apply this knowledge to understanding the evolution of life on our own planet.

Web references

w1 – To learn more about the European Space Agency, see: www.esa.int

w2 – To find out more about the CoRoT satellite and the partners of the mission, see: www.esa.int/science/corot

w3 – For more information about ESTEC, see the ESA website[w1] or use the direct link: http://tinyurl.com/39nw3r

w4 – To learn more about the European Southern Observatory, see: www.eso.org

Resources

Listen to the author's podcast about the CoRoT project, which can be found on the ESA website[w1] or via this direct link: http://tinyurl.com/ydoggpy

Find out more about the search for exoplanets in this article: Jørgensen UG (2006) Are there Earth-like planets around other stars? *Science in School* **2**: 11-16. www.scienceinschool.org/2006/issue2/exoplanet

To view all the *Science in School* articles about space science, see: www.scienceinschool.org/space

Malcolm Fridlund is a Swedish astronomer who has worked at the European Space Research and Technology Centre[w3] (ESTEC) for more than 20 years. He has specialised, scientifically, in the area of exoplanets and the methods used to find and study them. He is currently ESA's project scientist for the CoRoT mission.

The intracellular environment: not so muddy waters

Giuseppe Zaccai from the Institut Laue-Langevin (ILL) in Grenoble, France, describes how he and his co-workers have uncovered a way to explore water dynamics in the cell interior using neutron scattering and isotope labelling.

The Dead Sea

Image courtesy of EdwardShtern / iStockphoto

Compared to other liquids, water has extraordinary properties. As water is essential for all living organisms, its properties also play a truly vital role at the level of molecular biology – a discipline which seeks to understand life processes at the levels of atoms, molecules and their interactions.

The *hydrophobic effect* is one such property. It describes the observation that in a liquid solution, water and oil do not mix. The reason is that water molecules can form hydrogen bonds with each other and other molecules (which are called *hydrophilic*), but not with oil-like molecules (which are called *hydrophobic*) (for more on this topic, see Cicognani, 2006). This has fundamental consequences in molecular biology. The hydrophobic effect leads to the spontaneous organisation of lipid molecules to form the membranes that surround cells. It also contributes to the formation of three-dimensional structures in proteins, RNA and DNA, favouring their folding in such a way as to hide the hydrophobic parts of their structures from contact with water and to expose the hydrophilic parts.

The hydrophobic effect, as it is understood, depends critically on the special dynamic molecular properties of *liquid* water. The implication of this effect in membrane formation and


Image courtesy of Giuseppe Zaccai

Marion Jasnin and Giuseppe Zaccai at ILL

macromolecular folding was deduced from test-tube experiments on solutions in which water is clearly in the liquid state. There have been suggestions, however, that water in cells is not in its normal liquid state but is somehow 'tamed' and cannot move about as freely inside the viscous intracellular environment, a thick soup of proteins and other molecules. It was therefore very important to measure the dynamic state of water directly in living cells. This was not an easy task, but the special properties of the neutron helped scientists from my research group at the ILL[w1], as well as researchers at the Institut de Biologie Structurale CEA-CNRS-UJF[w2] in Grenoble, France, to tackle it successfully.

The first experiments on water dynamics in living cells were performed at ILL on cells from organisms that live in the extremely salty conditions of the Dead Sea (Tehei et al., 2007). Salt is used as a preservative because at high concentration it usually kills micro-organisms. The Dead Sea *halophilic* (salt-loving) organisms evolved to cope with the very high salt concentration by having macromolecules with markedly increased hydrophilic surfaces. These surfaces affect water dynamics inside the cell, leading to the observation of a major 'slow water' component in the Dead Sea cells.

Clearly, if this were true for all organisms, it would lead to a complete reassessment not only of the hydrophobic effect, but also of the role of water in biology in general. It was therefore essential to test whether this behaviour was special to the halophilic organisms or could be generalised (Jasnin et al., 2008).

A flask of deuterated *Haloarcula marismortui* cells. Note the red colour of the halophilic organisms, which in natural environments colours salt lakes and salt ponds. It is due to carotenoids in the cell membranes, which enter the food chain and are also responsible, for example, for the colour of pink flamingos


Image courtesy of Giuseppe Zaccai

At ILL, scientists use neutron beams to investigate a variety of solid and liquid materials. In neutron spectrometry experiments to measure dynamics (how atoms move in a substance), the neutrons in the beam collide with the atoms to be studied, like billiard balls bouncing off each other. Neutrons and atoms exchange energy and momentum – the neutrons are scattered. Thus, measuring how these values change for the neutrons after the collision gives us an indication of the energy and momentum of the atoms they encountered, and therefore of how these atoms move.

But how can we distinguish between the motions of different atoms in a complex sample, such as a cell that contains not only water but also many other molecules whose atoms move in different ways? Neutrons are scattered with different power by different atoms. To study complex systems, scientists use a trick to reduce the scattering power of everything they do not want to measure. Hydrogen scatters neutrons much more strongly than all other atom types (about 10-100 times, depending on which atom type you compare it with). In contrast, deuterium, a heavy isotope of hydrogen (its nucleus contains one neutron in addition to one proton), scatters neutrons about 40 times more weakly than hydrogen. Exploiting this property, scientists replace hydrogen with deuterium in the components of a complex system they are not interested in and render them practically 'invisible'. The contributions to the scattering signal by the molecules that contain deuterium are negligible; we 'see' only the motions of the molecules that contain hydrogen.

Marion Jasnin and her co-workers used this trick to analyse water dynamics *in vivo* in the cytoplasm of *Escherichia coli* bacteria, taking advantage of the neutron sources at ILL and ISIS[w3], UK. Studying physics with biological samples is always a difficult

Marion Jasnin mounting a sample on the cryostat rod of the IN6 spectrometer. The cryostat controls the sample temperature during data collection. The sample is in the flat aluminium box at the end of the rod. The discs on the rod are baffles to help maintain constant temperature at the bottom of the cryostat

Image courtesy of Giuseppe Zaccai

REVIEW

Much is made in school science of the scientific process, and yet our students typically do not have much exposure to cutting-edge research in science, or to the style of writing used in academic journals. The reasons for this distance include little apparent relevance to school science, and the often impenetrable style of academic prose.

These criticisms do not apply to Zaccai's article, which also addresses an important 'how do we know?' question. While the behaviour of molecules *in vitro* may be well studied and understood, it is often a matter of conjecture how much of this replicates behaviour *in vivo*. The article suggests that water, at least, does not behave differently, and the text is of interest to teachers and older students of biology, physics or chemistry, particularly as there is a cross-disciplinary nature to the reported studies.

Possible comprehension questions include:

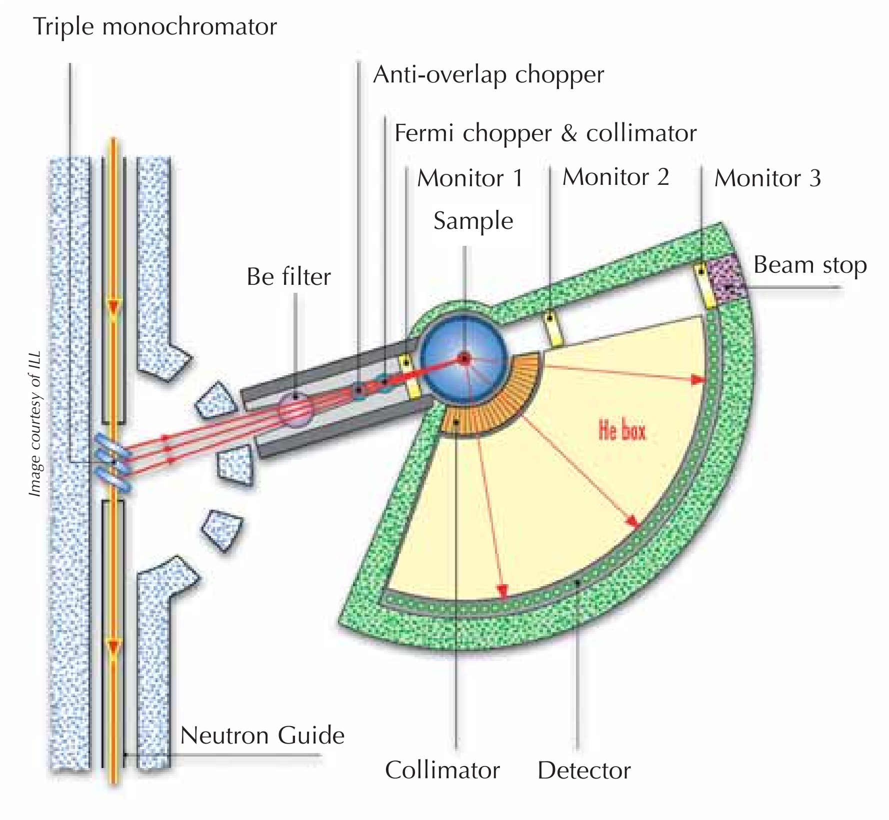
- Explain the analogy drawn between the lagoon in Venice and intracellular water.
- What non-SI unit(s) crop(s) up in the article? Express this/these in SI units.
- What does 'deuteration' mean?
- Why was *E. coli* a good experimental subject?
- Rank some of the materials mentioned in order of their ability to scatter neutrons.
- Define 'hydrophobic' and 'hydrophilic'.
- How were the irrelevant molecules rendered 'invisible' to the neutron beam?
- What conclusion can be drawn by the work described in the article?

Ian Francis, UK

task, and human cells are very delicate and complicated to work with. *E. coli* were a good alternative as they are easier to handle, yet live in the human gut under similar physiological conditions of temperature and salinity as our own cells; and remember, the adaptation of the cytoplasm to high salinity was thought to be the cause of the 'slowed down' water in the halophiles.

To replace the hydrogen atoms in the proteins and other cellular macromolecules by deuterium, *E. coli* cells were grown on deuterated nutrients and deuterated (heavy) water. For the measurements, they were then centrifuged gently and the heavy water was replaced with normal (hydrogen-containing) water, diluting out the deuterium-containing intracellular water but not the deuterium in the macromolecules. In such a sample, after diluting out, the neutron scattering signal comes mainly from the intracellular water. The pellet of living cells was placed in an aluminium sample holder. Aluminium, like all metals, is transparent to neutrons – though obviously not to light or X-rays.

Neutron energy and momentum are determined before and after scattering by measuring their wavelength (in the Ångström range). The two main methods used to do this (depending on the spectrometer) are by 'time of flight', in which the neutron velocity (inversely proportional to wavelength, velocity is in the km/s range for Ångström wavelengths) is measured over a determined path; and by diffraction of crystals (according to Bragg's law, only a certain wavelength is diffracted for a given crystal periodicity and angular setting – read more about this law in Hughes, 2007 and Cornuéjols, 2009). Find out more about these methods online[w4].



The layout of the IN6 neutron scattering spectrometer at ILL

Heat is motion: the speed at which atoms in a material move depends on the temperature. However, atoms in one material can also move at different speeds at the same temperature, depending on how they are bound to other atoms around them: water molecules are known to be slowed down by direct contact with macromolecules such as proteins or DNA. The question the scientists asked was: do cellular water molecules that are not in direct contact with macromolecules move as they would normally in liquid water, or are they, too, significantly slowed down?

Each neutron spectrometer is specialised for measuring atomic motions occurring within a given length scale–time scale window. Basically, there are three types: those measuring in the range of about 1 Ångström amplitude occurring in about 1 picosecond (10^{-12} s), which corresponds to the thermal motion of hydrogen atoms in liquid water at room temperature (note that this corresponds to speeds of about 100 m/s); those measuring in the range of 1-10 Ångström amplitudes in a nanosecond (10^{-9} s), which would pick up 'slowed down' water; and an intermediate type for the range of 1-10 Ångström amplitudes in 100 picoseconds.

By using a picosecond and a nanosecond spectrometer, Marion Jasnin and her co-workers established that water dynamics within a bacterial cell are similar to those in pure water. Water molecules rotate as well as diffuse linearly in the liquid, and a slightly slowed-down rotational diffusion was measured. From the fraction of hydrogen atoms that moved more slowly and the average surface of macromolecules inside an *E. coli* cell, the scientists calculated that this fraction corresponds to a single layer of water molecules next to the macromolecules that is slowed down, but the rest flows as freely as in liquid water.

What happens inside the cell, then, is similar to what is found around the islands of the Venetian lagoon in Italy. The water close to the macromolecules (islands) is held up, whereas in between – as little as one layer of water molecules from the macromolecules – the water regains its fluidity. This is in contrast to the 'taming' hypothesis that claimed that all the water in the cell would be slowed down.

Following up on the *E. coli* experiments, the group has now also managed to explore water dynamics in human red blood cells at neutron sources in Germany (FRM II[w5]) and Switzerland (PSI[w6]). The same behaviour as in *E. coli* was confirmed, with liquid water flowing freely beyond the first layer which is in contact with haemoglobin, the main protein contained in these cells (Stadler et al., 2009).

Scientists can heave a sigh of relief – and continue to do their experiments in liquid water solutions, thanks to this confirmation that such experiments are a valid model for what happens in cells.

References

Cicognani G (2006): Defying the laws of physics? *Science in School* **1**: 19-21. www.scienceinschool.org/2006/issue1/defying

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

Hughes D (2007) Taking the stress out of engineering. *Science in School* **5:** 61-65. www.scienceinschool.org/2007/issue5/stress

Public domain image; image source: Wikimedia Commons

Satellite photo of the Venice lagoon, taken by ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), an imaging instrument flying on Terra, a satellite part of NASA's Earth Observing System (EOS)

Jasnin M, Moulin M, Haertlein M, Zaccai G, Tehei M (2008) Down to atomic-scale intracellular water dynamics. *EMBO Reports* **9**: 543-547. doi:10.1038/embor.2008.50

Stadler AM, Embs JP, Digel I, Artmann GM, Unruh T, Buldt G, Zaccai G (2008) Cytoplasmic water and hydration layer dynamics in human red blood cells. *Journal of the American Chemical Society* **130**: 16852-16853. doi:10.1021/ja807691j

Tehei M, Franzetti B, Wood K, Gabel F, Fabiani E, Jasnin M, Zamponi M, Oesterhelt D, Zaccai G, Ginzburg M, Ginzburg BZ (2007) Neutron scattering reveals extremely slow cell water in a Dead Sea organism. *Proceedings of the National Academy of Sciences of the United States of America* **104**: 766-771. doi:10.1073/pnas.0601639104

Web references

w1 – To learn more about the Institut Laue-Langevin, see: www.ill.eu

w2 – To find out more about the Institut de Biologie Structurale CEA-CNRS-UJF, see: www.ibs.fr

w3 – Learn more about ISIS, the pulsed neutron and muon source located at the UK Rutherford Appleton Laboratory near Oxford, here: www.isis.rl.ac.uk

w4 – For more information about neutron diffraction, as well as about the time-of-flight and crystal diffraction techniques, see the following direct links to Wikipedia pages: http://tinyurl.com/yh436y4 for neutron diffraction, http://tinyurl.com/ykywxht for inelastic neutron scattering, http://tinyurl.com/yj4bnrf for time-of-flight, and http://tinyurl.com/yfho9gz for crystal diffraction

w5 – Find out more about the German research neutron source FRM II (Forschungs-Neutronenquelle Heinz Maier-Leibnitz) in Munich here: www.frm2.tum.de

w6 – To learn more about the Paul Scherrer Institute in Villingen, Switzerland, see: www.psi.ch

Resources

For a portrait of a young researcher working on halophiles, see: Leigh V (2008) Salt of the Earth. *Science in School* **8**: 60-62. www.scienceinschool.org/2008/issue8/prudencemutowo

If you enjoyed this article, you might also like to read other articles about science at ILL in *Science in School*. See: www.scienceinschool.org/ill

Giuseppe Zaccai was born in Alexandria, Egypt, and educated in English-language schools there and in Rome, Italy. After a PhD in physics from the University of Edinburgh, UK, he began to work on biophysics in the USA. He went on to ILL, where he is the Senior Fellow for Biology. He also holds the position of *directeur de recherche* with the Centre National de la Recherche Scientifique (CNRS) of France and has headed the molecular biophysics laboratory of the IBS in Grenoble since it was founded in 1992.

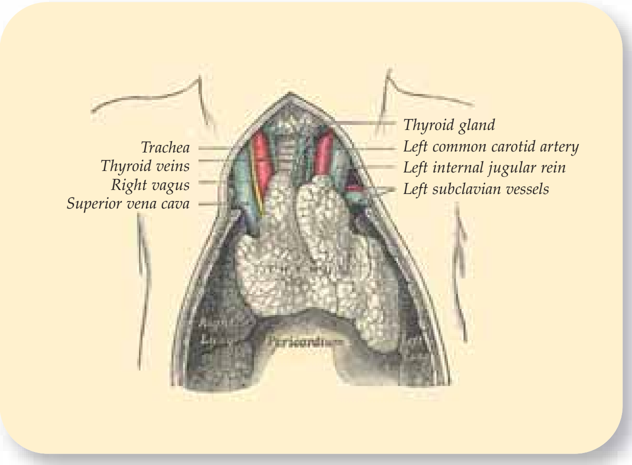
Winning an Oscar in immunology

Have you ever wondered what it is that scientists get so excited about? **Ana de Barros** from the Instituto de Medicina Molecular in Lisbon, Portugal, shares with us the excitement of researching the immune system.

Ana in the lab

When my phone rang and I was told that our article was to be published in *Nature Immunology* (Ribot et al, 2009), I just couldn't stay put. But even though a few people around me understood my hysterics, I had to explain to many others what this really meant for us: "It's like an actor receiving an Oscar!"

Our particular Oscar was not for best film, actor or soundtrack, but for a discovery in immunology. Having our work published in this prestigious journal meant that fellow scientists had deemed it noteworthy, and that others would now be able to learn from it and build upon it towards the common goals of understanding how our bodies fight disease and subsequently improving human medicine. Sitting on my shelf, 'our' issue may look like just another magazine, but it means as much to me as a trophy in a display cabinet.



Public domain image; image source: Wikimedia Commons

The human thymus. Reproduction of a lithographic plate from the 20th US edition of *Gray's Anatomy of the Human Body*, originally published in 1918

The subject of our research is the development of a type of white blood cell, called a T lymphocyte or T cell, in the thymus. T lymphocytes are distinguished from other lymphocytes by a molecule on their surface called a T-cell receptor, which recognises the antigen carried by a specific invader, such as a bacterium or virus.

T cells are generally considered part of the adaptive immune response, because they not only eliminate an invader (and the cells it has invaded), but also produce memory cells. As their name implies, these memory cells 'remember' that invader for as long as the animal lives, so this immune response adapts very quickly: if that same invader strikes again, the memory cells will recognise and destroy it. This adaptive immune response, which only vertebrates possess, is activated by the innate

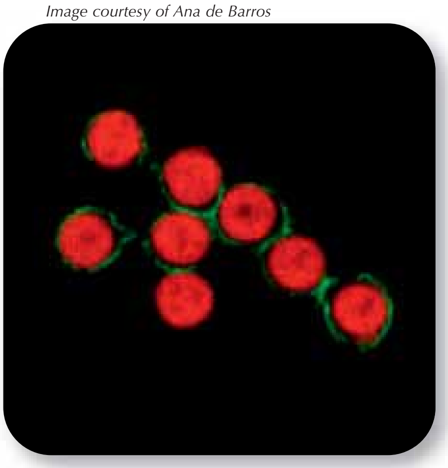
Images courtesy of Ana de Barros

Ana de Barros

immune response, the non-specific defence system found in all classes of animal and plant life. The innate immune response is the first line of defence: the initial reaction to (and attempted elimination of) invaders. Unlike the adaptive immune response, the innate immune response does not confer long-lasting or protective immunity, but it is a swifter and more general response.

Our work focuses on a specific type of T cell, the gamma delta (γδ) T cell, which is seen as an evolutionary bridge between the adaptive and the innate immune responses. γδ T cells form subtypes with different functions, depending on what tissue they are found in and which specific T-cell receptor they bear. Even though there is a growing consensus about the importance of γδ T cells, little is known about their behaviour or development, and scientists haven't yet found any molecular markers that they can use to identify the different subtypes.

Image courtesy of Ana de Barros



Confocal image of γδ T cells; the γδ T-cell receptors are stained green

In our research, we looked at a protein that we suspected might be a potential marker for one subtype of γδ T cells. This protein, called CD27, is a membrane receptor involved in cellular communication.

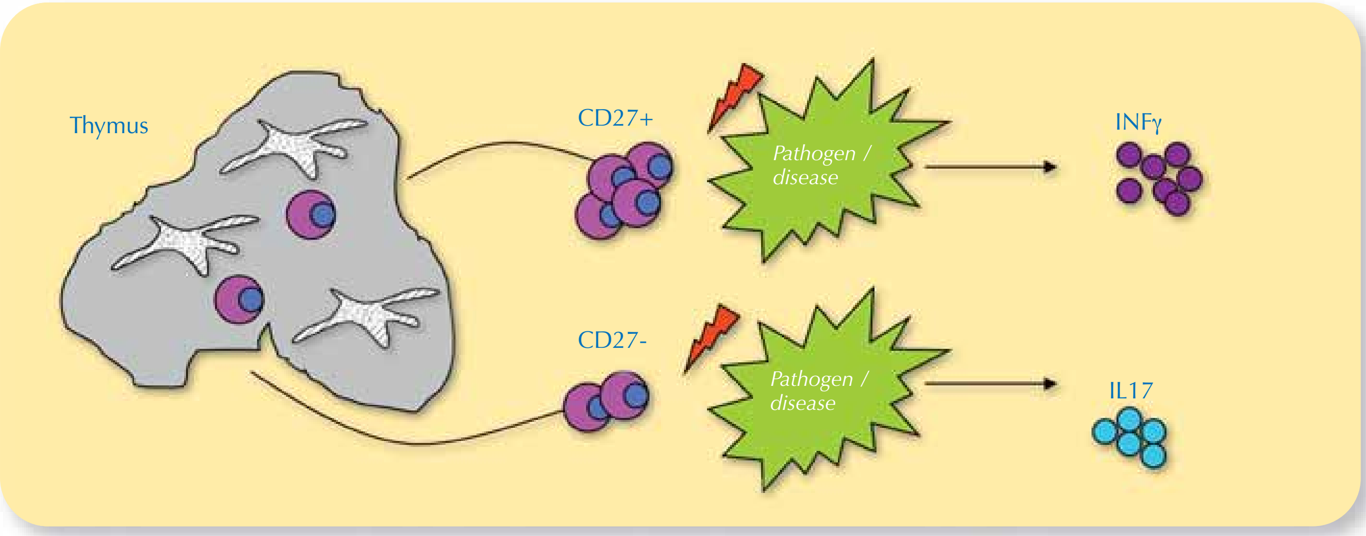
We found that our suspicions were well founded: CD27 can be used to identify a particular subtype of γδ T cell. But what was most interesting

REVIEW

Immunology is still a fast-moving subject as more is discovered about the involvement of the different types of cells and signalling molecules. Cerebral malaria in humans is currently very difficult to treat. A specific subtype of T cells and the signalling molecule CD27 are involved in the progress of cerebral malaria in mice and this research may have implications for the treatment of this disease in humans. Using this article for background information may stimulate discussion on malarial treatment and eradication, basic immunology, genetic manipulation of mice and whether animal experimentation is right. It could be used for comprehension with further questions set to probe students' understanding of immunology at the upper secondary level.

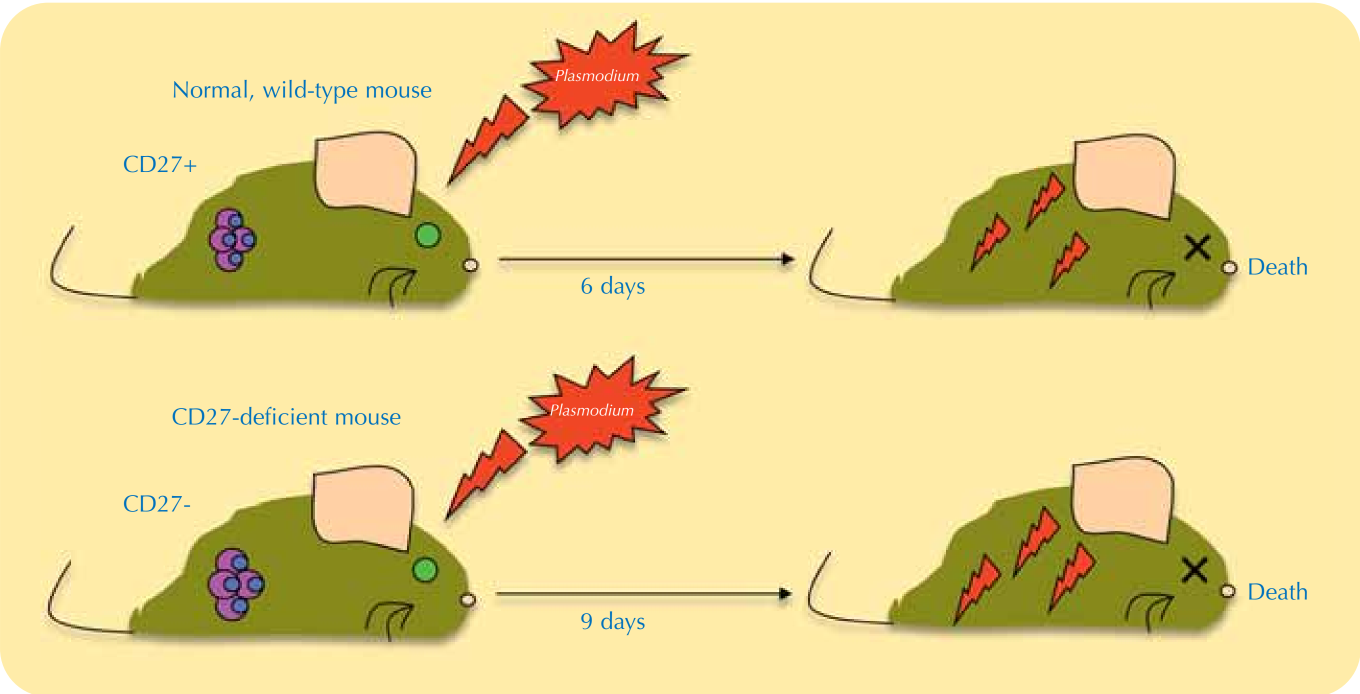
Shelley Goodman, UK

Image courtesy of Ana de Barros



The influence of CD27 on the formation of γδ T cells

Image courtesy of Ana de Barros



Normal, wild-type mice died more quickly when infected with *Plasmodium* than the CD27-deficient (CD27-) mice did

was that we discovered that the presence of this protein doesn't merely characterise this subtype of γδ T cell, it actually drives its formation. Within the thymus, the precursors of γδ T cells that mature in the presence of CD27 (CD27+) produce a cytokine called interferon-gamma (IFNγ) whereas cells that mature without CD27 (CD27-) produce primarily a different cytokine, interleukin-17 (IL-17). The presence or absence of the cytokine CD27 thus defines which subtype a γδT cell will belong to (see diagram above). The two cytokines IFNγ and IL-17 play an important role in the immune response, with very distinct consequences: those T cells producing IFNγ will play a crucial role in fighting viruses and tumours, whereas those producing IL-17 are associated with autoimmune diseases such as multiple sclerosis.

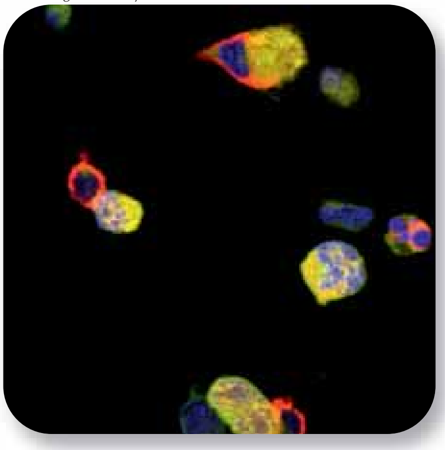
γδ T cells play an important role in initiating a quick immune response to various parasites, including the malaria parasite *Plasmodium*. In humans, this parasite multiplies in the liver, and then spreads to the blood stream, infecting red blood cells, which it destroys. In severe cases this can clog the blood vessels that carry blood to the brain, causing what is known as cerebral malaria. We were interested in discovering whether the different subtypes of γδ T cells influenced this outcome differently: was one subtype of γδ T cell better at preventing cerebral malaria than the other?

To analyse the behaviour of both γδ subtypes in the course of infection, we used mice infected with a strain of *Plasmodium* as a model for what happens in humans. We compared two groups of mice: one group with CD27 in most of their cells (so the majority of their cells produced IFNγ), and another genetically engineered group in which none of the maturing γδ T cells had CD27 – which meant that they produced less IFNγ. Both groups of mice were infected with the malaria parasite, and we found that CD27 does indeed seem to influence the development of cerebral malaria. Mice without CD27 suffered less from cerebral malaria, probably because they produce less IFN γ, which is involved in inflammation (see diagram on page 26). Whether this finding could be used in the development of future malaria drugs – perhaps by manipulating the expression of CD27, so that the cells produce lower levels of pro-inflammatory cytokines – remains to be seen.

In short, we were the first to describe a function for CD27 in T-cell precursors in the thymus – and the fact that *Nature Immunology* decided to publish our article is recognition of just how important these findings are. As our group leader, Bruno Silva-Santos, explains, “We are now investigating the analogous processes in human cells. Our long-term goal is to… be able to manipulate [γδ T cells] for therapeutic purposes such as fighting autoimmune diseases and cancer.” We still have a lot of work ahead of us, but this recognition of what we have already achieved reminds us that it is all worth it.

Long after I had hung up the phone, then finished explaining my excitement, I still couldn’t stop smiling.

Image courtesy of Bruno Silva-Santos’ lab



Confocal image of human γδ T cells (in red) attacking tumour cells (in yellow)

References

Ribot JC, deBarros A, Pang DJ, Neves JF, Peperzak V, Roberts SJ, Girardi M, Borst J, Hayday AC, Pennington DJ & Silva-Santos B (2009) CD27 is a thymic determinant of the balance between interferon-γ and interleukin 17-producing γδ T cell subsets. *Nature Immunology* **10**: 427-436. doi:10.1038/ni.1717

Web references

w1 – Find out more about the Instituto de Medicina Molecular in Lisbon here: www.imm.fm.ul.pt

Resources

To learn more about malaria, see:

Hodge R (2006) Fighting malaria on a new front. *Science in School* **1**: 72-75. www.scienceinschool.org/2006/issue1/malaria

To browse previously published cutting-edge articles in *Science in School*, see: www.scienceinschool.org/cuttingedge

Ana de Barros was born in Lisbon in 1983, and at the age of 19 moved to Newcastle, UK, where she graduated in genetics. She then stayed in the UK to do an MSc in biomolecular archaeology in Manchester. After working for 3 months in a lab in Athens, Greece, doing stem cell research, Ana went back to Portugal in 2007, where she started her PhD in immunology at the Instituto de Medicina Molecular in Lisbon[w1]. She is interested in scientific journalism, as is brings together communication and science. Outside the lab, she is involved in the arts and has a band where she plays the guitar, writes songs and sings. Ana also does a lot of photography and enjoys travelling.

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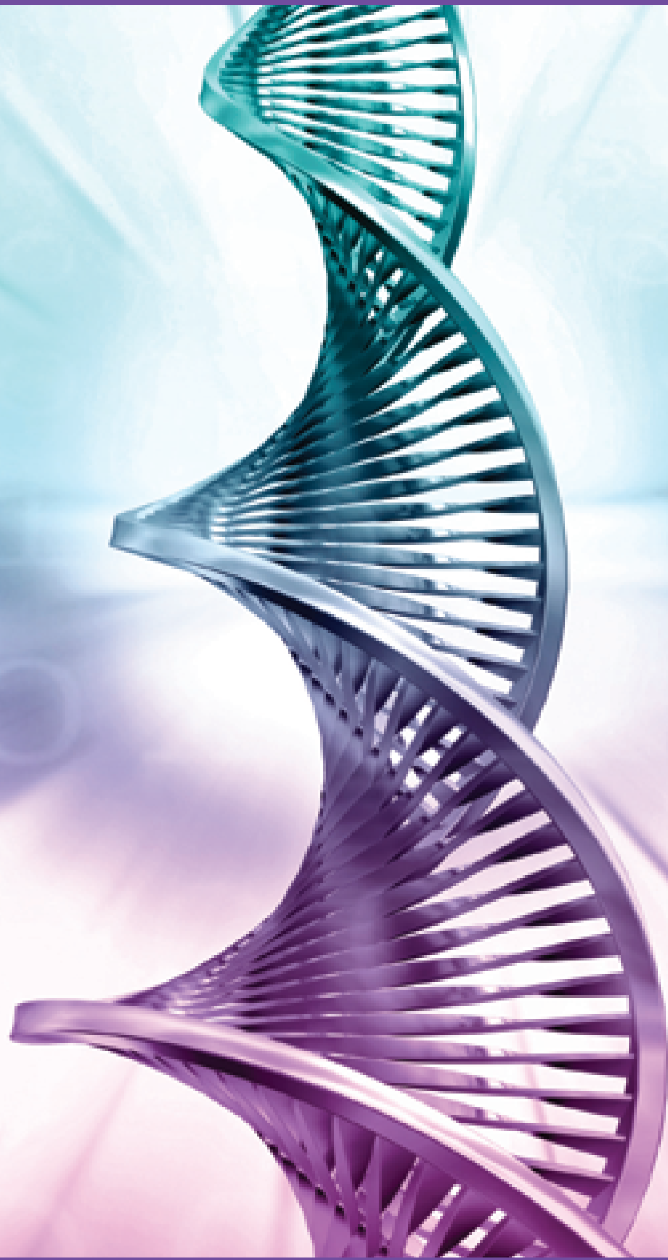

Enhancing biology teaching using biological databases

The European Learning Laboratory for the Life Sciences is an education facility which works with teachers and scientists to provide secondary-school teachers with interactive experiences with the life sciences, helping to bridge the gap between research and schools. This LearningLAB will provide an interactive introduction to the field of bioinformatics, a central part of modern biology that can be used effectively in the classroom to teach biological concepts.

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The drama of science

Do you enjoy the drama of science? The colour, the smells, the intricacies? Why not follow science teacher **Bernhard Sturm's** suggestions: let your students bring yet more drama into the classroom by (re-)enacting science, to help them visualise and remember the lesson.

Drama can combine elements of art, music and sport, and develop students' creativity and fitness as well as their emotional and aesthetic awareness. As team activities, they also promote communication and co-operation among young learners. So why not use drama in science teaching?

This article offers a selection of drama-based activities to act or re-enact science in the chemistry and physics classroom.

Chemistry

Redox reactions

This is a method to visualise the exchange of oxygen between different metal atoms within the redox series (after Lavoisier). Each student wears a top in one of three colours, representing atoms of oxygen and two different metals (there should be equal numbers of each colour). In groups of about 8-10, the students enact simple redox reactions with 1:1 stoichiometry, such as $CuO + Fe \rightarrow Cu + FeO$, and afterwards present them to the entire class. Students often find creative ways to represent both the activation energy and the release of energy in these reactions.

Image courtesy of *The Yorck Project: 10.000 Meisterwerke der Malerei*; image source: Wikimedia Commons

REVIEW

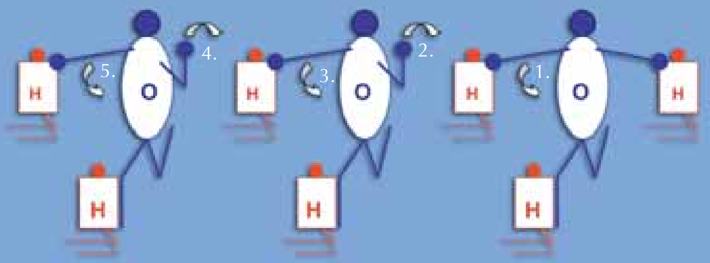
This article gives specific and clear ideas about how teachers can use drama to facilitate students' learning of abstract concepts in physics and chemistry. The activities can be used mainly while tackling standard topics in the curriculum.

The fact that the suggested activities do not need complicated or expensive resources makes them easy to use in the classroom. Teachers are given clear and concise guidelines about how to include creative writing and role playing in their lessons. This not only makes science lessons more interesting and fun for the students, but also means they will feel more involved and responsible for their own learning experience. This will also attract students who are more oriented towards languages and the arts because it stimulates their imagination and creativity. Additionally, it can help teachers to start applying small changes to their teaching, as well as provide new ideas for teachers who have already started implementing similar activities in class.

Catherine Cutajar, Malta

Image courtesy of Bernhard Sturm

Staging the Grotthuss mechanism:



Red: hydrogen atom (kneeling)
Blue: oxygen atom (standing)
Bent arms/legs: free electron pairs in the oxygen atom
Stretched arms/legs: binding electron pairs

The positive charge passes rapidly down from the right side of the line (H_3O^+) to the left (H^+) by rearranging electron pairs and exchanging protons from one water molecule to the next

Chemical bonding: conductivity of water (Grotthuss mechanism)

The following method can be used to demonstrate how an electric current passes rapidly through water, although the protons do not travel: instead, a positive charge is transmitted. The students should wear tops in one of two colours, representing hydrogen and oxygen atoms (ratio 2:1). Arrange a line of water molecules: each molecule consists of two (kneeling) hydrogen atoms and one (standing) oxygen atom. The oxygen atom touches one hydrogen atom with his or her right hand and the other hydrogen atom with his or her right foot (see diagram above). The hydrogen atom's arms and legs have no function. One extra hydrogen atom is attached to the oxygen atom (touched by his or her left hand) at one end of the line (H_3O^+). The arms and legs of the oxygen students represent electron pairs. The surplus binding electron pair is passed from one end of the line of water molecules to the other, as the oxygen atom in the H_3O^+ molecule lets go of the hydrogen atom with his or her right hand; instead, the oxygen atom of the neighbouring molecule touches this hydrogen atom with his or her left hand, and so on down the line.

Radical polymerisation of ethene to polyethylene

The following method is useful for understanding the mechanism of polymerisation and differentiating between the synthesis of linear and cross-linked polymers. The polymerisation of ethene is illustrated, integrating all students one by one. Each body represents a carbon atom, each foot a hydrogen atom and each arm a binding electron. A single student (representing a methyl radical) waves his or her arm (an unpaired electron). Two students holding both hands (a double bond) represent an ethene molecule. The radical binds to the ethene molecule: one of the components of the ethene molecule has to break one handclasp (binding electron) and bind to the free electron of the radical (new handclasp). The resulting molecule with three carbon atoms is again a radical. It binds another ethene molecule, and so on (see diagram on page 31).

This model can be extended to represent the cross-linking of buta-1,3-diene: the students representing the C_2 and C_3 atoms of the molecule touch feet to symbolise the single bond (see diagram on page 30). The arrival of a methyl radical causes one of the double bonds (double handclasps) in the buta-1,3-diene molecule to break, and a new single bond (handclasp) is formed between the methyl radical and, for example, the C_4 atom. The newly formed molecule is also a radical, with a free electron at

C_3. The C_1 atom of a second buta-1,3-diene molecule can thus bind, breaking its double bond (double handclasp) and forming a cross-link (handclasp) with C_3 of the original molecule. The resultant nine-carbon molecule is also a radical, with a free binding electron at C_2 of the second buta-1,3-diene molecule.

Physical states of water

The spacing and velocity of water molecules differs between solid, liquid and gaseous states. In this exercise, students act as water molecules. In my experience, it is best done outside, where there is more space, and it helps to separate the class into male and female teenagers – one group acts, the other watches. The teacher tells the students how to move around: beginning with winter (0 °C), the students should stand still and in a grid formation. As the year goes on, it becomes spring and summer, and the molecules move faster (up to 40 °C), but still stay in contact. Finally, the molecules end up in a kettle, heat up and evaporate (100 °C).

In each phase, the teacher takes a snapshot of the state by shouting "Stop!". Actors (e.g. the girls) and spectators (e.g. the boys) describe what was happening before and what they can see around themselves now.

The groups of actors and spectators then swap roles, and the molecules 'cool down' to 0 °C again.

This activity can be modified to demonstrate the thermal expansion of benzene, with eight students surrounding about 20 'benzene' students with a slack rope, until the pressure through 'heating' becomes too strong and the surrounding students are forced to let go of the rope.

Physics

Vacuum

The painting *An Experiment on a Bird in the Air Pump*[w1] by Joseph Wright of Derby (1768) can be used to teach the history of vacuum.

Divide the class into groups of three, and give each group a reprint of the painting and a worksheet showing the silhouette of the main devices and characters (see image on page 32; to be downloaded online[w3]). The following three questions tend to promote discussion about the painting:

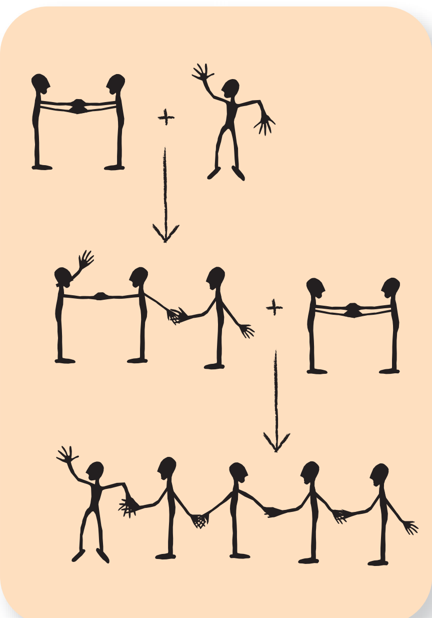
1. What is the experiment about?
2. How does it end?
3. What are the roles and attitudes of the different characters depicted?

After the discussion, the whole scene can be re-enacted by the students using a vacuum pump, with a 'Schokokuss' (a small chocolate-covered cream cake) to replace the bird.

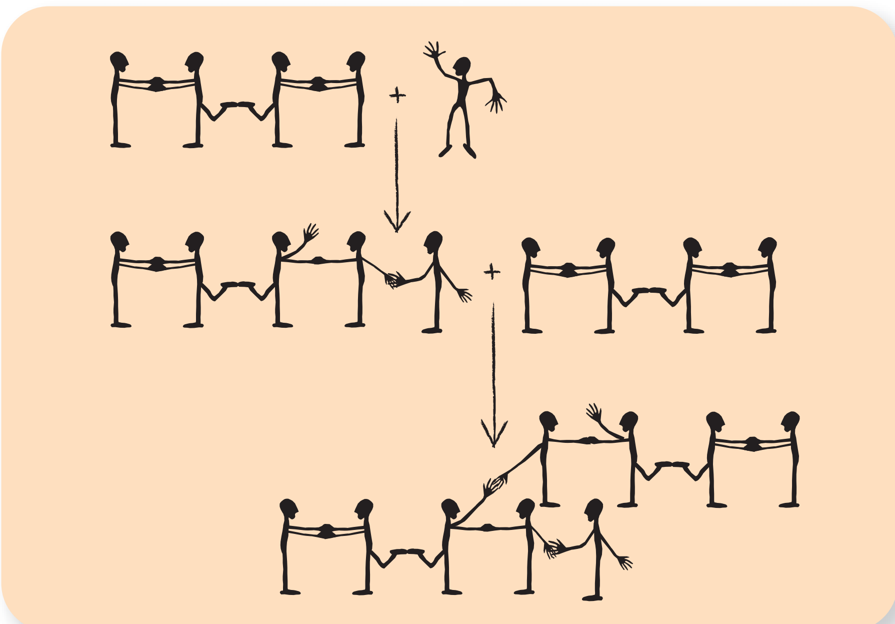
Electric circuit

This activity is useful for introducing the idea of electrons as moving charges that transport energy. One student represents the source of energy (a battery): he or she stands at one end of the classroom and hands out small bags of jelly babies (energy). At the other end of the classroom, another student represents the 'consumer' of energy: he or she collects the bags. You can put some tables in the centre of the room to mark out a circuit. The remaining students represent the electrons: they queue at the energy source and, one by one, are given a bag of jelly babies, then enter the 'electric circuit' and walk/run to the 'consumer' to hand over the sweets (energy).

Diagrams adapted from Pöpping (2003)



Radical polymerisation of ethene



Cross-linking of buta-1,3-diene

Silhouette of the painting, including the characters' lines of vision

Image courtesy of The Yorck Project: 10.000 Meisterwerke der Malerei; image source: Wikimedia Commons

Joseph Wright of Derby, "An Experiment on a Bird in the Air Pump", 1768, oil on canvas in The National Gallery, London, UK

Images courtesy of Bernhard Sturm

Re-enacting the vacuum painting with students aged 13-14

They then go back to the source to queue again. The 'electricity' keeps flowing until the source student runs out of bags (the battery is flat). This activity can be extended to represent parallel and series circuits.

Temperature-dependent conductivity

This activity is a useful way to demonstrate that the conductivity of metals decreases with increasing temperature, something that can otherwise only be determined experimentally. Outdoors, use chalk to draw a rectangle of 2 x 5 m to represent the cross-section of a conducting cable. Ask about 20 students to stand inside the rectangle; they represent metal atoms. The remaining 10 students (electrons) try to run through the cable while the atoms either stand still (low temperature) or oscillate by moving their bodies (high temperature). The time it takes for the 'electrons' to pass through the 'cable' is measured with a stopwatch.

Galileo's law of free fall

To introduce the topic, ask one student (student 1) to read aloud the story of the discovery of the law of free fall[w2]. While one of Galileo's assistants (student 2) marks time by playing regular guitar beats, Galileo himself (student 3) and his second assistant (student 4) carry out their experiments with a table-tennis ball (or similar – a more solid ball gives better results) and an inclined plane with (metal) cross-strings at different heights (see image on page 33). The ball is allowed to roll down the inclined plane from different heights. Student 4 records:

- The number of beats it takes for the ball to roll down the inclined plane
- The distance covered by the ball, as indicated by the cross-strings (e.g. 0, 4, 16, 36, 64 cm).

Nuclear disintegration and half-life

In just one lesson, this method yields excellent material to illustrate the idea of half-life, without any complicated or dangerous experimental apparatus.

A game board of 6 x 6 fields is filled with 36 red gaming pieces. Two easily distinguishable dice are thrown and their numbers are used as the X value (die 1) and the Y value (die 2). The red gaming piece on the field that corresponds to the coordinates (X, Y) on the dice disintegrates into (is replaced by) a blue piece. If a pair of numbers is thrown a second time, nothing happens to the pieces, but the double throw is counted. After each set of 10 double throws, the total number of times that the two dice have been thrown (t) and the number

Re-anacting Galileo's discovery of the law of free fall

of remaining red gaming pieces (N) are recorded. A graph of t against N is used to determine the half-life.

To illustrate different half-lives, you could use 8-sided dice and a game board with 8 x 8 fields, or change the rules so that each field has to be hit twice before the red pieces disintegrate.

Acknowledgements

Some of the activities in this article were inspired by the work of others. The author, therefore, would like to acknowledge his debt to Pöpping (2003; Radical polymerisation of ethene to polyethylene), Schreiber (2004; Physical states of water), Fallscheer (2006; Electric circuit), Bührke (2003), Drake (1975), Hepp (2004) and Riess et al. (2005; Galileo's law of free fall), and Barke & Harsch (2001; Nuclear disintegration and half-life).

References

Barke HD, Harsch G (2001) *Chemiedidaktik heute*. Lernprozesse in Theorie und Praxis. Berlin/Heidelberg, Germany: Springer. ISBN: 9783540417255

Bührke T (2003) *Sternstunden der Physik: Von Galilei bis Lise Meitner*. München, Germany: Beck. ISBN: 9783406494932

Drake S (1975) The Role of Music in Galileo's Experiments. *Scientific American* **6**: 98-104

Fallscheer H (2006) Der Gummibärchen-Stromkreis. *Unterricht Physik* **17**: 38-41

Hepp R (2004) Mit dem freien Fall beginnen. *Unterricht Physik* **15**: 23-26

Pöpping W (2003) Lineare und vernetzte Kunststoffe bilden. *Unterricht Chemie* **14**: 39-40

Riess F, Heering P, Nawrath D (2005) Reconstructing Galileo's Inclined Plane Experiments for Teaching Purposes. www.ihpst2005.leeds.ac.uk/papers/Riess_Heering_Nawrath.pdf

Schreiber S (2004) Lebendiges Teilchenmodell. *Unterricht Chemie* **15**: 15-17

Web references

w1 – An electronic version of the painting with a zoom function can be found on the website of the National Gallery in London, UK (www.nationalgallery.org.uk) or through this direct link: www.tinyurl.com/2bqhvx

For information about Joseph Wright's painting, see the detailed description on http://en.wikipedia.org/wiki/An_Experiment_on_a_Bird_in_the_Air_Pump

w2 – The silhouette of the vacuum painting can be downloaded here: www.scienceinschool.org/2009/issue13/drama

w3 – For the story of Galileo's inclined plane and detailed suggestions for introducing it in the classroom, see: www.ihpst2005.leeds.ac.uk/papers/Riess_Heering_Nawrath.pdf

Resources

If you enjoyed this and other teaching activities in this issue of *Science in School*, you might like to browse our collection of previously published teaching activities. See: www.scienceinschool.org/teaching

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Bernhard Sturm obtained his PhD in chemistry at the GKSS Research Centre Geesthacht, Germany. He now teaches chemistry and physics at the Neues Gymnasium, a secondary school in Oldenburg, Germany. Over the past few years, his students have won a number of science competitions, especially on geoanalytical and climate topics. One of his main interests is interdisciplinary work linking science, art, language and sports.

Image courtesy of Science on Stage Germany

Winners of the audience award at Science on Stage in Berlin, 2008: Harald Gollner, Christoph Eidenberger, Ludwig Eidenberger, Florian Altendorfer (from left to right)

The latex motor

Can you imagine building a motor from latex gloves? Physics teachers **Ludwig Eidenberger** and **Harald Gollner**, and their students **Florian Altendorfer** and **Christoph Eidenberger** show how, exploiting the reversible thermodynamic processes of thin layers of latex.

How the project began

In 2006, we took part in the Experimentale 2007[w1] in Wels, Austria, a biennial regional science exhibition for schools. The inspiration for our project came from a simple effect described in the chapter on thermodynamics of the popular physics book *Feynman Lectures*[w2]: a stretched rubber band contracts when heated. This is unusual, since most materials expand when heated, rather than contract.

We concentrated on how best to visualise this effect, and developed an elevator and a motor, as well as two types of refrigerator – all driven by the expansion and contraction of latex, a type of rubber. The advantages of latex over other types of rubber are its high quality, lack of additives, the thin layers in which it is available – plus the added fun factor of using coloured condoms.

Image courtesy of the latex motor team

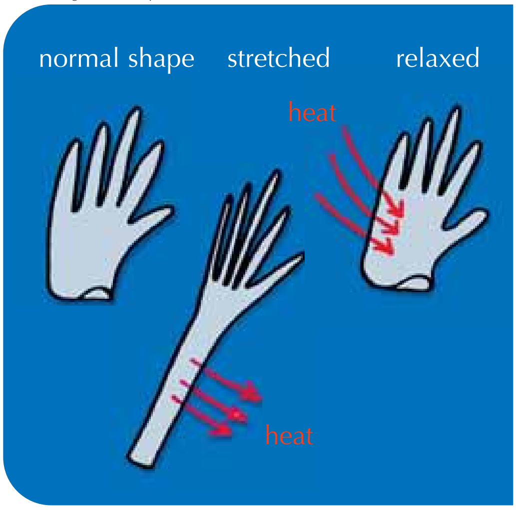
The axis of the latex motor

This interdisciplinary project was a valuable experience for everyone involved: we collaborated with art and technology teachers on the experimental design; the students translated texts, designed posters and a website[w3], and practised their presentation and communication skills, not only in German, but also in English and Spanish. They carried on working on the project for over a year after leaving school in 2007, and the whole team are still running teacher workshops on the project, such as in Technorama, The Swiss Science Center[w4] in Zürich (2009), and in Berlin, Germany (2010)[w5].

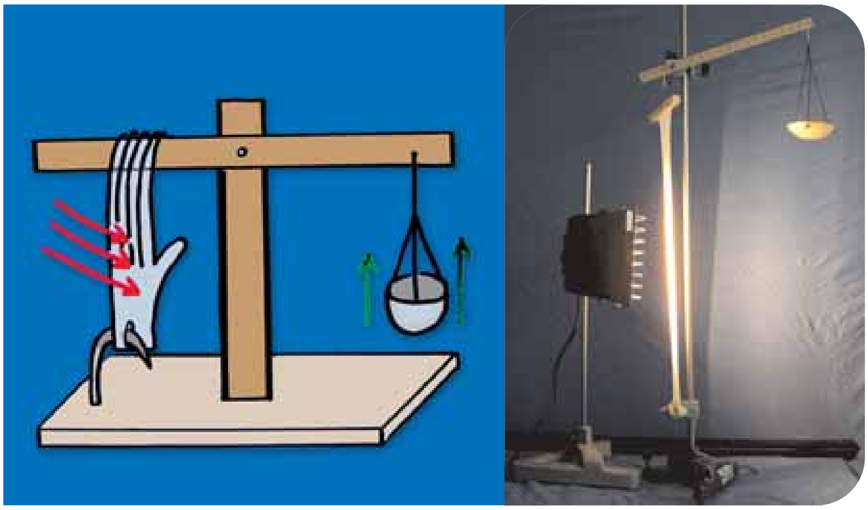
The principle

Latex is a polymer consisting of long, chain-like molecules of repeating isoprene units (C_5H_8). In its relaxed state, the chains are interlinked at a few points. Between a pair of links, each monomer can rotate freely about its neighbour, and at room temperature, latex stores enough kinetic energy for them to do so. When latex is stretched, though, the monomers are no longer able to oscillate, and their kinetic energy is given off as excess heat. When the expanded latex is heated, the process is reversed: the latex absorbs the heat, the molecular motion increases, and the latex contracts.

Images courtesy of the latex motor team



A latex glove emits heat when expanded and absorbs heat when it contracts again



The elevator experiment

Experiment 1: the elevator

This is a simple experiment, suitable for students aged 11 and above, to introduce the thermodynamics of latex, as it shows the conversion of energy. A latex glove emits heat when expanded and absorbs heat when it contracts again.

Kinetic energy -> thermal energy

As this effect is reversible, a stretched latex glove contracts when heated by a spotlight. We can use this to build an elevator.

Thermal energy -> kinetic energy

The difference between the effect that stretched latex contracts when heated and heat expansion should be mentioned.

The elevator can be built by students with little effort and basic materials (such as a Lego® construction set). In the teacher workshop we ran in Zürich, participants built very diverse elevators with great success entirely without instructions. Instructions that are too detailed will constrain the students' creativity – try formulating the aim instead: the effect that the stretched latex band will contract when heated should be visualised. Mechanisms to enhance the visibility of this effect could be a lever, a pulley, etc. Below are some guidelines you might like to use.

Materials:

- A thin latex glove or condom
- A spotlight (minimum 500 W)
- A clamp stand with two clamps
- A wingnut clamp or sealing clip
- A plastic / metal / wooden balance arm with holes spaced at regular intervals
- A nail or similar object as a pivot (if possible with a ball bearing)
- Two hooks
- A hanging scale pan and weights

Image courtesy of Yannick Patois; image source: Wikimedia Commons

A ball bearing

Procedure:

1. Fix the two clamps at a distance of about 40 cm along the stand (depending on the latex band you use – it needs to be stretched).
2. Fix the balance arm flexibly to the upper clamp, using the nail as a pivot point. One arm should be much shorter than the other: the shortening you will observe in the latex band when applying the spotlight is minimal, and it's easier to see if the lever is longer.
3. Attach the latex glove to the bottom clamp (using its fingers).

REVIEW

Although thermodynamics are important in any physics course, they are very often addressed only indirectly at secondary-school level. This article explores the subject through a number of innovative and interesting experiments making use of a very commonly found material, latex. The experiments are useful for discussing the concepts of the heat engine and the convertion of heat to work, as well as of heat pumps.

Paul Xuereb, Malta

4. Attach the hand end of the glove to the wingnut clamp / sealing clip.
5. Attach the wingnut clamp / sealing clip with the glove to the short end of the bar using a hook. Be careful not to damage the latex. The glove should be stretched to about ¾ of its maximum so that it can shorten visibly in the experiment.
6. Hang the scale pan from the other (long) end of the bar using the second hook.
7. Use the weights to adjust the balance arm's position to be horizontal.
8. Shine the spotlight onto the glove – the weight will be lifted due to the glove's contraction.

Image courtesy of Olaf Brust

Sealing clips

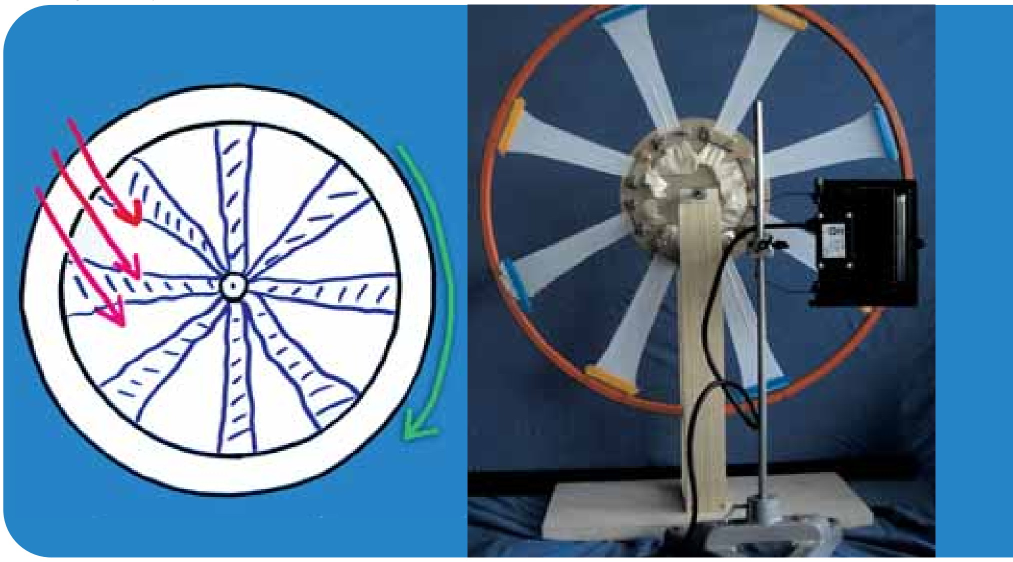
This experiment can be used

- To explain that Joule is the dimension of both work and heat
- To show that machines can transform heat into work
- To introduce reversible processes in physics
- To calculate the efficiency factor of the elevator.

Experiment 2: the latex motor

This experiment takes advantage of the thermodynamics of rubber to generate power, creating a thermal engine.

Images courtesy of the latex motor team



The latex motor

Materials

- A hula hoop (diameter about 1 m)
- 8 thin latex gloves or condoms
- A spotlight (minimum 500 W)
- A ball bearing (this will increase the motor's efficiency)
- A hub (diameter about 20 cm)
- An axis (thread rod)
- A stand
- 16 sealing clips / wingnut clamps

Procedure

1. Build a stand that will limit the friction exerted on the axis.
2. Connect the axis and hub to the stand.
3. Attach 8 clips / clamps to the hub (e.g. using wire).
4. Attach 8 clips / clamps at regularly spaced intervals to the hula hoop.
5. Work in groups to fix the moderately stretched gloves / condoms between the hub and the hula hoop with the sealing clips.
6. Make sure that the hula hoop is perfectly balanced on the hub – otherwise it won't work. Adjust the tension of the gloves / condoms; use small weights to balance the system.
7. Shine the spotlight onto one side of the motor – it will start turning.

The latex spokes contract on the side that is heated, so the centre of mass shifts. Thus the wheel starts turning, and due to the cooling-down of the spokes on the other side, a continuous energy conversion is possible.

Thermal energy -> rotational energy

This experiment can be used

- To introduce heat engines
- To show the application of a physical effect in a simple machine.

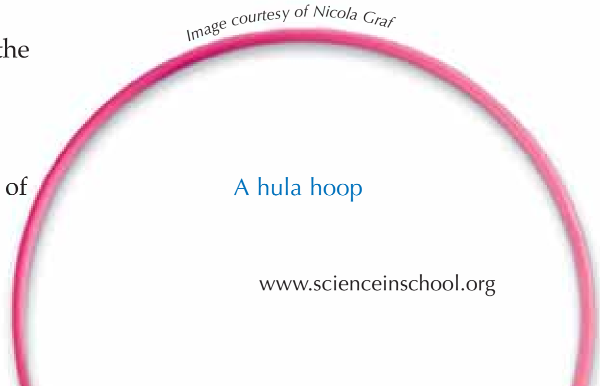
Experiment 3: refrigerator I

As an introduction, expand a latex glove and wait for it to emit its heat to the surrounding air. If you now let the glove contract, it will be cold.

Kinetic energy -> heat transmission

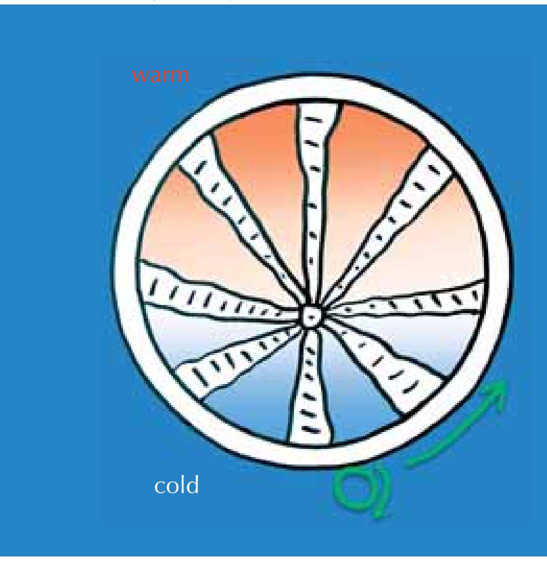
The following experiment illustrates that the latex motor is a reversible process. If the hula hoop runs in guide rolls (powered by an electric motor) and the axis is not in the centre, the condom spokes are warm on

Image courtesy of Nicola Graf

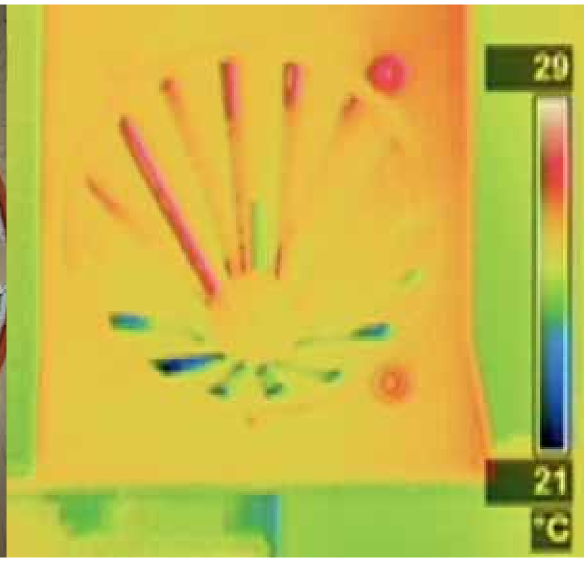


A hula hoop

Images courtesy of the latex motor team



The latex motor as a refrigerator, type I



The infrared camera shows the temperature difference in the latex refrigerator

the expanded side and cool on the other side. The resulting temperature difference can only be visualised using an infrared camera (see images above).

Motor: temperature difference -> rotation

Refrigerator: rotation -> temperature difference

Experiment 4: refrigerator II

The following is a variation of the experiment above, and can be used to explain the concept of a refrigerator (a closed circle which absorbs heat on one side and emits heat on the other side).

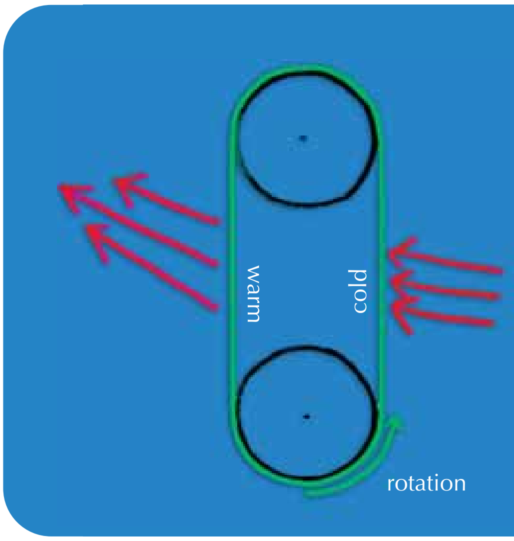
Materials

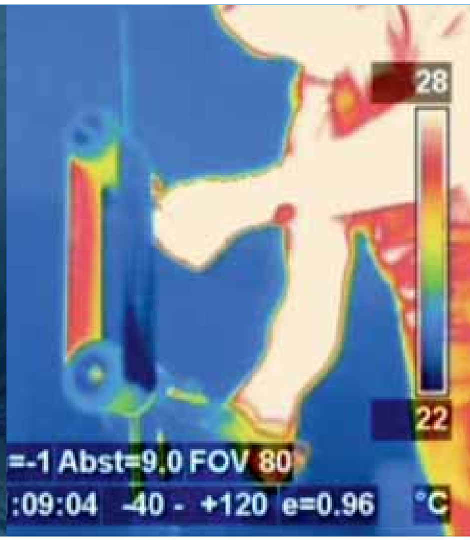
- A clamp stand with two clamps
- Two wooden rollers covered with rubber (e.g. a small balloon), one of them with a handle
- A latex glove
- Scissors
- An infrared camera (optional)

Procedure

1. Fix the two clamps at a distance of about 20-40 cm along the stand (the latex loop will need to be stretched).
2. Fix the two rollers in the clamps: both should be motile.
3. Cut off the finger part of the glove and the rolled up edge at the bottom, if present. A clean cut without frayed edges is important.
4. Stretch the resulting latex loop over the two rollers.
5. If you have an infrared camera, you can use it to monitor the temperature in different parts of the machine.
6. Turn the handle to power one of the rollers. Slow the other one down gently by hand.
7. Thus, the latex loop is permanently expanded (warm) on one side and permanently relaxed (cold) on the other side. This machine produces a temperature difference of about 10 °C.

The type II latex refrigerator





Images courtesy of the latex motor team

Experiment 4: refrigerator II (students' version)

This is a simplified version of Experiment 3 which can easily be performed in class without a lot of preparation. It is best done in groups of three students.

Materials

- Two round wooden sticks (diameter 3-5 cm, can be bought in hardware shops)
- A balloon
- A glove
- Scissors

Procedure

1. Cover one wooden stick with the balloon.
2. Cut a latex loop from a glove as described for Experiment 3.
3. Stretch the latex loop over the two sticks.
4. Each stick should be held horizontally by a student, with one hand at each end (see image).
5. The stick covered with the balloon should now be rotated around its axis. The second stick is held still or rotated slowly. Friction between the balloon and the latex loop drags one half of the latex loop towards the stick being turned; the other half becomes slack.
6. A third student should now feel the temperature difference between the upper and the lower halves of the latex loop.

Hints and tips

- For higher heat emission, stretch the latex close to its elastic limit.
- Very thin layers of latex give the best results. Use thin latex gloves (disposable gloves) or condoms. Replace the materials after some time to ensure good results.
- Note: some students may be allergic to latex, so be sure to check.
- Let the students invent new machines based on those effects!

Web references

w1 – For more information on Experimentale 2009, visit the Netzwerk Nawi OÖ website (www.nawi4you.at) or use the direct link: http://tinyurl.com/ybutsr2

w2 – For more physics experiments, see the Feynman Lectures website: www.feynmanlectures.info

w3 – The website of the latex motor project (in English and German), including videos of the experiment, can be found here: http://latexmotor.brgrohrbach.at

w4 – You can visit the website of Technorama, the Swiss Science Center, here: www.technorama.ch

w5 – The teacher workshop in Berlin on 'European concepts in science teaching' will take place on 18 June 2010 in the PhysLab of the Freie Universität Berlin. Interested teachers can contact the organiser, Science on Stage Germany: www.scienceonstage.de

w6 – Learn more about Science on Stage Austria here: www.scienceonstage.at

References

Hayes E (2008) Science on Stage: recent activities. *Science in School* **10**: 4-7. www.scienceinschool.org/2008/issue10/sos

Furtado S (2009) Science on Stage: recent international events. *Science in School* **11**: 11-14. www.scienceinschool.org/2009/issue11/sos

Resources

Suggestions on working in the primary-school science classroom with the effect that a rubber band heats up when stretched and cools down when relaxed can be found on the website 'Science is Fun in the Lab of Shakhashiri' (http://scifun.chem.wisc.edu) or follow the direct link: http://tinyurl.com/yc2hjtg

To learn more about latex and other rubbers, and how to test their characteristics in the classroom, see:

Stanley H (2008) Materials science to the rescue: easily removable chewing gum. *Science in School* **9**: 56-61. www.scienceinschool.org/2008/issue9/chewinggum

If you enjoyed this and other teaching activities in this issue of *Science in School*, you might like to browse our collection of previously published teaching activities. See: www.scienceinschool.org/teaching

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Professor Ludwig Eidenberger teaches mathematics and physics at Rohrbach secondary school in Upper Austria. Harald Gollner is a teacher of physics and chemistry at the same school. In 2006, when the latex motor project began, Florian Altendorfer and Christoph Eidenberger were aged 19 and still at school. Today, Florian is studying mechanical engineering at Graz Technical University. For the latex motor project and in his spare time, he designs websites and printed material. Christoph is studying in Linz to become a mathematics and physics teacher in secondary school.

The latex motor project received awards both at the Science on Stage Austria[w6] competition in Vienna, in April 2008 (see Hayes, 2008), and the international Science on Stage Festival in Berlin, Germany, in October 2008 (see Furtado, 2009).

Image courtesy of the latex motor team

Student's version of the type II latex refrigerator

Looking for antioxidant food

The author, Gianluca Farusi

Image courtesy of Gianluca Farusi

We've all heard that an antioxidant-rich diet is healthy. Together with his students, **Gianluca Farusi** compared the antioxidant levels in a range of foods and drinks.

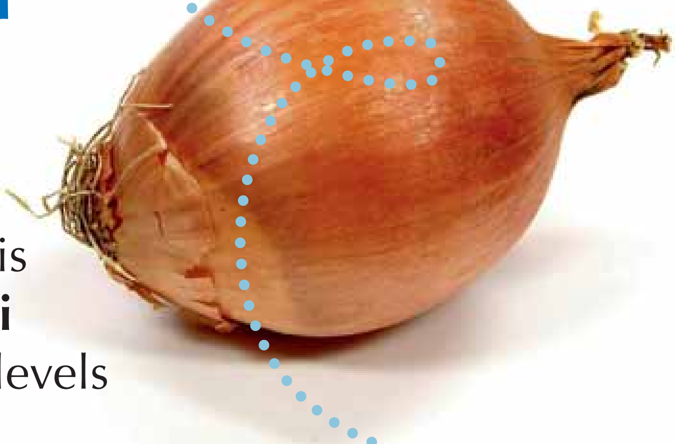
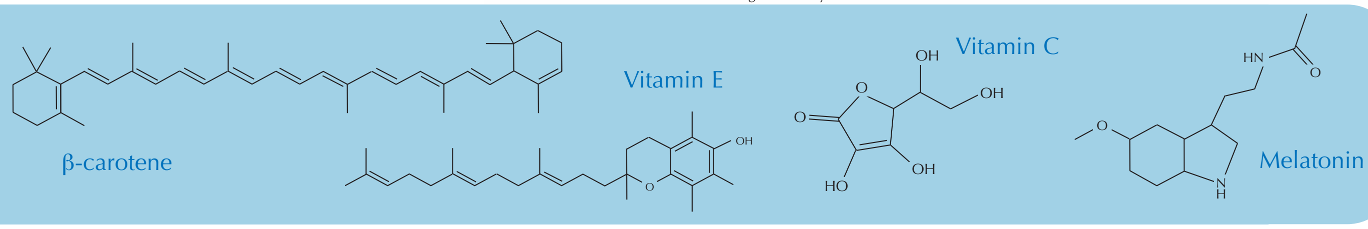


Image courtesy of wrw / pixelio.de

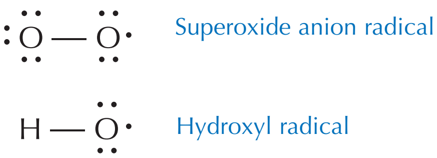
Image courtesy of Nicola Graf



Many health problems, including atherosclerosis, heart attack, Alzheimer's disease, some tumours and senile cataracts, are associated with very reactive molecules called *free radicals*. These molecules are produced normally during aerobic respiration and are used by the body, for example to defend it against micro-organisms. If, however, there is an imbalance between radicals (oxidants) and antioxidants, this can lead to disease.

Free radicals are so reactive because they possess one or more unpaired electrons. They are produced and found in many cells and cell organelles; the superoxide anion radical (O_2^-), for example, is the most common radical in the body, being used by white blood cells to attack viruses and bacteria. By far the most reactive radical, however, is the hydroxyl radical (HO·), found in the peroxisome (where fatty acids are broken down) and the endoplasmic reticulum. External factors influence the production of radicals too; for example, ultraviolet (UV) light shining on our skin causes singlet state oxygen radicals ($^1\Delta O_2\cdot$) to be formed.

Images courtesy of Gianluca Farusi



Within the body, free radicals can lead to a variety of problems. In particular, they react with – and damage – lipids, proteins and nucleic acids, including DNA (Arking, 2006). To protect itself from the continuous radical attack, our body has two basic forms of protection: enzymatic and non-enzymatic. The most important enzymes used to defend our bodies from free radical attack are the antioxidant enzymes superoxide dismutase, catalase and glutathione peroxidase. The principal non-enzymatic antioxidants are melatonin, α-tocopherol (vitamin E), ascorbic acid (vitamin C) and β-carotene (the vitamin A precursor).

All four non-enzymatic antioxidants are essential in the diet and are found in a range of foods. Cancer in particular is less common among people who eat plenty of fruit and vegetables, and it has been suggested that the health benefits are due to the antioxidants they contain (Polidori et al., 2009; Swirsky Gold et al., 1997), which counteract the damaging effects of free radicals. Currently, there is little evidence that antioxidant supplements (e.g. tablets) have any health benefits.

The experiment below compares the levels of antioxidants in various types of food and drink, i.e. the effectiveness of the different types of food and drink as radical scavengers.

The experiment: searching for antioxidants in food and drink

To educate my 17-year-old students about a responsible diet, in the hope of reducing their risk of developing the diseases mentioned above, I designed an activity based on the Briggs-Rauscher reaction: an oscillating reaction in which amber radical and blue non-radical steps alternate. By adding samples of different types of food and drink to the reaction and measuring the time intervals between colours, the students could compare the effectiveness of the samples as radical scavengers. Of course it is a comparative and not an absolute evaluation. But one thing at a time….

Image courtesy of Valentyn Volkov/ iStockphoto

Materials and equipment

- 4 M hydrogen peroxide (H_2O_2) aqueous solution
- 0.20 M potassium iodate (KIO_3) and 0.077 M sulphuric acid (H_2SO_4) aqueous solution
- 0.15 M malonic acid ($CH_2(COOH)_2$) and 0.20 M manganese sulphate ($MnSO_4$) aqueous solution
- Distilled water
- Food and drink, e.g. samples of wine, teas, infusions; samples of food as aqueous extracts (see Table 1[w1])
- Magnetic stirring plate with magnetic stirrer
- 100 ml and 400 ml beakers
- 2 ml and 10 ml pipettes
- Wash bottle
- Spatula
- Glass rod
- Test tubes
- 1 l flask
- Bunsen burner

Preparing the solutions

4 M hydrogen peroxide solution: pour 400 ml distilled water into a 1 l flask. Wearing gloves, add 410 ml 30% hydrogen peroxide. Using distilled water, dilute the solution to 1.0 l.

0.20 M potassium iodate and 0.077 M sulphuric acid solution: place 43 g potassium iodate and approximately 800 ml distilled water into a 1 l flask. Add 4.3 ml concentrated sulphuric acid. Warm and stir the mixture until the potassium iodate dissolves. Dilute the solution to 1.0 l with distilled water.

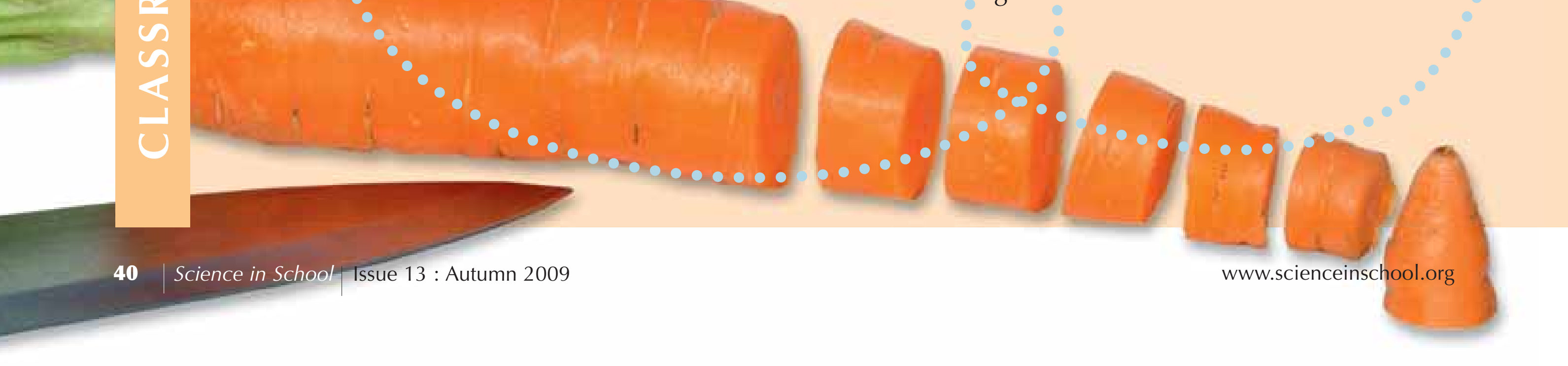
0.15 M malonic acid and 0.20 M manganese sulphate solution: dissolve 16 g malonic acid and 3.4 g manganese (II) sulphate monohydrate in approximately 500 ml distilled water in a 1 l flask. In a 100 ml beaker, heat 50 ml distilled water to boiling. In a 50 ml beaker, mix 0.30 g soluble starch with about 5 ml distilled water and stir the mixture to form a slurry. Pour the slurry into the boiling water and continue heating and stirring the mixture until the starch has dissolved. Pour the starch solution into the solution of malonic acid and manganese (II) sulphate. Dilute the mixture to 1.0 l with distilled water.

Food samples: to prepare the food samples as aqueous solutions or suspensions, put 2.0 g into a 400 ml beaker. Add 100 ml distilled water and stir with a glass rod. Decant, pour a portion into a test tube and centrifuge. For drinks, such as coffee or wine, take 2.0 ml, add 100 ml distilled water and stir.

Method

Into a 100 ml beaker containing a magnetic stirrer, pipette: 10 ml 4 M hydrogen peroxide aqueous solution, 10 ml aqueous solution of 0.20 M potassium iodate and 0.077 M sulphuric acid, and 10 ml aqueous solution of 0.15 M malonic acid and 0.20 M manganese sulphate. Start the magnetic stirring. When the amber solution turns blue for the second time, add 1 ml food solution or suspension. A video of the colour changes is available online.[w2]

Image courtesy of Ernst Rose / pixelio.de



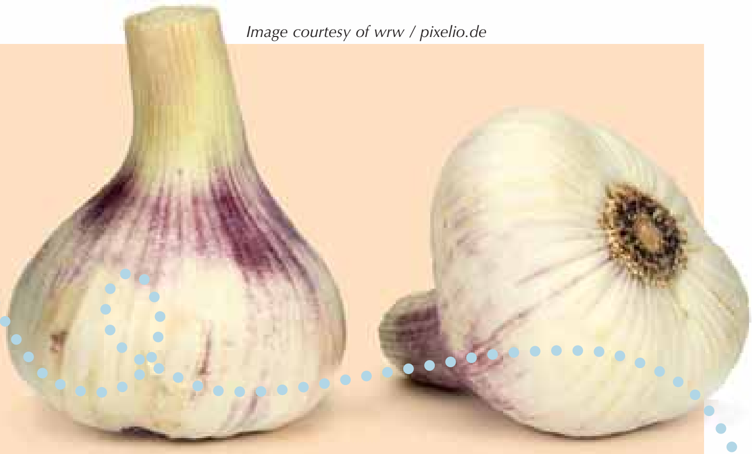


Image courtesy of wrw / pixelio.de

The Briggs-Rauscher reaction is an oscillating reaction – that is, a mixture of chemicals goes through a sequence of colour changes which repeats periodically. The exact mechanism of the reaction is still under investigation, but the nature of the oscillations is sufficiently clear. For the purposes of this article, it is enough to know that as long as the **radical** process maintains the concentration of the intermediate HOI higher than the concentration of the intermediate I^-, the solution remains **amber**; when the **non-radical** process takes place, $[I^-]$ is greater than [HIO] and the iodide ion combines with I_2 to form a **blue** complex with starch. A more detailed description of the reaction can be downloaded from the *Science in School* website[w1].

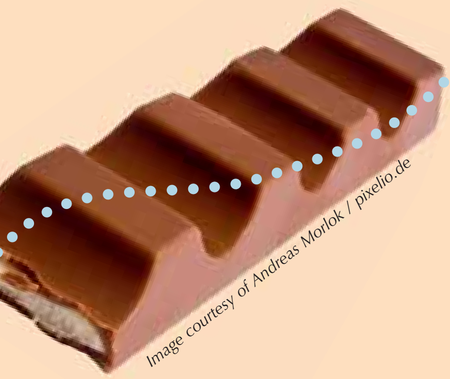


Image courtesy of Andreas Morlok / pixelio.de

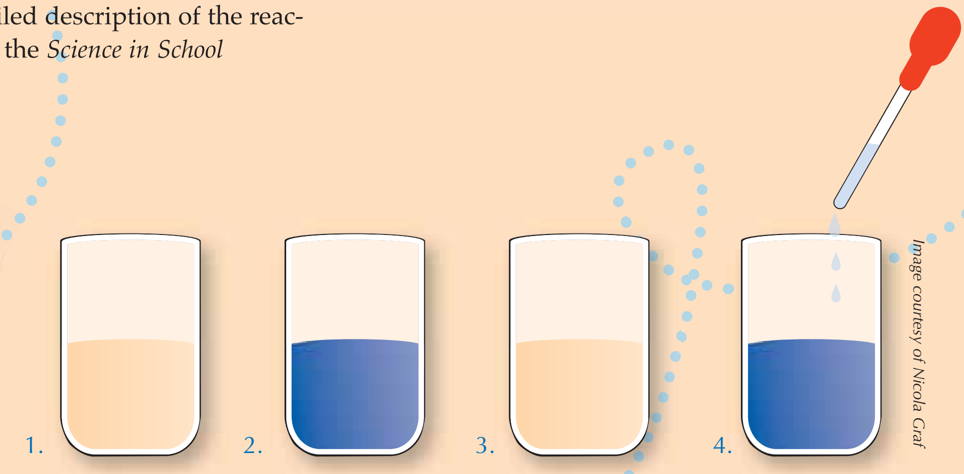


Image courtesy of Nicola Graf

Since we add the food solution or suspension after the second blue phase, when the non-radical phase is ending and the radical phase is about to start, the longer the time interval between the second and the third blue phases, the greater the antioxidant capacity of the food. In other words, the food has reacted with the radicals produced and the reaction takes longer to produce enough radicals to allow the oscillating reaction to continue.

We dedicated much time to choosing the best food or drink concentration to use, since too-dilute solutions lowered the antioxidant capacity and too-concentrated solutions increased the reaction time so much that it was not practical to make a statistically significant number of trials during the course of the lesson.

Safety notes:

Both malonic acid and iodine (produced during the reaction) can irritate the skin, eyes and mucous membranes; for this reason the reaction must be carried out in a fume cupboard.

Because 30% hydrogen peroxide is a very strong oxidising agent, eye protection, lab coats and gloves must be worn. Any contact between hydrogen peroxide and combustible materials must be avoided.

Sulphuric acid is a strong dehydrating agent; eye protection, lab coats and gloves must be worn.

To safely dispose of the mixture at the end of the experiment, slowly add sodium thiosulphate ($Na_2S_2O_3$) to the reaction products, until the excess iodine turns into colourless iodide ions (the reaction is quite exothermic).

Image courtesy of Gianluca Farusi

Sample results

When I performed the activity with my students, we found the greatest antioxidant activity in espresso coffee: 6970 seconds. See the graph below.

More details of our results can be downloaded from the *Science in School* website[w1]. Table 1 shows the foods we tested, the antioxidant activity (time interval) and the main substance presumed to be responsible for the activity.

Discussion

What, then, should we conclude from the results? Clearly, a diet consisting purely of espresso may contain high levels of antioxidants but would be far from healthy. When I did this activity with my students, it led to detailed discussion of radical reactions. Below are some questions that could be used to start a discussion.

1. Which groups of foods tested tend to contain the highest levels of antioxidants? Is that what you expected? Why/why not?
2. Table 1[w1] lists the antioxidant molecules presumed to be responsible for the antioxidant activity of the foods tested. Choose five antioxidants from the table, find their chemical formulae and discuss which functional groups are responsible for their antioxidant (free-radical scavenging) activity.
3. Some of the foods tested have been heat-treated (e.g. jams, chocolate). Does that appear to affect their antioxidant abilities? Table 2, which can be downloaded from the *Science in School* website[w1], shows the molecular structures of several antioxidant molecules, and gives examples of the foods they are found in. Looking at the molecular structures, would you expect these antioxidants to be thermolabile?
4. Apart from antioxidant activity, why might a diet rich in fruit and vegetables reduce your chance of developing the diseases mentioned at the beginning of the article? What other health benefits could it offer?

Antioxidant activity of the types of food and drink tested. The values in the graph were obtained from about 0.02 g samples (100 ml distilled water added to 2.0 g food or drink sample). Thus 0.02 g blackberry jam, for instance, has an antioxidant activity 50 times greater than that of distilled water!

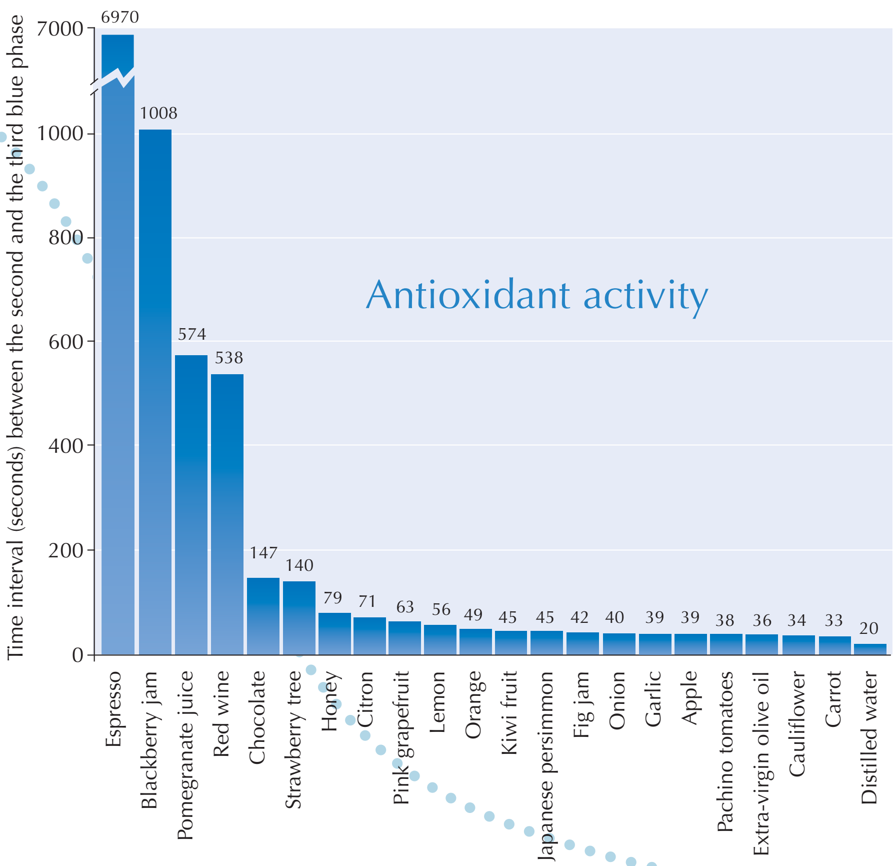


Image courtesy of Nicola Graf

References

Arking R (2006) *The Biology of Aging: Observations and Principles* 3rd edition. Oxford, UK: Oxford University Press. ISBN: 9780195167399

Polidori CM et al. (2009) High fruit and vegetable intake is positively correlated with antioxidant status and cognitive performance in healthy subjects. *Journal of Alzheimer's Disease* **17**: 921-927. Brief coverage of the article is available on the *Science Daily* website: www.sciencedaily.com/releases/2009/09/090909064910.htm

Swirsky Gold L, Slone TH, Ames BN (1997) Prioritization of possible carcinogenic hazards in food. In Tennant DR (ed) *Food Chemical Risk Analysis*, pp 267-295. New York, NY, USA: Chapman and Hall. This chapter is freely available online: http://potency.berkeley.edu/text/maff.html

Web references

w1 – Tables 1 and 2 and a detailed description of the Briggs-Rauscher reaction can be downloaded from the *Science in School* website: www.scienceinschool.org/2009/issue13/antioxidants

w2 – A video of the colour changes can be viewed here: www.youtube.com/watch?v=WXf6-bRwPfM

Resources

For descriptions of experimental methods similar to the one used in this article, see:

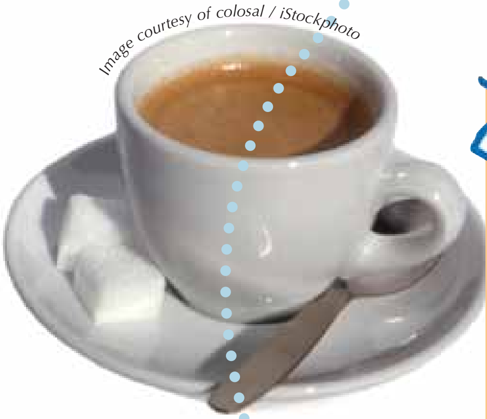


Image courtesy of colosal / iStockphoto

Höner K, Cervellati R (2002) Attività antiossidante di bevande. Esperimenti per le scuole secondarie superiori. *La Chimica nella Scuola* **24**: 30-38

Shakhashiri BZ (1985) *Chemical Demonstrations* Volume 2. Madison, WI, USA: University of Wisconsin Press. ISBN: 9780299101305

For a good (freely available) article about the effects of free radicals, see:

Sies H (1997) Oxidative stress: oxidants and antioxidants. *Experimental Physiology* **82**: 291-295. This article and all other *Experimental Physiology* articles older than 12 months can be downloaded free of charge from the journal website: http://ep.physoc.org

To learn about haemochromatosis, a disease in which free radicals play a role, see:

Patterson L (2009) Getting a grip on genetic diseases. *Science in School* **13**: 53-57. www.scienceinschool.org/2009/issue12/insight

For more information about free radicals and their activities in the body, see:

Dansen TB, Wirtz KWA (2001) The peroxisome in oxidative stress. *IUBMB Life* **51**: 223-230. doi:10.1080/152165401753311762

Rosen GM, Rauckman EJ (1981) Spin trapping of free radicals during hepatic microsomal lipid peroxidation. *Proceedings of the National Academy of Sciences USA* **78**: 7346-7349

See also Gianluca Farusi`s previous articles in *Science in School*:

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

Farusi G (2007) Monastic ink: linking chemistry and history. *Science in School* **6**: 30-40. www.scienceinschool.org/2007/issue6/galls

A complete list of all chemistry-related articles published in *Science in School* is available here: www.scienceinschool.org/chemistry

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Gianluca Farusi teaches chemistry at the technical school (Istituto Tecnico Industriale) Galileo Galilei in Avenza-Carrara, Italy, and stoichiometry at the University of Pisa, Italy. He has been teaching for 12 years and nothing gratifies him more than the delight on his students' faces when they grasp a difficult chemical concept.

This activity, which was carried out with his school students, won Gianluca an EIROforum Science Teaching Award: the ILL Prize (Science on Stage 2, 2007). He has also been awarded the ESRF Prize (Science on Stage 1, 2005) and the Italian Chemical Society's Illuminati Prize for Chemistry Didactics (2006).


Image courtesy of Gianluca Farusi

REVIEW

This is a superb article which underlines the importance of chemistry in the behaviour of biological systems. It is so important to instil an appreciation of the way in which scientific knowledge is multidisciplinary. Teachers and students could use the article for a practical activity in chemistry, biochemistry, food-science or health-science lessons. It could also form the basis of science-fair projects.

If the experimental part were left out, the introduction, discussion and results could be a sound basis for a comprehension exercise. Suitable questions, which could be used to spark off a discussion about food and health, or chemistry in everyday life, could include:

1. Explain the term radical.
2. What do you understand by the term 'antioxidant'? Explain how this type of substance can be important for good health.
3. What types of food are the best sources of antioxidant molecules?
4. How could an average person ensure that their diet maximises the levels of antioxidants?

Marie Walsh, Republic of Ireland

The Bio Academy

French biology teacher **Jean-Yves Guichot** explains his project to link secondary-school students with molecular biology researchers.

Image courtesy of Stella Diamant

The idea for this project came to me during a teachers training course organised by the European Learning Laboratory for the Life Sciences (ELLS)[w1] at the European Molecular Biology Laboratory[w2] (EMBL). Several years ago, I had taken a break from teaching to spend a year at the University of Grenoble, France, doing research on plant gene expression. I had found the experience very rewarding and thought it would be great if I could find a way to expose my biology students to the work of researchers. I wanted to offer my students the chance to:

- Perform molecular biology experiments in a lab
- Follow the advancement of a scientific research project over a period of two years (the students would get regular input from the scientists by email and phone calls)
- Explain this research (and other topics of molecular biology) to other students via a website, which they should update regularly
- Learn about the reality of working as a scientific researcher, and realise that a scientific career lies within their reach.

Through contact with the ELLS team, my students and I were soon taking part in an exciting collaboration: the Bio Academy[w3]. In February 2006, 14 biology students aged 17 and 18 who were studying for the European Baccalaureate at the European School in Brussels[w4], Belgium, visited EMBL for the first time to work alongside and talk to young French-speaking scientific researchers:

- Team 1: Cleo, Stella and Claude-Lee studied the dynamics of chromosomes during mitosis with Felipe Mora-Bermudez
- Team 2: Lukas, Vincent, Georgios and Roxane researched the immune defence mechanisms of mosquitoes against malarial agents with Stéphanie Blandin
- Team 3: Simon, Karin and Charline looked at the role of kinesin in mitosis and the mitotic spindle with Julie Cahu and Aurélien Olichon
- Team 4: Zoé, William, Paul and Gery worked on the embryonic development of the fruit fly with Céline Pugieux and Jean-Baptiste Coutelis.

Having fun between exhausting experiments

Image courtesy of Jean-Yves Guichot

Co-operation at its best

Image courtesy of Jean-Yves Guichot

During their second visit to EMBL, a year later, each team of 3-4 students presented the work they had produced with their mentor scientists to the entire Bio Academy. Then, each team met with their mentors to learn about recent developments in the research projects and to perform experiments related to the different scientific topics. The students also had the chance to talk to these young experts about issues related to their own future, such as the reality of work as a scientist, and university life.

To give the students a taste of a research facility in action, there were plenty of opportunities for all students to take part in hands-on activities using state-of-the-art techniques such as X-ray crystallography[w5], ELISA and electron microscopy. After their visit, the students put details of their work and described the techniques they had used on the project website[w6].

At the end of this two-year project, three of the young scientists returned the visit, taking part in the *La recherche en fête* event at the school in Brussels, helped by the Bio Academy students. All school students who were interested in biology had the opportunity to meet the researchers and work with materials that they had brought along (fruit flies for genetic experiments, live cells to study mitosis).

Early in their careers, scientists are really busy: collecting data, learning new techniques, writing up papers and dissertations. Why on Earth would they spend their valuable time running workshops and discussing their research projects with school students? "Because it's fun to talk about science with young people," says Felipe Mora Bermúdez, one of the scientists. "They are so imaginative and curious. We often tend to focus on our specific research, with little time to step back and see the bigger picture. Having a group of enthusiastic students asking intelligent questions helps us to look at our work from a different perspective."

"It was an amazing experience to meet potential future scientists," says Aurélien Olichon. "They were wonderfully well informed about the molecular level of life, which I didn't have a clue about when I was their age. They even asked probing questions about modern biological research." All scientists came to realise just how distant they are from current school science, and how challenging it is to explain complex molecular science in a simple way.

The students were grateful for the effort: "I really appreciated the opportunity to get to know some of the researchers who could answer my questions and share their thoughts with me," said Zoé, aged 18. "They told me a lot about the challenging parts of their career: you have to cope with a lot of stress, and there isn't any guarantee you will always have a job, so you really need to work hard. However, the diversity of the work, the possibility to create international connections with other researchers, the passion for science and the satisfaction of doing what you like makes it a very attractive career…and I think I might just have the courage to dive in." Zoé is one of seven Bio Academy participants who went on to study medicine, while Stella is now studying cellular biology (see box). Altogether, eight out of the 14 participants went on to biomedical studies – an indication of the project's success.

There was plenty of fun too – good food, films and an experimental treasure hunt, for which the students performed three types of activities: DNA gel electrophoresis, protein separation in columns, and molecule model building. For each

REVIEW

In this article, Jean-Yves Guichot describes his science teaching project, in which a group of upper secondary-school students experienced molecular biology research at EMBL in Heidelberg, Germany. It was very successful, resulting in over half of the students enrolling in biomedical studies at university.

The author gives advice on how to set up similar school projects. The web references allow the reader to deepen their knowledge of the Bio Academy project through documents and materials created by the students.

I recommend this article to secondary-school teachers interested in filling the gap between science teaching at school and doing 'the real thing' in research labs. If they need encouragement to plan a joint project with a science faculty or research institution in their country, Guichot's account is very helpful.

Giulia Realdon, Italy

successful activity, the students obtained a number of pieces of a puzzle, corresponding to a treasure map. The group discovered the 'treasure' hidden on the EMBL campus, consisting of EMBL publicity materials (T-shirts, ties, key holders, mouse pads, notebooks, pencils and pens) and some sweets to supply them with energy for the train trip back to Brussels.

Felipe Mora Bermúdez summed up the whole experience perfectly: "All students enjoyed it, and these two visits showed them that science is a challenge...but an extremely fun challenge."

Image courtesy of Jean-Yves Guichot

Bio Academy students interview EMBL scientists Claude Antony and Jean-Baptiste Coutelis

Acknowledgements

I would like to thank all the researchers who gave up their precious time for me and for my students. Without them, nothing would have been possible. Special thanks also to Alexandra Manaia who co-ordinated the training courses in Heidelberg.

Web references

w1 – The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary-school teachers

BACKGROUND

Participants' experiences

Zoé Pletschette, aged 20, is now studying medicine at the Free University of Brussels, Belgium:

"The Bio Academy really reinforced my intention to be part of the scientific community. At school, science was all theory: we had to integrate all sorts of scientific facts and rarely gave a thought to how they were generated in the first place. Meeting such enthusiastic researchers allowed me to appreciate the practical aspects of the scientific world and how incredibly varied and exciting it is. Even if I stayed with my first career choice, medicine, I wouldn't mind joining a lab in a few years, something I would have (wrongly) thought to be very boring before my visit to EMBL."

Image courtesy of Jean-Yves Guichot

Zoé Pletschette and an electron microscope

Image courtesy of Stella Diamant

Stella Diamant

Stella Diamant, aged 20, is now studying biology at the University of Warwick, UK:

"Although I had always been passionate about biology, I wanted to see what research was really like. Meeting friendly scientists and getting an insight into their current work was a revelation. Everything suddenly fell into place and made sense. The topics we learned at school turned into visible processes. What impressed me the most though was the working environment, how people joined forces for the sake of science and discovery. At school, 'university' always sounded like an unreachable new universe. However, having met the EMBL scientists, I didn't hesitate to apply for a place at a UK university, and I am glad I chose a career which fulfils my curiosity every day."

BACKGROUND

How to set up such a collaboration

I feel that the experience was truly beneficial, and I loved getting back in touch with experimental research. If you would like to organise a similar event for your students, you might find the following hints and advice helpful:

1. Find a research laboratory with young scientists who are willing to collaborate, and find a good contact there. In larger universities, school liaison officers are in charge of linking secondary schools with research departments at their university.
2. Convince the head of your school that the project is important. Explain that it will give students the opportunity to meet researchers and work closely with them. It is also a challenge for the students – stretching their abilities and offering them the chance to learn new skills that cannot be gained in school laboratories. Students are more enthusiastic about learning advanced science when faced with a 'high-tech' environment and real scientists. It is also worth producing a detailed programme with the aims and procedures in order to ask the school for some funding to help cover accommodation and transport costs.
3. Form several teams of 3-4 students and allocate these teams to one or two researchers. It is a good idea to have a few meetings with the researchers beforehand to consider possible topics and experiments. Then tell the students about these topics in class, and let them make their own choices. The students can keep in touch with the researchers by email to discuss their research.
4. Take the students to a training course at the chosen research facility to practise and understand the work of their researcher partners, watching and performing experiments in the lab.
5. Get the students to write about what they did and what they understood during their training course, and they can then send their work to be corrected by the researchers.
6. Create and manage a website to collate the reports and other work (interviews with scientists, description of techniques, guided tour of the laboratory, etc.). Many secondary schools have their own website, so it should be possible to ask for a dedicated space on this site for use by your students. There is nothing more motivating for them than to see the almost instantaneous publication of their work on a website that is easily accessible to everyone.
7. Every two years, repeat the experience with a new class, so that they can follow the research and keep the website going with new information. The researchers may have finished their PhDs and left the institute, but their projects may be continued by others.

into a research laboratory. Based at EMBL Heidelberg, Germany, it welcomes European teachers to its free three-day practical workshops. Education materials designed together with teachers are available in the ELLS TeachingBASE. See: www.embl.org/ells

w2 – For more information about EMBL, see: www.embl.org

w3 – Further information about the Bio Academy visits to EMBL is available on the EMBL website (www.embl.org), and can be viewed directly here: http://tinyurl.com/l522ru and http://tinyurl.com/n4vyxs

w4 – Find out more about the European School Bruxelles I here: www.eeb1.com

w5 – To perform protein crystallography experiments with your own class, see:

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

w6 – The Bio Academy website (in French) includes the students' reports on their activities at EMBL, information they learned, pictures of the teams and much more. See: www.bioacademy.eeb1.com

Resources

If you enjoyed this article, you might also like to read other articles on science education projects in *Science in School*. See: www.scienceinschool.org/projects

Jean-Yves Guichot is now working at the International School of Ferney-Voltaire, France. For more information about the Bio Academy, please send an email in French or English to: Jean-Yves.Guichot@ac-lyon.fr

The first light in the Universe

The WMAP satellite. After three phasing loops around Earth, WMAP flew just behind the orbit of the Moon, three weeks after launch

Image courtesy of NASA / WMAP Science Team

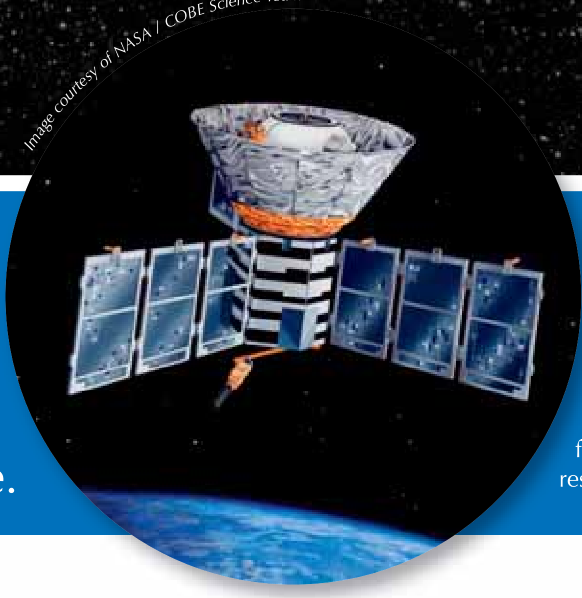


Image courtesy of NASA / COBE Science Team

An artist's impression of the COBE spacecraft, launched by NASA into an Earth orbit in 1989 to make a full-sky map of the cosmic microwave background radiation left over from the Big Bang. The first results were released in 1992

Ana Lopes and **Henri Boffin** take us on a trip back in time – probing the history of the Universe.

Have you ever wondered when the first lights in the Universe began to shine? Most of us have watched the rising of the Sun in the morning, the dawn of a new day. Astronomers go a step further and look for the first sources of light – peering into the history of the Universe using powerful telescopes. Their ultimate aspiration is even more ambitious: to trace the entire history of the Universe, from its birth – the Big Bang – to the present day, almost 14 000 million (14 billion) years later.

Photographs of the Universe

It was not until about 400 000 years after the Big Bang that light was able to travel freely in the Universe. Ever since the Big Bang, the Universe has been expanding and cooling (for a description, see Boffin & Pierce-Price, 2007), stretching that primeval light from its initial high frequency, until it can be detected today as photons in the microwave range: cosmic microwave background radiation, coming from all over the Universe.

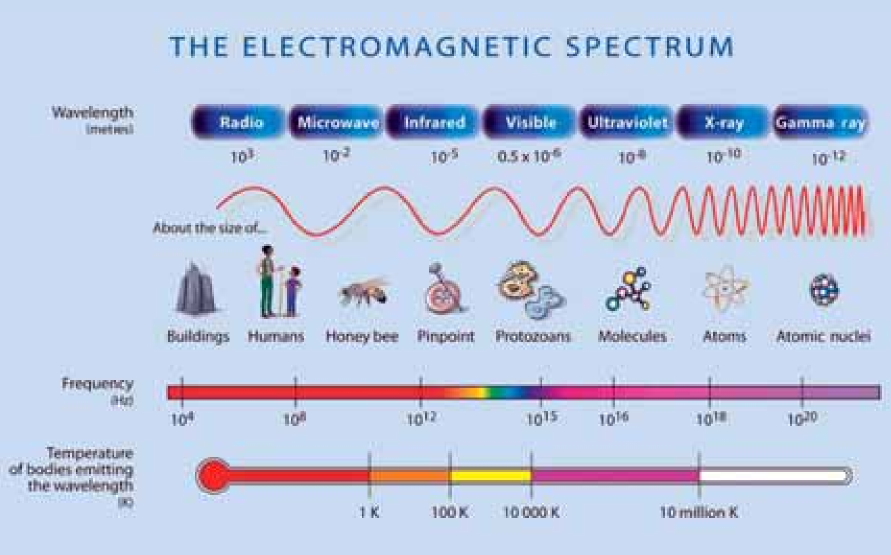
Historians often use photographs and other pictures to tell them about the past, and in this respect, astronomers are no different. Using the COBE (COsmic Background Explorer) and Wilkinson Microwave Anisotropy Probe (WMAP)[w1] satellites to map the cosmic microwave background radiation, astronomers have created a 'photograph' of the Universe as it was approximately 400 000 years after the Big Bang. The data from COBE won John Mather and George Smoot the 2006 Nobel Prize in Physics.[w2]

REVIEW

This article offers interesting and detailed information about modern research into the history of the Universe and its evolution. It could be used for interdisciplinary teaching, for example in physics, astronomy, astrophysics or philosophy. As well as providing valuable background reading, teachers could use it to develop educational materials.

Vangelis Koltsakis, Greece

Original image courtesy of NASA



The electromagnetic spectrum

The standard cosmological model of how the Universe evolved tells us that by about 400 000 years after the Big Bang, the Universe had cooled to about 3000 degrees Kelvin, a temperature low enough for all the electrons and protons to combine, forming neutral hydrogen from the ionised gas. Electrons in neutral hydrogen (as in other atoms or molecules) absorb photons very efficiently, so a universe full of neutral hydrogen is opaque. In contrast, when protons and electrons are separate, they cannot capture photons so a universe full of ionised gas – as was the case until about 400 000 years after the Big Bang, and is again the case today – is relatively transparent. The COBE and WMAP maps show us the Universe during its opaque stage, at the beginning of the 'dark ages' of the Universe. This period came to an end when the Universe became ionised again (see diagram to the right).

We also have 'photographs' of a much more recent Universe: galaxies full of stars, as they were 1000 million years after the Big Bang – once the Universe had become transparent again. Because of the finite speed of light (300 000 km s^{-1}), the light from

Original image courtesy of SG Djorgovski and Digital Media Center, Caltech

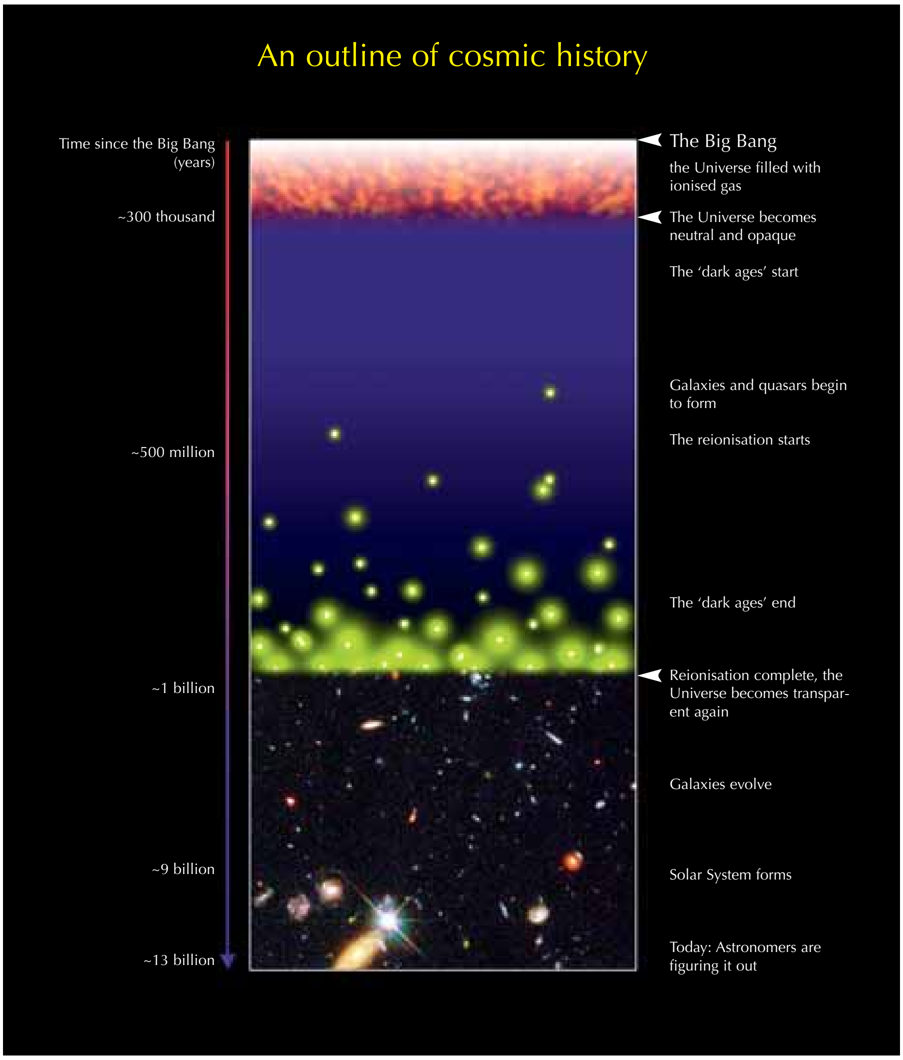
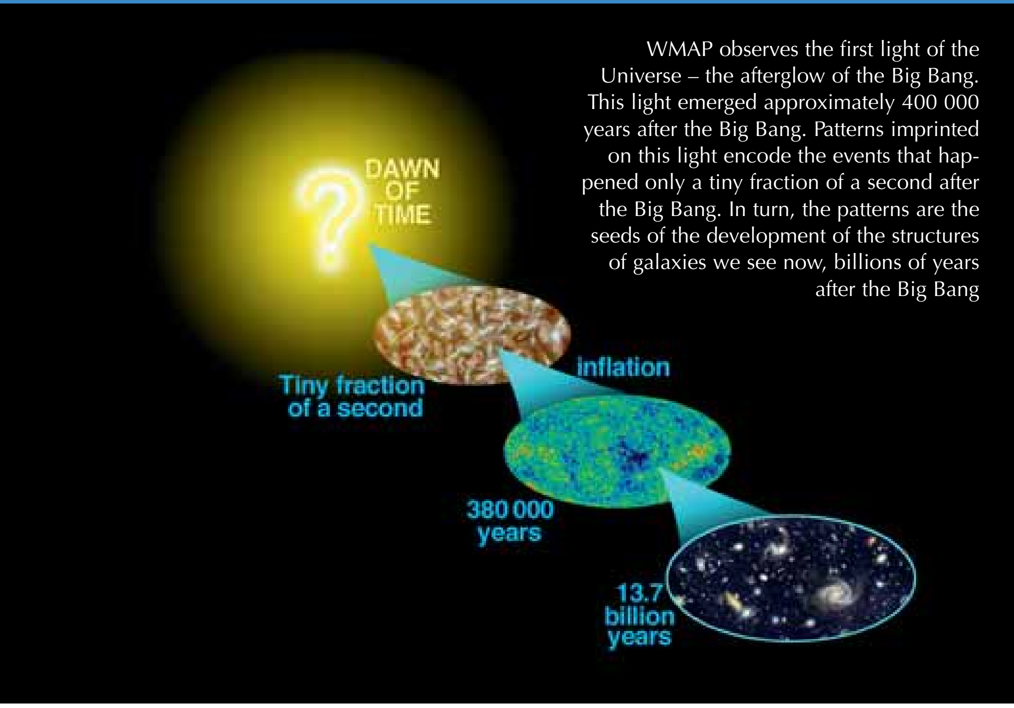
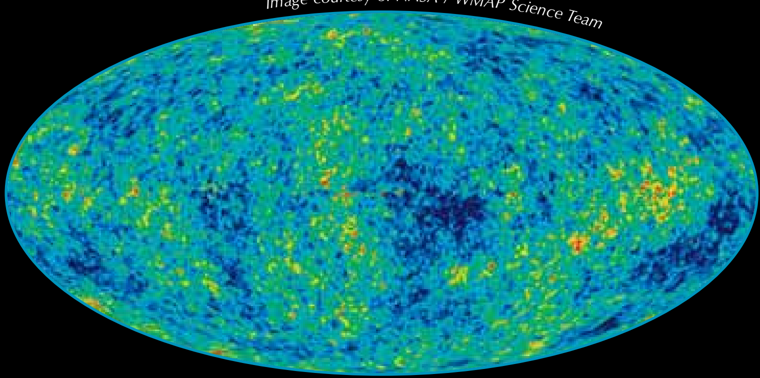


Image courtesy of NASA / WMAP Science Team



WMAP observes the first light of the Universe – the afterglow of the Big Bang. This light emerged approximately 400 000 years after the Big Bang. Patterns imprinted on this light encode the events that happened only a tiny fraction of a second after the Big Bang. In turn, the patterns are the seeds of the development of the structures of galaxies we see now, billions of years after the Big Bang

Image courtesy of NASA / WMAP Science Team



The detailed, all-sky picture of the infant universe created from five years of WMAP data. The image reveals 13.7 billion-year-old temperature fluctuations (red regions are warmer and blue are cooler) that correspond to the seeds that grew to become the galaxies

Image courtesy of NASA, ESA, S Beckwith (Space Telescope Science Institute) and the Hubble Ultra Deep Field Team

This view of nearly 10 000 galaxies is the deepest visible-light image of the cosmos. Called the Hubble Ultra Deep Field, this galaxy-studded view represents a 'deep' core sample of the universe, cutting across billions of light-years. The snapshot includes galaxies of various ages, sizes, shapes, and colours. The smallest, reddest galaxies may be among the most distant known, existing when the Universe was just 800 million years old. The nearest galaxies – the larger, brighter, well-defined spirals and ellipses – thrived about 1 billion years ago, when the cosmos was 13 billion years old

distant objects takes much longer to reach us than that from neighbouring objects; we therefore see these distant objects as they were a very long time ago. By looking at very distant objects, astronomers were able to see the light that has travelled for almost 13 000 million years – that is, they saw those objects as they had been less than 1000 million years after the Big Bang.

But what happened between these two photographs, between the release of the cosmic microwave background radiation 400 000 years after the Big Bang and the light emitted by these very distant galaxies, nearly 1000 million years later? When and how did the cosmic fog lift? What changed a sea of particles almost devoid of structure into a Universe lit by numerous stars in young galaxies?

As Harvard University astronomer Abraham Loeb puts it: "The situation that astronomers face is similar to having a photo album containing the first ultrasound image of an unborn baby and some additional photos of that same person as a teenager and an adult" (Loeb, 2006). What scientists do not know – but are trying to figure out – is when and how the very first stars and galaxies were born. Loeb continues: "Astronomers are currently searching for the missing pages of the cosmic photo album, which will show how the Universe evolved during its infancy and made the building blocks of galaxies like our own Milky Way."

Before any stars were formed, the Universe contained mostly hydrogen, helium and some traces of light elements (as described in Rebusco et al., 2007). To ionise hydrogen requires energy in excess of 13.6 eV – the sort of energy level corresponding to photons in the ultraviolet (UV) domain. Therefore whatever reionised the Universe must have released significant amounts of UV radiation. Although astronomers are still uncertain what could have released this ionising UV radiation, they speculate

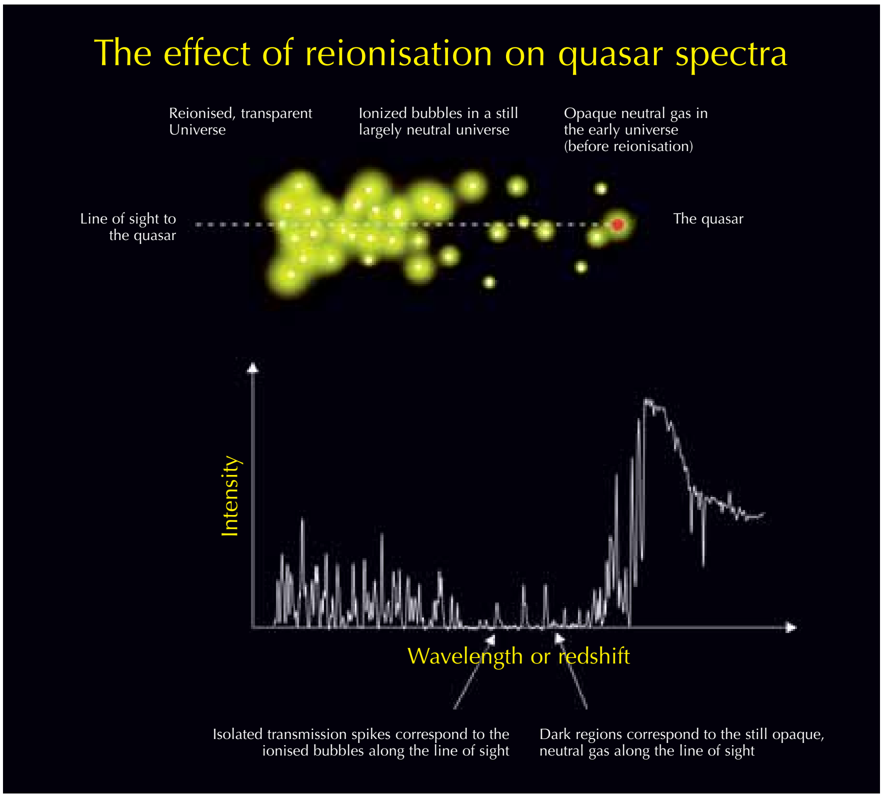


Image courtesy of SG Djorgovski and Digital Media Center, Caltech

that it was either the first, very hot, stars, or early black holes, releasing huge amounts of UV radiation as material fell into them. If this is the case, stars must have formed before the reionisation epoch – thus if we can date the reionisation, we have at least a latest date for the emergence of the first stars.

The ultraviolet footprint

In 1965, American astronomers James Gunn and Bruce Peterson predicted that the spectra of quasars could be used to date the final stages of the reionisation epoch. Quasars are very distant and ancient galaxies of extreme brilliance, thought to be powered by material falling into giant black holes at their centres. If the quasar is so distant that the light we observe from it escaped during the 'dark ages', its UV light will have been absorbed by the neutral hydrogen present at the time; if the quasar is closer and the light we observe was emitted only after the reionisation, there will have been no neutral hydrogen to impede it (see diagram above). (Note that while the neutral hydrogen atoms absorb all wavelengths of light, most wavelengths are released again. UV light, in contrast, ionises the atoms and is completely absorbed.)

If even a tiny portion of the intergalactic medium (as little as one part in a million) had been neutral when the quasar released the light we now see from Earth, this would have left a noticeable imprint on the spectrum – a suppression of light in the UV range, known as the Gunn-Peterson trough. Therefore James Gunn and Bruce Peterson predicted that quasars beyond a certain distance from Earth, for which we observe light that was released before the reionisation had finished, would show a 'trough' in their spectra. Quasars closer than this would not – they released the light we observe from Earth only after the reionisation had finished.

In 2001, a team of scientists led by Robert Becker from the University of California, USA, confirmed Gunn and Peterson's prediction: they detected an unambiguous trough in the spectrum of a very distant quasar discovered during the Sloan Digital Sky Survey[w3], a huge astronomical survey that examined the spectra of about a hundred thousand quasars. The trough was in the infra-red part of the spectrum, because the quasar is so far away: its light started the journey towards Earth only about 900 million years after the Big Bang, and so has taken almost 13 000 million years to reach us, during which time its initially UV light has been stretched (redshifted) into the infra-red by the expansion of the Universe. Quasars slightly closer to Earth did not show such a trough. This indicated that the last patches of neutral hydrogen in the Universe were ionised about 900 million years after the Big Bang.

The microwave footprint

The cosmic microwave background radiation released soon after the Big Bang is another source of information about the reionisation epoch.

As the Universe started to be reionised, the electrons that were released affected the polarity of light. A free electron can interact with a photon in a process called Thomson scattering: the electron is accelerated and the incident light is polarised along the direction of motion of the electron. This effect was most pronounced during and just after the reionisation; later, because the Universe continued to expand, the density of free electrons decreased, reducing their polarising effect.

Between 2001 and 2006, the WMAP satellite[w1] was used to study the degree of polarisation of the cosmic microwave background photons. By looking at different frequencies of light, astronomers could look at different periods in the Universe's history – and the degree of polarity gave an indication of the density of free electrons around at that time (the greater the polarity, the higher the density of free electrons). From these studies, they concluded that reionisation started about 400 million years after the Big Bang, and was completed 400 to 500 million years later. This is in agreement with the findings of the quasar studies: 900 million years after the Big Bang.

Future research

On 14 May 2009, the European Space Agency[w4] launched the Planck satellite[w5] to provide us with a photograph of the cosmic background radiation with even more sensitivity and angular resolution than the WMAP achieved. It will certainly help astronomers to answer with more details the questions of how the Universe evolved from a glowing soup to what we see today.

Although the time when reionisation occurred has been successfully identified, a photograph of the Universe from that time is still lacking, as current telescopes are unable to image it. The good news, however, is that the European Southern Observatory (ESO), together with astronomers and engineers from across Europe, is now engaged in the design of the European Extremely Large Telescope[w6], 42 m in diameter, which will allow us to look this far back in time and possibly see the first starlight.

References

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

Loeb A (2006) The dark ages of the Universe. *Scientific American* **Nov**: 46-53. This article is available to download from http://www.cfa.harvard.edu/~loeb/sciam.pdf

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

Web references

w1 – For more information about the WMAP satellite, see: http://map.gsfc.nasa.gov

w2 – An overview of John Mather and George Smoot's work on cosmic microwave background radiation with COBE and links to further information are given in the press release announcing their Nobel Prize: http://nobelprize.org/nobel_prizes/physics/laureates/2006/press.html

w3 – The Sloan Digital Sky Survey is the most ambitious astronomical survey ever undertaken. When completed, it will provide detailed optical images covering more than a quarter of the sky, and a three-dimensional map of about a million galaxies and quasars. As the survey progresses, the data are released to the scientific community and the general public in annual increments. See: www.sdss.org

w4 – For more information about the European Space Agency, see: www.esa.int

w5 – To learn more about the Planck satellite, see: www.esa.int/esaSC/120398_index_0_m.html

w6 – For more information about ESO's Extremely Large Telescope, see: www.eso.org/public/astronomy/teles-instr/e-elt.html

Resources

The WMAP section of the NASA website provides some teacher resources, including a brief overview of the WMAP project and an inflatable model of the Universe. See: http://map.gsfc.nasa.gov/resources/edresources1.html

For a full list of *Science in School* articles about fusion and the evolution of the Universe, see: www.scienceinschool.org/fusion

If you enjoyed this article, you might like to browse all science topics previously published in *Science in School*. See: www.scienceinschool.org/sciencetopics

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Larson RB, Bromm V (2001) The first stars in the Universe. *Scientific American* **Dec**: 64-71. This article is available for download from http://www.astro.yale.edu/larson/papers/SciAm01.pdf

Madau P (2006) Astronomy: trouble at first light. *Nature* **440**: 1002-1003. doi:10.1038/4401002a. Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2009/issue13/light), or subscribe to *Nature* today: www.nature.com/subscribe

Scannapieco E, Petitjean P, Broadhurst T (2002) The emptiest places. *Scientific American* **Oct**: 56-63. This article is available to download from http://scannapieco.asu.edu/papers/sciam.pdf

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Ana Lopes is an associate editor at *Nature*, the international weekly journal of science. She has a degree in physics from the Technical University of Lisbon, Portugal, and a PhD in astrophysics from the University of Oxford, UK. Ana was formerly a science journalism intern at ESO.

Getting a grip on genetic diseases

Sabine Hentze and Martina Muckenthaler tell **Lucy Patterson** about their work – detecting genetic diseases and counselling potentially affected patients.

Sabine Hentze

Images courtesy of the EMBL Photolab

Martina Muckenthaler

As part of the recent SET-routes[w1] Insight Lectures[w2] series, two scientists from Heidelberg, Germany, talked about their work and experience in the field of genetic disease: Sabine Hentze, a medical doctor specialising in human genetics and genetic counselling, and Martina Muckenthaler, a professor at the Centre for Paediatric Medicine at Heidelberg University Hospital working on the hereditary iron storage disease haemochromatosis (see page 56/57).

Genetic diseases are caused by abnormalities in a person's DNA. These can be as simple as a single nucleotide mutation in a single gene, or as complex as deletions and rearrangements of parts of or entire chromosomes.

Our DNA is constantly under attack by a range of factors that can cause mutations, such as naturally occurring radiation (for classroom experiments on radiation, see Peralta & Oliveira, 2009). In addition, copying the entire DNA sequence of a cell during each mitosis is not a fail-safe process. In response, each cell in our body keeps a fleet of DNA-repair enzymes that constantly patches up the damage. From time to time, however, mutations escape the repair

Image courtesy of alex-mit / iStockphoto

REVIEW

Inherited diseases and syndromes are pivotal for any genetics class: the topic is relevant to all students and will encourage them to involve the family in 'family-tree research'. It will trigger even more discussions in the class if students are ready to talk about rare diseases or chromosome aberrations in their extended family. Haemochromatosis is an issue that need not be avoided, since it is medically manageable when diagnosed. It is also a good example of an evolutionary advantage that can lead to a dead end when the environment changes. This promises to spark many interesting discussions.

In addition, the article describes all major techniques that are currently used to analyse inherited defects, including a cutting-edge technique, the microarray.

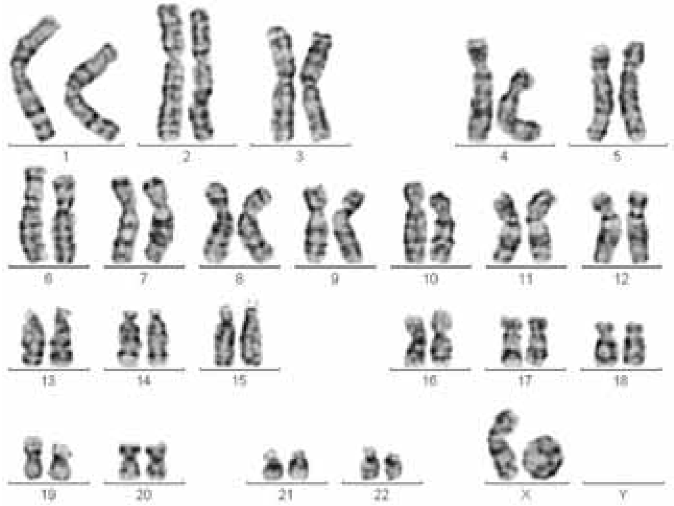
Possible topics for discussion include: genetic ethics in general; in vitro fertilisation; pre-implantation genetics; family planning in cases of known diseases; and the question of when life starts. All these are topics related to ethics and religion.

Here are a few suggestions for tasks to set students, using this article:

1. In a table, list the described techniques and their feasibility in determining an inherited syndrome or disease.
2. Discuss the features of each technique concerning its validity for the patient.
3. Discuss 'the right to know' or 'not to know' and the ethical dilemma that doctors face when they discover severe genetic mutations.
4. Illustrate iron uptake and regulation in humans using a flowchart or pictures.
5. Draw a diagram of the inheritance pattern of the mutation in the HFE gene, using Mendelian genetics.

Friedlinde Krotscheck, Austria

Image courtesy of Sabine Hentze



Chromosomal analysis of a female. One of the X chromosomes forms what is known as a ring chromosome, causing Turner syndrome

process and become fixed in the DNA.

If these mutations occur in important genes, they can cause serious diseases. As we have two copies of each gene (one from our mother and one from our father), mutations that damage only one copy of the gene do not necessarily cause immediate problems, as we still have one healthy copy. Indeed, we all carry between five and ten such recessively mutated genes without even realising it. Only dominant mutations will manifest as a disease when just one copy of the gene is damaged. Recessive mutations can become problematic, though, if both your mother and father happened to carry a mutant copy of the same gene: there is a risk that you could inherit both. This can cause diseases such as cystic fibrosis or sickle cell anaemia.

When whole sections of chromosomes go missing or are switched around, or even entire chromosomes are duplicated or deleted, these aberrations are often lethal, so that the child dies before birth, or they lead to mental retardation and malformations, *syndromes* such as Down syndrome.

It is also possible to inherit increased susceptibility to diseases. Certain mutations, although they do not actually cause diseases, dramatically increase a person's risk of developing particular conditions: for instance, inherited mutations in the *BRCA1* and *BRCA2* genes lead to an increased risk of breast cancer.

It is part of Sabine's job to investigate and diagnose these kinds of diseases in her patients: "A typical situation is one where parents introduce me to their child, saying 'He has not developed properly for his age. Our neighbour's son who is the same age is much taller, he's already crawling. Mine can't do that'." There are a number of tools and tests available, but when it comes to making a diagnosis, she says: "First and foremost, at the centre are we, the doctors, whose job it is to look, listen, examine and assess." After a thorough clinical examination, and armed with a detailed family history, Sabine may already be able to guess what might be the underlying cause of a patient's disorder. The next step is to find out what kind of mutation lies at the heart of the disease.

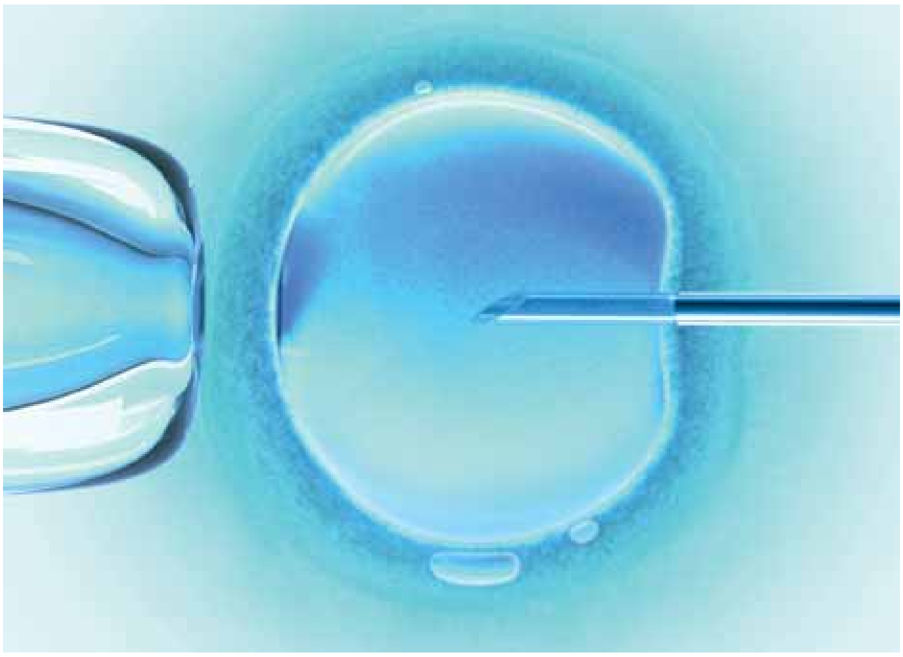
Chromosome analysis was first used by French geneticist and paediatrician Jérôme Lejeune, who in 1959 determined that children suffering from Down syndrome had an extra copy of chromosome 21. Even today, there are many questions that can be more fully answered using this technique than with a genetic test: cells taken from a patient are cultured in the lab, then fixed, prepared and stained so that their chromosomes can be studied under the microscope.

Yet some diseases are caused by rearrangements or deletions too small to be seen by conventional chromosome analysis, so a technique called FISH (fluorescent *in situ* hybridisation) is used. Tiny, fluorescently labelled DNA probes are designed to hybridise, or stick, to a specific sequence in the region of the chromosome which is thought to be affected, and doctors check if and where they hybridise on a sample of the patient's chromosomes.

So when do we ultimately use a genetic test? "I use one if I strongly suspect a particular disease for which we know the gene and the possible mutation," says Sabine. Haemochromatosis, the disease Martina has specialised in, is not only the most common hereditary disease in the western world, but in 85-90% of cases in central Europe, is caused by one specific single mutation in the *HFE* gene (see box on page 56/57). If patients seem to be suffering from the disease or are concerned that it runs in their family, it is possible to carry out a genetic test to look for *HFE* mutations. The patient's DNA is isolated, usually from a blood sample, and the nucleotides of the *HFE* gene in which the most common point mutations occur are sequenced, and compared with the sequence found in healthy individuals.

When children suffer from an unspecific mental or physical disability, mutations in a range of genes on different chromosomes can be the

Image courtesy of ktsimage / iStockphoto



In vitro fertilisation

cause. Here, chromosome-staining techniques don't have a sufficiently high resolution to identify the defective gene – however, it would be an incredible amount of work to sequence all potentially affected genes individually. In these cases, geneticists like Sabine are starting to use a new technology: microarrays (for an in-depth explanation of microarrays and a suggestion of how to introduce them in the classroom, see Koutsos et al., 2009). Microarrays vastly speed up the process of genetic testing; as tens or hundreds of thousands of regions of the genome can be tested at the same time, it is possible to test for many disorders simultaneously. In the future, scientists hope that it might be possible to develop a microarray that can test for all genetic diseases and predispositions in one quick and simple test.

No parents would wish their child to be born with a genetic disease. Until recently, prenatal screening was the only option available to determine whether a baby would be born with a serious disorder. However, since the advent of *in vitro* fertilisation, it has become possible to examine the genetic makeup of an embryo before it is implanted into the womb, a technique called pre-implantation genetic diagnosis.

At present, many tests are available for well-known genetic diseases, allowing parents who are at risk of passing on a genetic disease to select a healthy embryo for implantation. In many respects this is great news, as it means that expectant parents do not have to go through the process of screening the embryo in the womb (amniocentesis, which itself carries a risk to the baby), waiting for the results, and taking the decision whether to terminate the pregnancy if the outcome is bad.

The more we learn about the genetic basis of different diseases and traits, and the more sophisticated our screening methods become, the more we can screen for. Of course, no parent would want their child to suffer from a serious disease – but what about less severe disorders such as haemochromatosis, congenital deafness, or even short-sightedness? Who is to say that a child growing up with such a condition wouldn't live as full a life as an otherwise healthy person? In essence, this issue raises the subject of what is normal. Where do we draw the line as to which genetically determined conditions or traits are acceptable and which are not? Furthermore, should parents ever be allowed to choose if their child is male or female, how tall or attractive or how intelligent they are?

Another question raised by genetic testing is whether you would really want to know what your genes have in store for you. What if you were to find out that you were at high risk of developing a serious disease? You

Image courtesy of John Crolla, Wellcome Images

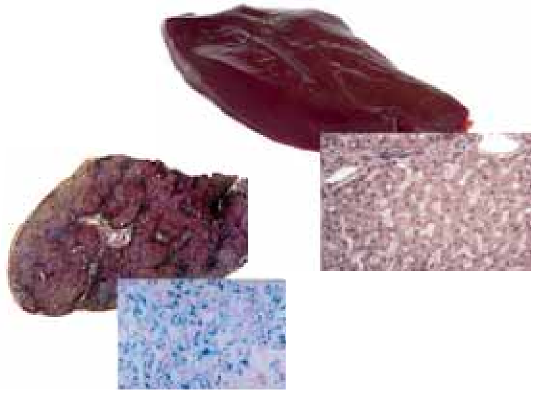
FISH with probes that bind to specific sequences of DNA. Note the deletion in chromosome 22 in the sample on the right. This causes DiGeorge Syndrome, which is marked by the absence of thymus and parathyroid glands, and results in impaired immunity, short stature, and deformities of the face, heart and great vessels

BACKGROUND

Haemochromatosis

Haemochromatosis is the most common hereditary disease in the western world. It is a condition that causes the body to absorb and store dangerously high levels of iron from the diet in the liver, heart, pancreas and other tissues. Besides a bronze pigmentation of the skin, this can eventually cause liver failure, heart failure or diabetes, since humans, like most animals, have no means to excrete excess iron.

Iron is an essential component of haemoglobin, the molecule responsible for oxygen transport in red blood cells. In addition, it is a cofactor of cytochromes, proteins which are important in generating energy in the respiratory chain of each cell. In the past, it was noticed



Images courtesy of Martina Muckenthaler

A liver affected by haemochromatosis (left), compared with a healthy liver (right above). Note the excess iron (stained with Prussian blue)

that the then-common practice of bloodletting using leeches seemed to alleviate the disease. In fact, this remains the mainstay of treatment for haemochromatosis today, albeit without the leeches. The synthesis of new red blood cells helps to use up excess iron. Initially, the disease was thought to affect only men, becoming evident only in their forties and fifties. However, we now know that women are just as likely to have the disease, but that loss of blood through menstruation and pregnancy naturally helps to alleviate the symptoms.

In 85-90% of cases in central Europe, haemochromatosis is caused by one specific mutation in the *HFE* gene,

Public domain image; image source National Library of Medicine

A woman standing at a table has placed a leech on her left forearm; on the table is a large jar containing leeches.
From *Historia medica, in qua libris IV animalium natura, et eorum medica utilitas esacte & luculenter* by Guillaume van den Bossche (1638)

located on chromosome 6. It is thought to have spontaneously originated about 500 BC in one individual of a Celtic tribe living in the Danube valley, and from there it spread across Europe, and with emigrants to America and Australia. In Australia, all patients can actually be traced back to one single immigrant carrying the mutation. One in eight people in the western world carry this mutation, but since it is recessive, only one in every 250 people will develop symptoms of haemochromatosis.

Researchers like Martina Muckenthaler think that it is likely that the *HFE* mutation spread so widely as it conferred a selective advantage: "Historically, women gave birth to many children. Both the developing child and the births themselves, which resulted in blood loss, emptied the iron stores. Besides, there was very little meat to eat, and since this contains the most iron in our diet, it was very difficult to replenish ones iron stores. Moreover, in the past, humans tended not to live so long, so the symptoms of the disease didn't get to develop. This means that the mutation of the *HFE* gene was a great advantage in terms of natural selection: people with this mutation were better able to reproduce successfully than those without the mutation."

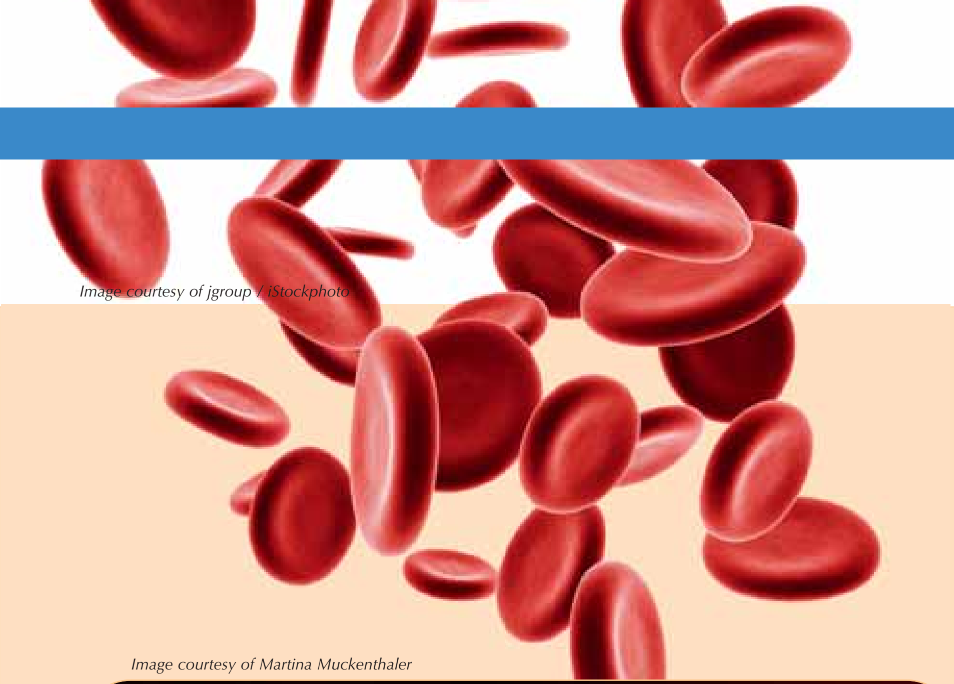
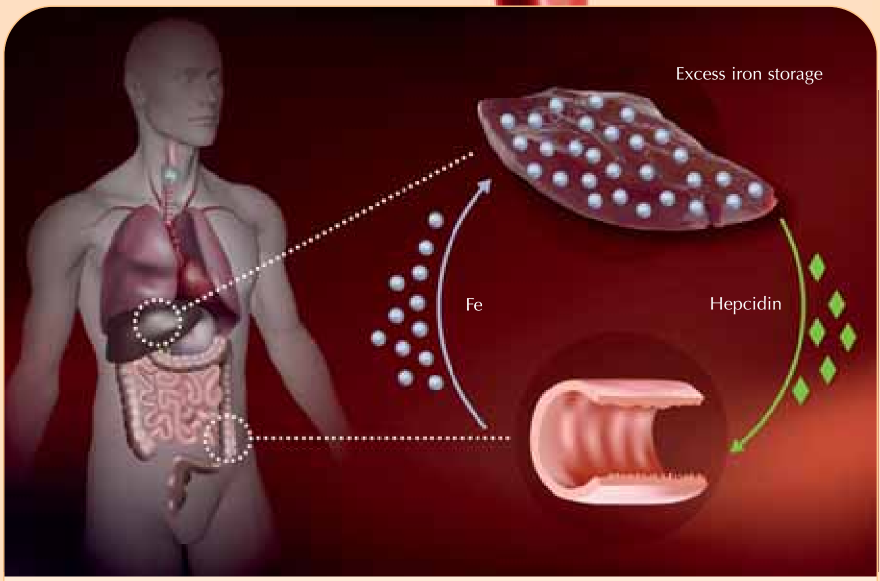


Image courtesy of jgroup / iStockphoto

Image courtesy of Martina Muckenthaler



Hepcidin is not sufficiently up-regulated in people with haemochromatosis, leading to excess iron being taken up in the intestines and stored in the liver

How does this mutation cause excess iron uptake? The body absorbs iron in the intestine via a specialised transport protein. Iron is then stored inside liver cells bound to an iron storage protein, ferritin, until it needs to be mobilised. Too much iron can lead to the production of oxygen radicals, damaging cells and causing them to die. To ensure that no surplus iron is taken up, the liver measures how much iron is available and translates this information into the production of a hormone named hepcidin – the more iron, the more hepcidin. In the intestine, hepcidin destroys the iron transporter proteins, so they won't take up any more iron.

Martina has developed a special microarray containing 500 genes related to iron metabolism and using the mouse as a model organism. With this method, her group compared the gene activity of liver cells from healthy mice with that of liver cells from mice engineered to carry the *HFE* mutation that causes haemochromatosis in humans. They found that with the *HFE* mutation, hepcidin is not sufficiently up-regulated even when there is already enough iron in the body, causing an excess iron uptake. Through their research, Martina and others are now trying to understand this process in more detail.

might be able to adjust your lifestyle to delay its onset or decrease the symptoms, but how would you feel if you knew your risk? And what if insurance companies or prospective employers were to have access to that information? What if there was a risk that you could pass this disease on to your children? Wouldn't your partner want to know? Might it change the way he or she felt about you? For suggestions on how to stimulate discussions on such issues in the classroom, see Strieth et al. (2008).

It is at this point that the work of genetic counsellors like Sabine Hentze is really essential: "Besides my laboratory work, I spend much of my time on counselling patients, in other words on communication: what does this test result mean? What does it mean for me, for our child, for our family, for our future?"

And it is through the work of genetic counsellors that we have come to realise that perhaps one of the most important considerations in genetic testing is that people also have the right *not* to know.

References

Koutsos A, Manaia A, Willingale-Theune J (2009) Fishing for genes: DNA microarrays in the classroom. *Science in School* **12**: 44-49. www.scienceinschool.org/2009/issue12/microarray

Peralta L, Oliveira C (2009) Radioactivity in the classroom. *Science in School* **12**: 57-61. www.scienceinschool.org/2009/issue12/radioactivity

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

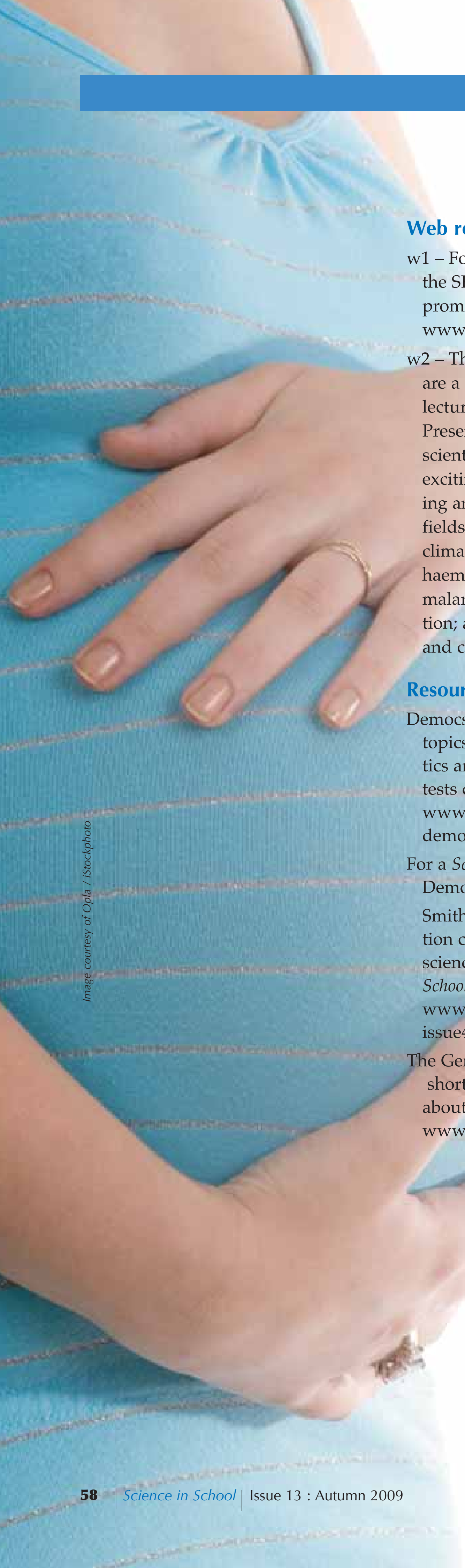


Image courtesy of Opla / iStockphoto

Web references

w1 – For more information about the SET-routes organisation, promoting women in science, see www.set-routes.org

w2 – The SET-routes Insight Lectures are a series of interactive scientific lectures for use in schools. Presented by exceptional women scientists, the lectures introduce the exciting world of science, engineering and technology (SET), covering fields as diverse as space science; climate change; genetic counselling; haemochromatosis and DNA chips; malaria; stem cells and regeneration; archaeology of the Universe; and cosmology.

Resources

Democs card games to debate the topics of pre-implantation diagnostics and over-the-counter genetic tests can be downloaded free here: www.neweconomics.org/gen/democs.aspx

For a *Science in School* article about Democs, see:

Smith K (2007) Democs: a conversation card activity for teaching science and citizenship. *Science in School* **4**: 27-19. www.scienceinschool.org/2007/issue4/democs

The Genes are Us website offers short films and classroom activities about genetic diseases, see: www.genesareus.org

For an introduction to many of the most common genetic diseases, see the Genetic Disorders Library (http://learn.genetics.utah.edu/content/disorders/whataregd) section of Learn.Genetics (http://learn.genetics.utah.edu), the Genetic Science Learning Center from the University of Utah, USA.

To learn more about oxygen radicals in your body and how to counteract them, including a classroom activity, see: Farusi G (2009) Looking for antioxidant food. *Science in School* **13**: 39-43. www.scienceinschool.org/2009/issue13/antioxidants

If this article has whet your appetite, you can find further reading on the most cutting-edge advances and opinion on genetic testing and personal genomics at Daniel MacArthur's science blog, Genetic Future: http://scienceblogs.com/geneticfuture

If you found this article interesting and useful, you might like to browse all the medicine-related articles published in *Science in School*. See: www.scienceinschool.org/medicine

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Lucy Patterson finished her PhD at the University of Nottingham, UK, in 2005, and has since been working as a postdoctoral researcher, first in Oxford, UK, then in Freiburg and Cologne, Germany. During this time she has worked on answering several different questions in developmental biology, the study of how organisms grow and develop from a fertilised egg into a mature adult, using zebrafish embryos. She has a broad interest and enthusiasm for science, and is currently developing her own embryonic career as a science communicator.

Folic acid: why school students need to know about it

Eleanor Hayes, **Holger Maul** and **Nele Freerksen** investigate why folic acid is an essential component of your students' diet – now and for a future healthy family.

Image courtesy of Melissa Schalke/iStockphoto

A tear rolled down Lucy's cheek. "I never imagined anything could go wrong. I thought I'd stop taking the Pill, get pregnant, and have a healthy baby. And it all seemed to be working according to plan: I quickly got pregnant. When I went to the doctor, I thought he was over-reacting when he gave me some dietary tips, and told me to take folic acid supplements. I took the tablets, but asked myself 'What could possibly go wrong with my baby?'"

When she was 17 weeks pregnant, though, she was told that her baby had spina bifida: the spinal cord had not fully closed, leaving the nerves unprotected. Damage to the nerves meant that her child would be confined to a wheelchair, incontinent, and have severe learning difficulties. After several weeks, much consultation and much thought, Lucy and her boyfriend took the agonising decision to terminate the pregnancy. A year later, she is still convinced that they made the right decision for their child, but the pain remains.

Very few biology textbooks stress the importance of folate in foetal development or in any other context. This article is overdue as an enrichment to the existing biology curricula, as it can be used as an excellent example when reviewing all of the main topics in human biology (see diagram). The metabolism of folate can be used to connect the major metabolic pathways while giving students a very useful understanding of their own body. For example, it could be employed in lessons to address an important principle in biology: the chain reactions in human metabolism that occur if one vitamin is in low supply.

Suitable comprehension questions include:

1. Why is the lack of folate life-threatening under certain conditions?
2. Describe the role of tetrahydrofolate as a coenzyme.
3. Anaemia is a lack of enough erythrocytes to carry oxygen; how does folate deficiency interact with the production of red blood cells?
4. Levels of homocysteine in the blood are known to be higher in older adults at risk of cardiovascular disease. Develop a hypothesis of why this occurs and what could be done to lower the homocysteine level.
5. Using the diagram below (which can also be downloaded from the *Science in School* website[w5]), decide which of the segments the following deficiencies fit into:

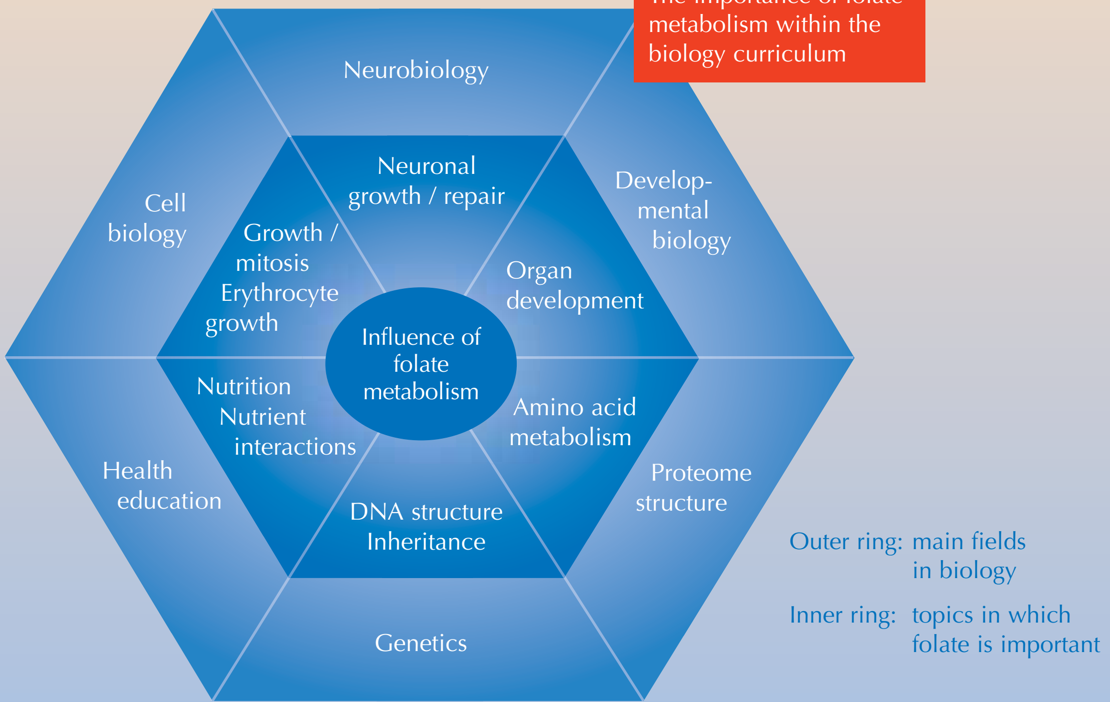
- Neural tube defects, heart defects and cleft palates
- Chromosomal defects in sperm and ovum
- Megaloblastic anaemia
- Cardiovascular disease
- Memory loss.

Discussion topics that could emerge from the article include family planning, lifestyle, government-prescribed nutrients in processed food, as well as the life-threatening conditions caused by folate deficiency. The positive message is that knowing and providing the right nutrients can eliminate or alleviate syndromes and metabolic diseases.

The accompanying questionnaire makes it possible for students to participate in ongoing research: taking part in data collection, the everyday work of the scientist. Seriously applied and truthfully answered, the questionnaire can be used to motivate a science class.

Students should learn about this topic even before puberty to understand the importance of a healthy lifestyle and then be reminded again and again as they grow older: folic acid – are you getting enough of it?

Friedlinde Krotscheck, Germany



The importance of folate metabolism within the biology curriculum

Image courtesy of Nicola Graf

REVIEW

A folic acid supplement

The tragedy of Lucy's story is that it could probably have been avoided if she had taken the supplements earlier. Worryingly few young people, however, seem to know how essential folic acid is – or that it is important to take the supplement for at least a month before a pregnancy.

Each year, more than 4500 pregnancies in the European Union are affected by spina bifida and related disorders, known collectively as neural tube defects (Busby et al. 2005). In the UK, approximately 85% of pregnancies are terminated after the diagnosis, and around 150 people per year are born severely disabled by the spina bifida[w1].

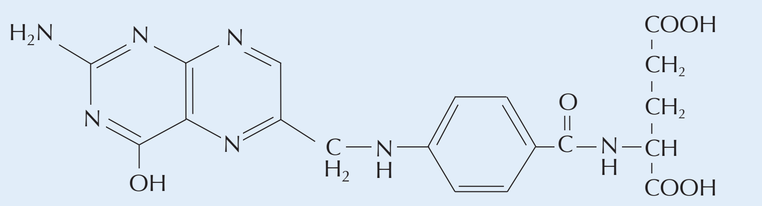
It is estimated that in 75% of cases, spina bifida could have been prevented if the mother had taken folic acid supplements at the correct dose and early enough. A European study showed that in all 18 countries considered, only a minority of women took folic acid supplements before conceiving. The highest percentages of women taking folic acid before a pregnancy were found in the Netherlands, the UK, Ireland and Norway: 30-46%. In France, Spain, Germany and Italy, the percentages were much lower, at less than 5% (Eurocat Folic Acid Working Group, 2005).

Folic acid could have prevented 75% of spina bifida cases. However, in the remaining 25% of affected pregnancies, the situation is more complex: the risk of spina bifida is higher among women who have a family history of neural tube defects, have diabetes or are overweight. Spina bifida is also associated with certain medicines, for example some drugs that are used in chemotherapy or prescribed for certain autoimmune diseases. However, some of these complications are also associated with folic acid deficiency: some genetic mutations reduce the ability to metabolise folic acid, as do some drugs (e.g. methotrexate, used to treat rheumatoid arthritis and some cancers).

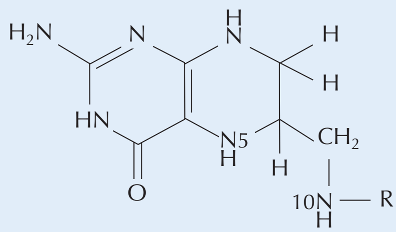
Folic acid and its biological role

Folic acid is a water-soluble B vitamin, also known as vitamin B9. Folic acid or its naturally occurring form, folate, are essential for numerous physiological processes. Thus, both children and adults require a certain amount of folic acid; lack of folic acid can cause anaemia and severe birth defects. (We use the term 'folate' for the forms found in the body and 'folic acid' for the more stable form found in supplements.)

High levels of folate are found in fruit and vegetables, particularly leafy vegetables (such as spinach and lettuce), as well as in lentils, peas, and baker's yeast[w2]. Humans are not capable of synthesising folate in the body, which means that they depend on sufficient levels of it in their diet. Although folate deficiency can have a number of biological causes – which reduce the ability of the body to absorb folate – the most common cause is simply that they eat too little folate (or folic acid).



Folic acid



Tetrahydrofolate (THF)

Images courtesy of Nicola Graf

Image courtesy of fajean / iStockphoto

In the body, folate is reduced to tetrahydrofolate, the biologically active form of folic acid. Tetrahydrofolate and its derivatives are essential co-enzymes in various carbon transfer reactions, receiving and accepting one-carbon units such as the methyl group (CH_3).

A series of biochemical reactions use tetrahydrofolate to form methyl-tetrahydrofolate, an essential substrate in nucleotide synthesis. For example, together with vitamin B12, methyl-tetrahydrofolate is necessary for the formation of the pyrimidine base thymine (in DNA) as well as the purine bases adenine and guanine (in both DNA and RNA).

Tetrahydrofolate is also essential for the synthesis of several important amino acids. For example, it is a co-enzyme in the methylation of homocysteine to methionine, an amino acid required in numerous biochemical reactions such as the methylation of DNA and RNA.

A sufficient supply of folate is therefore required for both DNA and RNA synthesis and, as a result, for cell formation and regeneration. This is particularly important for all kinds of cells that undergo rapid division and growth – something that occurs especially during pregnancy and infancy, but also throughout life in the bone marrow. As cancerous tissues also undergo rapid cell division, this can be exploited: some drugs used in chemotherapy (e.g. methotrexate) actually target folate metabolism, limiting the growth rate of the tumour.

Folic acid deficiency

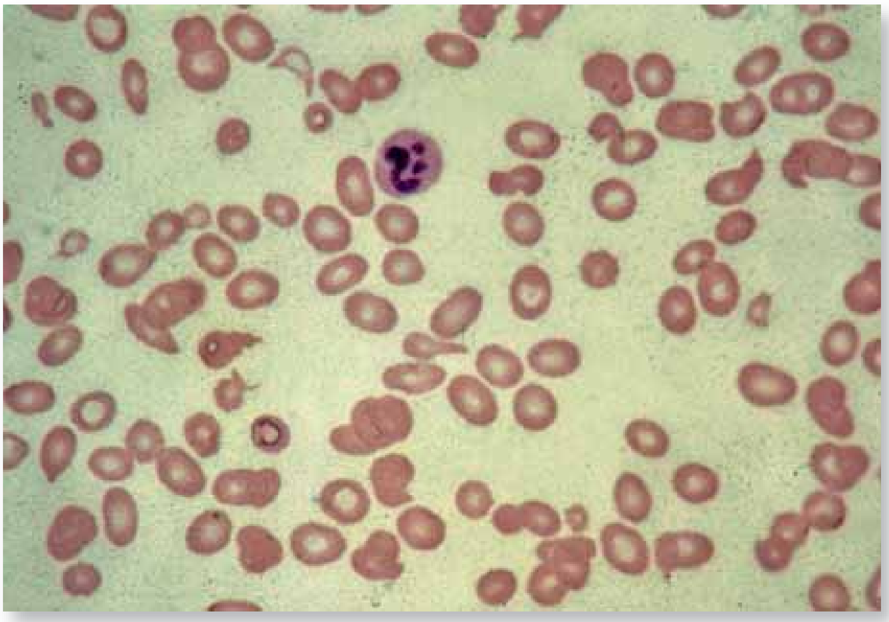
During the first three months of pregnancy, a lack of folic acid may lead to malformation of the embryo's central nervous system – this results in neural tube defects such as spina bifida, or malformations of the brain or skull. A dietary intake of 400 µg folic acid per day has been shown to reduce neural tube defects in the embryo by up to 70%. Other studies have shown that folic acid supplements are also important for other developing organs in the embryo, reducing the risk of heart and limb defects or a cleft palate.

For these reasons, folic acid supplementation during pregnancy has become standard in many countries; in Germany and some other countries, women are also advised to take folic acid when they are planning to become pregnant. At present, the internationally recommended daily supplementation of folic acid for pregnant women or those who plan to conceive is 400 µg per day. Various research groups suggest that men who are planning to father a child should also increase their daily folic acid intake, because this has been shown to reduce the incidence of chromosomal defects in sperm.

Another manifestation of folic acid deficiency is megaloblastic anaemia – which can affect people of all ages, both male and female. A lack of folic acid slows down the rate of cell division in the bone marrow, resulting in the production of fewer but larger, immature red blood cells (erythrocytes). These abnormal erythrocytes are less able to carry oxygen to the tis-

Image courtesy of Stefanie Timmermann / iStockphoto

Image courtesy of the Wellcome Photo Library



Photomicrograph of peripheral blood cells. Note the hypersegmented neutrophil, characteristic of megaloblastic anemia

sues, and the sufferer will feel tired, weak and short of breath. Other effects include paleness and gastrointestinal symptoms such as gastric ulcers. Anaemia caused by folic acid deficiency can be treated with folic acid supplements; as the average life of a red blood cell is 40 days and all of them need to be replaced, though, it will take approximately 120 days for the treatment to be fully effective.

Vitamin B12 deficiency has very similar symptoms due to the interdependence of folic acid and vitamin B12 in DNA synthesis, but – unlike anaemia caused by folic acid deficiency – is also associated with neurological problems, which may be irreversible. Clearly, to treat the anaemia correctly, it is necessary to know which deficiency is causing the condition. In the early stages (before the neurological problems appear), the two types of deficiency can be distinguished by examining the blood levels of the two vitamins.

A further potential result of folic acid deficiency is the accumulation of homocysteine (normally methylised to methionine by tetrahydrofolate). Elevated levels of this sulphur-containing amino acid in the blood have been associated with an increased risk of cardiovascular disease.

Folic acid in the classroom

Folic acid, therefore, is an important topic for school students to learn about – not only to ensure they are healthy now, but also to avoid problems in the future. To help our readers introduce the topic into their classroom and to motivate the students, *Science in School* has teamed up with a group of researchers at the medical faculty of the Otto von Guericke University in Magdeburg, Germany. In 2004, Dr Simone Pötzsch and her research group surveyed students at schools in one region of Germany to see how much they knew about the importance of vitamins and minerals – in particular folic acid (Plötsch et al., 2006).

For *Science in School*, we have translated and adapted this survey so that teachers can assess their students' knowledge – perhaps before introducing this article in a lesson. Teachers, however, should exercise sensitivity when deciding whether to use the questionnaire, and if so, with which students. We also recommend asking the students' parents for permission before using the survey, explaining that the data will be used in a European-wide survey.

The survey can be downloaded from the *Science in School* website[w3] or completed online[w4]. We will pass onto Dr Pötzsch all results that we receive by **31 December 2010**. If enough schools take part, she and her group will use the data for a further European-wide study. The results will also be published in *Science in School*.

All surveys completed online will be automatically included. All printed surveys should be returned (by post or email) to:

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Germany
Email: editor@scienceinschool.org

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References

Busby A, et al. (2005) Preventing neural tube defects in Europe: population based study. *British Medical Journal* **330**: 574-575. doi:10.1136/bmj.330.7491.574. This article is freely available on the journal website (www.bmj.com).

Pötzsch S et al. (2006). Knowledge among young people about folic acid and its importance during pregnancy: a survey in the Federal State of Saxony-Anhalt (Germany). *Journal of Applied Genetics* **47**: 187–190. This article can be freely downloaded from the website of the *Journal of Applied Genetics* (http://jag.igr.poznan.pl) or via the direct link: http://tinyurl.com/yde6dyw

The German-language report on the survey (*Einige Untersuchungen zum Ernährungsverhalten von Schülerinnen und Schülern Sachsen-Anhalts unter besonderer Berücksichtigung des Kenntnisstandes der Fehlbildungsprotektion durch Folsäure*) can be downloaded from the Angeborene Fehlbildung website: www.angeborene-fehlbildungen.com

Eurocat Folic Acid Working Group (2005) *Prevention of Neural Tube Defects by Periconceptional Folic Acid Supplementation in Europe*. Special report by Eurocat (European Surveillance of Congenital Anomalies). This report can be downloaded from the Eurocat website (www.eurocat.ulster.ac.uk) or via the direct link: http://tinyurl.com/yhfse4y

Web references

w1 – The website of the UK's Association for Spina Bifida and Hydrocephalus has several articles about folic acid and information about current research into folic acid. See: www.asbah.org

w2 – For a comprehensive table of different foods and the folic acid levels they contain, see the United States Department of Agriculture's National Nutrient Database for Standard Reference: www.ars.usda.gov/Services/docs.htm?docid=17477

w3 – The survey to test your students' knowledge about folic acid can be downloaded from the *Science in School* website: www.scienceinschool.org/2009/issue13/folicacid

w4 – The folic acid questionnaire can also be completed online: www.scienceinschool.org/folicacidsurvey

w5 – The diagram of how this article fits into the biology curriculum (see review) can also be downloaded from the *Science in School* website: www.scienceinschool.org/2009/issue13/folicacid

Resources

A German-language presentation about the importance of folic acid can be downloaded from the Angeborene Fehlbildung website: www.angeborene-fehlbildungen.com

For a complete list of medicine-related articles that have been published in *Science in School*, see: www.scienceinschool.org/medicine

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Image courtesy of rphotos / iStockphoto

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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. Users 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, users 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 substances
- Good laboratory practice is observed when chemicals or living organisms are used
- Eye protection is worn whenever there is any recognised risk to the eyes
- Pupils and / or students are taught safe techniques for activities such as handling living organisms, hazardous materials and equipment.

Credits

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A star-struck teacher in Italy

Research offers exciting and challenging job opportunities, but sometimes the price to pay in terms of personal sacrifice is very high. **Claudia Mignone** interviews a young astronomer who found satisfaction in the classroom – teaching mathematics.

Image courtesy of ESO

Image courtesy of Alessandro Berton

Alessandro Berton

Astronomy has always been Alessandro Berton's greatest passion: after his undergraduate studies at the University of Padua, Italy, he moved to the Max Planck Institute for Astronomy in Heidelberg, Germany, for his PhD. His research focused on the development of new, cutting-edge techniques to detect extrasolar planets. The quest for planets outside our solar system has been one of the most fascinating topics in astronomy for the past 15 years (see Jørgensen, 2006 and Fridlund, 2009), and Alessandro was thrilled to be a part of it. Yet something was missing.

"During those years, I always felt the lack of social, human interaction – a lack that is typical of many research environments," he explains. "I longed for a job where I could spend more time with other people than in front of my computer screen." Hence, a few months after receiving his PhD, Alessandro enrolled in the Italian high-school teacher-training program, and at the same time he began to teach mathematics to his very first students.

"I had been thinking about teaching long before the end of my PhD," he admits. As an undergraduate student of astronomy, Alessandro had occasionally worked for a small observatory, taking care of the planetarium and telescopes, and introducing schoolchildren to the mysteries of the night sky. He enjoyed this job a lot, but more than that, he was really good at it. Nearly every other day during his PhD, Alessandro wondered whether it would be better to go on with his research, or to leave it and start teaching.

The scientific work involved in a PhD has its natural ups and downs. Sometimes you have to wait longer than you wished, and the results are not as exciting as you had hoped. Yet you have to hide your scepticism and always look bright and confident: let's not forget it is a highly competitive environment. This competitiveness was not one of Alessandro's favourite aspects of astronomy: the environment of a school, with your own students, where you are the only person in charge within the four walls of your classroom, sounded much more appealing to him.

With several, contradictory thoughts on his mind, Alessandro decided to give teaching a try. After all, he already knew how he felt about research. He discovered that he had made the right decision. "It was exactly what I was looking for," he says, smiling. "Every day something different happens. There is the pleasure of preparing a lesson, the joy of teaching, the thrill of explaining things… On top of it, you have to deal with a bunch of 14- to 19-year-old students: an extremely delicate task, but most of the time it's a lot of fun!"

After two years of teaching, Alessandro's impression is entirely positive: "The feedback from your own students is an overwhelming reward. Nothing compares to such a feeling." Nearly every day, after teaching, he goes home with some small satisfaction, whereas during his previous research work, daily gratification was just about impossible to achieve.

Image courtesy of C. Huerta

REVIEW

There is always a drift between working in science and technology and teaching, for a variety of reasons. Here is a good example – a dedicated astronomer who became a dedicated teacher. Teachers could use this article in a range of contexts, including demonstrating the appeal of science and illustrating the different careers available to scientists.

Eric Deeson, UK

He acknowledges, however, that the transition was not exactly smooth. When I ask him what he misses most from his research years, the answer erupts immediately: "Astronomy!" Unfortunately, the Italian school system only allows astronomy graduates to teach mathematics or physics, basic subjects of an astronomer's education; strangely enough, astronomy is counted amongst the natural sciences, along with chemistry, biology and geology, and is taught by graduates of other subjects. "It's a struggle to see my students learning astronomy from a teacher who does not share my enthusiasm for the subject," he says. It is almost inevitable that you will

An artist's impression of the extrasolar planet Gliese 581 c

Image courtesy of ESO

miss something that has been such a big part of your life for years. Alessandro tries to compensate for this through amateur astronomy and science communication. His dream, however, is to teach his own after-school class – covering not only basic astronomy but also real astronomical observations and data analysis.

In the meantime, Alessandro uses astronomy as a motivational tool. Motivating students every day is probably the most difficult task for a teacher. When difficult mathematical concepts are introduced, a practical example can be very helpful. And where would he draw his examples from, but from astronomy? "When I had to explain logarithmic equations, I drew a parallel to the magnitude system used to classify stars. When we were dealing with conic sections, I told them the orbit of the Earth around the Sun is an ellipse, and that of a comet is a parabola." The students were excited, mostly because they could spot (and appreciate) a high degree of motivation in the teacher himself.

Although years spent doing research may not be the standard training for a teacher, they have interesting advantages: the lack of practical experience in the classroom is compensated by experience of day-to-day scientific research, which makes the delivery of a scientific message more straightforward. Alessandro became aware of this fact during an unusual teaching activity he's recently been involved in: a robotics lab class. The students were asked to build a little robot with sensors, which they then used for small experiments. Although the experiments were of minor importance, such as studying the motion of the robot along an inclined plane, the class taught them something of a much greater value: the scientific method.

"My active research background was very useful: unlike other teachers at my school, I had concrete experience of doing science," he shyly admits. "It was a pleasure to watch the students learn how to take measurements properly and treat statistical error, how to draw conclusions and summarise them in a report that slightly resembled a scientific paper."

After two years, Alessandro is still very satisfied with his choice, and is looking forward to the beginning of the new school year. "It is a difficult job though, and you cannot start teaching if you are not truly convinced," he points out. "After all, you have the students' future in your hands". He suggests to young scientists who might consider the option of moving to the classroom: "If you think you have enough patience, communication and organisation skills, and you are looking for a job for which human contact is crucial, then think about teaching. When you've finished thinking, think again. Maybe try some teaching activities, or science communication – if you enjoy it, then you might be a good teacher. And then, good luck!"

References

Fridlund M (2009) The CoRoT satellite: the search for Earthlike planets. *Science in School* **13**: 15-18. www.scienceinschool.org/2009/issue13/corot

Jørgensen UG (2006) Are there Earth-like planets around other stars? *Science in School* **2**: 11-16. www.scienceinschool.org/2006/issue2/exoplanet

Web references

w1 – To learn more about the European Southern Observatory (ESO), see: www.eso.org

Resources

To view all the *Science in School* articles about astronomy, see: www.scienceinschool.org/astronomy

If you enjoyed this article, you might also like to read other teacher profiles in *Science in School*. See: www.scienceinschool.org/teachers

Claudia Mignone studied astronomy at the University of Bologna, Italy, and then moved to Germany for a PhD in cosmology at the University of Heidelberg. Her research focused on methods to infer the properties of the expansion of the Universe.

Currently, Claudia is concentrating on communicating with the public, as an intern at the European Southern Observatory (ESO)[w1]. She enjoys writing about science and society, and explaining science to people who are not closely involved with it. She particularly appreciates their unexpected questions and reactions.

Image courtesy of frugola / pixelio.de

Virtual reality: the Haptic Cow

With the help of former vet, Sarah Baillie, **Vienna Leigh** takes us on a virtual reality trip – deep into a cow's insides!

Have you ever wondered what the inside of a cow feels like? If you want to be a veterinarian, it's something you'll have to get very used to indeed! Vets often find themselves needing arm-length gloves for some of the more 'hands-on' parts of the job, but without visual indications it can be hard to teach veterinary students about what exactly they should be feeling for.

That's where an ingenious invention by former vet Sarah Baillie, the Haptic Cow, comes in. "*Haptic* is a Greek word, relating to the sense of touch," she explains. "The Haptic Cow is essentially a fibreglass model of the rear half of a cow that uses virtual reality to simulate the reproductive or rectal tracts of the animal."

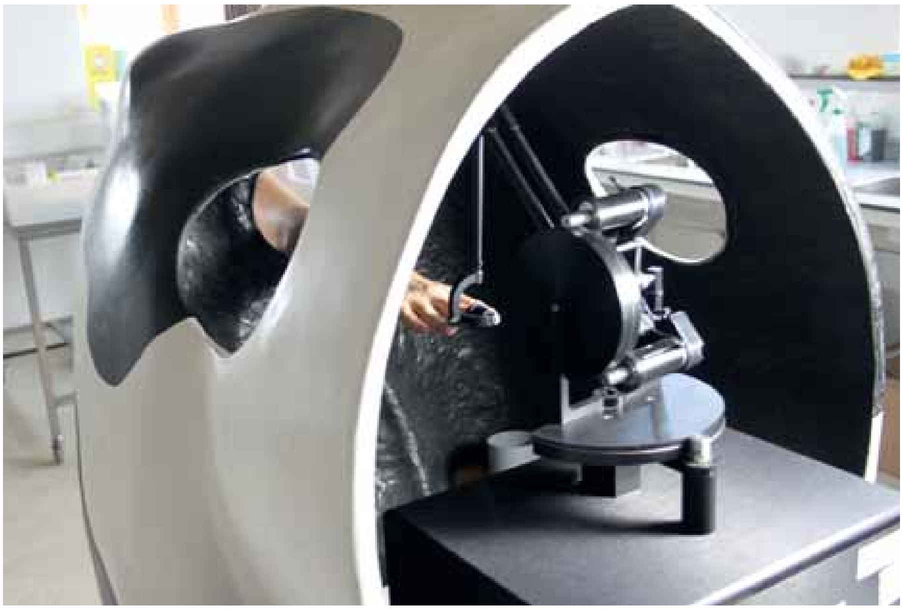
So, how does it work? "Your hand is suspended from a robotic arm positioned inside," explains Sarah. "The motors of the arm control your hand movements and produce resistant forces, depending on which simulation is created via the software – a pregnancy, perhaps, or an ovarian cyst – and you get the impression of feeling objects in the abdomen and identifying them by their position, shape, size and texture or softness."

After inserting his or her arm through the rectum of the 'cow', the student will be instructed to feel forwards to the single 'bump' which is the cervix, and then

REVIEW

This interesting article explains how virtual reality helps veterinary students learn to examine the internal organs of the cow via its rectal or reproductive tracts. It would be particularly useful for biology teachers when teaching the topics of the digestive tract and reproductive systems. It could also be linked to virtual reality or simulation studies in computer technology lessons. For a more interdisciplinary approach, the article could provide the basis of a discussion on the use of information technology and computers in science and medicinal practice.

Andrew Galea, Malta



Inside the haptic cow

further to the double bump that can only be the uterus. "If the cow is pregnant, pressing down on the side of the double or m-shaped bump of the womb will reveal to the student a thin wall and a watery feel," explains Sarah. But be warned – press too hard or in the wrong place, and the Haptic Cow will utter a baleful 'moo'!

It doesn't stop at bovines, either. "I've also developed a Haptic Horse for which the simulations include common ailments of the digestive tract – colic, for example, which could be due to a twisted gut," Sarah says. Moving a hand around the abdominal 'landmarks' teaches students how to tell the difference between, for example, a normal caecum (the beginning of the large intestine) – which feels 'squishy', according to Sarah – and constipation, which apparently feels more 'doughy'. "For vets, learning or teaching how to do these kinds of manual diagnoses – which are often stressful, high-stakes events both for the animal and its owner – has always proved to be very difficult, because you can't see what's going on," she says.

Sarah practiced as a vet for many years before a back injury meant she had to consider an alternative career.

A career as a vet requires a broad mix of abilities – a knowledge of science, technical competencies, clinical reasoning, and good communication and teaching skills, to name a few – and so Sarah had an unusual and useful skill set to take with her. While still working as a vet, she began to retrain in information technology (IT) – "I'd always been interested in computers, but I was of a generation where they were a very small part of my education" – and came across haptic technology during her MSc in IT at the University of Glasgow[w1], UK. "Haptics create the illusion of feeling around 3D objects," she says. "A few programmers had looked at using haptic technology to help doctors train (in keyhole surgery, for example) and I decided to see if I could use it to solve the problems I'd had teaching internal examinations of cows to vet students."

She embarked on a PhD focusing on using the technology to develop the Haptic Cow. "We now have a whole set of simulators for different species and techniques," says Sarah, who, when she's not inventing virtual reality innards, is a senior lecturer in veterinary education at the Royal Veterinary College, London[w2] and a founder member of ViEW[w3] (Veterinary Education Worldwide). "Most recently we've also developed haptic games to allow students to practice skills they'll need for their clinical work in a fun, hands-on way."

Sarah feels her experiences of the real issues faced in the workplace by vets have given her invaluable insight into the problems that research into education needs to solve. "The simulators I develop help to address the three Rs in veterinary education – to 'reduce, replace and refine' the use of animals in education," she says. "The real animal or patient still has a vital role in a trainee clinician's learning, but it helps to use alternatives to complement the traditional training methods where possible and appropriate."

The haptic farmyard isn't just restricted to the classroom, though; Sarah regularly takes her inventions to events, exhibitions and conferences. "The Haptic Cow has been at the Science Museum in London, and we were at the Royal Society's Summer Science Exhibition[w4] this year," she says. "Nearly 1500 people had a go on the simulators. It's one of those technologies that still gets a

Reality and virtual reality face to face

Images courtesy of Peter Nunn

'wow!' reaction from people – after all, you're feeling something that's not really there!"

Web references

w1 – To learn more about the University of Glasgow's department of computing science, see: www.dcs.gla.ac.uk

w2 – To learn more about the Royal Veterinary College, see: www.rvc.ac.uk

w3 – To learn more about ViEW, see: www.veteducation.org

w3 – For more information about The Royal Society, the UK's national academy of science, see: http://royalsociety.org

w4 – For a video covering some of the exhibits at the Royal Society's Summer Science Exhibition, see: http://news.bbc.co.uk/2/hi/science/nature/8125651.stm

Resources

For a video of Sarah demonstrating the use of the Haptic Cow to identify pelvic landmarks and undertake pregnancy diagnosis and fertility tests, see: www.vetpulse.tv/associations-congress/bcva/61_sarah-baillie-haptic-cow-in-action

More information about the Haptic Cow is also available on the website of LIVE (Lifelong Independent Veterinary Education): www.live.ac.uk/html/projects_haptic_01.html

If you enjoyed this article, you might also like to read other scientist profiles in *Science in School*. See: www.scienceinschool.org/scientists

Vienna Leigh studied linguistics at the University of York, UK, and has a master's degree in contemporary literature. As well as spending several years as a journalist in London, she has worked in travel and reference publishing as a writer, editor and designer. She's been widening her scientific horizons in recent years as the information and publications officer at the European Molecular Biology Laboratory and as editor of its newsletter, *EMBL&cetera.*

Classic Chemistry Demonstrations: One Hundred Tried and Tested Experiments

By Ted Lister

Reviewed by Tim Harrison, University of Bristol, UK

The vast majority of chemists with whom I come into contact recall that the first experiences that excited them about chemistry were either seeing or doing practical work. It seems that the use of practical work at schools is decreasing; reasons include health and safety concerns and a lack of guidance. So I think it is time to review a classic textbook in this area: *Classic Chemistry Demonstrations: One Hundred Tried and Tested Experiments*, a book aimed at teachers which was given to every UK school when it was first published in 1995.

Many of the 100 demonstrations in this paperback are not original, but were nominated by experienced chemistry teachers from all over the world. The demonstrations, all of which have been thoroughly tested, afford students the opportunity to see experiments that they cannot do themselves for a myriad of reasons. It is important that students can see a "skilled practitioner at work" performing experiments that are "often spectacular, stimulating and motivating". Naturally, chemistry demonstrations enhance teaching and learning and often provide a fun element to lessons.

For each demonstration, the author provides the topic for which the demonstration may be relevant, the time to perform the demonstration (once set up), the appropriate age for the students, a description of the experiment and the apparatus, and the quantities of the chemicals needed.

Naturally the method (procedure) is given in sufficient detail to carry out the demonstration, as well as tips on teaching and visual tips, possible extensions to the work, and both simple and fuller details of the theory (where appropriate). Lastly, but by no means unimportantly, safety notes, although not a full risk assessment, are provided.

The full list of the 100 demonstrations may be found on the website of the UK's Royal Society of Chemistry[w1], which also gives an example of one of the experiments: the ammonium dichromate volcano.

An additional ten reactions that are not included in the book ('Chemistry demonstrations to enhance teaching and learning') are available to download as Word or PDF files[w2]. These reactions include that of sodium and potassium with concentrated hydrochloric acid, and the dehydration of N-(4-nitrophenyl)ethanamide by sulphuric acid.

Another useful guide to chemistry practical work by the Royal Society of Chemistry is the Practical Chemistry website[w3]. The Royal Society of Chemistry also provides teachers with readable notes on 'Health and safety', 'Banned chemicals' and 'Chemicals not recommended for use in schools'[w4]. Although these notes are written for UK schools and colleges, much of the advice applies to classrooms everywhere.

Details

Publisher: Royal Society of Chemistry
Publication year: 1995
ISBN: 9781870343381

Web references

w1 – For the full list of the 100 demonstrations, see: www.rsc.org/education/teachers/learnnet/pdf/LearnNet/rsc/classic_select.pdf

w2 – Details of ten reactions not in the book ('Chemistry demonstrations to enhance teaching and learning') may be downloaded from the Royal Society of Chemistry website: www.rsc.org/education/teachers/learnnet/cldemo_contents.htm

w3 – The Royal Society of Chemistry's Practical Chemistry website provides chemistry teachers with a wide range of experiments to illustrate concepts or processes, as starting points for investigations and enhancement activities such as club or open-day events: www.practicalchemistry.org

w4 – To download the teacher notes on safety, visit: www.rsc.org/education/teachers/learnnet/cldemo.htm

Why is science important? website

By Alom Shaha

Reviewed by Christine Rüth, European Fusion Development Agreement, Germany

Why is science important?

- "It helps us find out what on Earth is going on."
- "It can lay the groundwork for a great career."
- "It is our best chance for tomorrow."
- "It provides us with opportunities and choices."

These and more statements can be found on Alom Shaha's webpage, *Why is science important?* (http://whyscience.co.uk).

Alom Shaha is a British school teacher who collects videos and blogs from scientists, science writers and science teachers with their very personal answers to his question, "Why is science important?"

As a teacher, Alom wants to convey to his students "that science is something worth doing for reasons beyond the need to pass exams". On his webpage, there are videos, blogs and a documentary film in which he visits scientists at their workplaces and asks them "why is science important?". Viewers can watch Alom talk to scientists in places such as Antarctica or JET, the biggest fusion reactor in the world. (Note that the video clips can take a while to load; switching off the high-definition version can help. There is a helpful note on the front page explaining how to do this.)

Maybe your next class could start with a short video of PhD student Rosie Coates showing what will happen if too much CO_2 enters our oceans. Watch Francisco Diego with his space rock, which is older than our planet. Ponder with Chris Langley about why we need more mp3 players, or listen to Mark Lythgoe describing the excitement of trotting on ground where no one else has ever been before. Read about how science allows partly deaf scientist Laura Goodall to lead the life she does.

The website might inspire teachers and students to contribute, or even to produce their own collection of statements to explain "Why is science important?"

Molecules of Murder: Criminal Molecules and Classic Cases

By John Emsley

Reviewed by Tim Harrison, University of Bristol, UK

Molecules of Murder: Criminal Molecules and Classic Cases is a highly readable book that is a must-read for those interested in crime or popular science. It follows on from author John Emsley's earlier book: *Elements of Murder: Criminal Molecules and Classic Cases*.

The book is divided into several sections: a preface which contains a brief history of the milestones in the analysis of poisons, two main sections covering ten poisons, a glossary explaining some of the technical terms used in the book, and finally, further reading suggestions. The main body of the book consists of ten chapters covering five naturally occurring chemicals, and five poisons made by humans. All ten poisons have been used in famous murders. The final part of Chapter 10 also includes details of other poisons used to assassinate prominent people through the ages.

Each chapter in the main sections begins by covering the chemistry of the poison, its discovery, its use in medicine, its effects on the human body and why it is poisonous. The last part of each chapter details the part that the molecule played in one or more infamous murders in the UK or the USA, how the murderer operated and (sometimes) how they were eventually caught. The substances discussed are ricin, hyoscine, atropine, heroin (diamorphine), adrenaline (epinephrine), chloroform (trichloromethane), carbon monoxide, cyanide, Paraquat and polonium-210.

Key scientific terms found in the 20-page glossary are highlighted in bold in the main text; the glossary offers further information on the chemistry involved – particularly useful for those whose science knowledge is very limited. This includes some formulae and imperial/metric conversion tables. For those who wish to develop their knowledge, suggestions for further reading on general and specific poisons are also provided.

This very well written book should find its way into most school libraries, as it will appeal to those – young and old – who are fascinated either by the chemistry involved, or by the history of several murder cases.

Details

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