Winter 2007 Issue 7

SCIENCE in SCHOOL

In this Issue:

Climate change

Climate researcher Rasmus Benestad examines the evidence for climate change

Also:

Highlighting the best in science teaching and research

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EIROforum
www.eiroforum.org

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ISSN

Print version: 1818-0353
Online version: 1818-0361

Cover Image

Eisberg in Chile
Image courtesy of Dagmar Schmidt

Contents

Welcome to the seventh issue of *Science in School*

In our feature article, Vienna Leigh interviews Professor Lewis Wolpert, who leads a research group on the development of the embryo and is active in science communication. He shares with us his controversial ideas about belief, science education and much more. Whether you agree with him or not, why not leave your comments on our website?

Matthias Wilmanns studies development, not of the embryo, but of a disease: tuberculosis, caused by the bacterium *Mycobacterium tuberculosis*. Once nearly eradicated, this potentially fatal disease is now on the increase. Matthias and his team are searching for a cure using modern molecular biology tools.

Even more worrying than disease is the question of climate change. In response to readers' suggestions, we asked climate researcher Rasmus Benestad to write us a two-part article. In this issue, he discusses the evidence of climate change; in the next issue, he will consider the impact of humans on the Earth's climate.

In the latest article in our popular 'Fusion in the Universe' series, Henri Boffin looks way beyond the Earth's atmosphere to consider gamma-ray bursts. You may notice the increasing power of this series: in the last issue, we talked about supernovas, 'one of the most powerful events in the Universe since the Big Bang'. This time, we go a step further. First detected in 1967, gamma-ray bursts are – not **one** of the most – but **the** most powerful events since the Big Bang.

From the heavens to the depths of the oceans: Vikki Gunn's Classroom@Sea project involved a few lucky science teachers in a multidisciplinary research cruise. Together, the teachers and research scientists have produced an archive of information and teaching materials for those of us left at home.

While I sadly couldn't join Vikki's cruise, I was lucky enough to be invited to Serbia, where I visited the Petnica Science Center. Created by students and young scientists, this wonderful organisation brings together enthusiastic school students, university students and teachers from

across Europe to discover the joy and fascination of science. In his article, Srdjan Verbic introduces Petnica and its many programmes.

Our teacher profile in this issue also comes from outside the EU. Prize-winning Ukrainian biology teacher Halyna Yagenska tells Sai Pathmanathan about memorable moments in her career and describes the network she and other Ukrainian teachers have established to swap ideas and materials.

Science in School aims to encourage communication between teachers, scientists and everyone else involved in European science education. Until now, we have done this by publishing articles in which teachers, scientists and others share their scientific knowledge, teaching experience and project ideas. We are also keen, however, to encourage direct contact between our readers – across national and subject boundaries.

For this purpose, we have added a discussion forum to the *Science in School* website (www.scienceinschool.org/forum). Here, you can ask other readers for advice or collaboration, or offer your own tips. For example, a teacher in Poland may be searching for teachers in Portugal or Ireland to join an international project. Or if a Spanish science teacher needs advice about teaching a difficult topic, perhaps a Dutch teacher can help. To get the discussion started, I have added a topic about school visits to science museums. Do add your own museum recommendations or start a new discussion topic.

Another exciting change to our website is you can now download – free of charge – all all *Nature* articles that we cite in *Science in School*. We are grateful to Nature Publishing Group for supporting the European teaching community in this way, and hope that other publishers will allow us to make their articles available in the same way.

The number of translated articles on our website is increasing steadily. Italian, Spanish and Greek are particularly well represented, but we have articles in 25 languages. If you would like more articles online in your native language, you might like to either translate some yourself, or encourage others to help. Translation guidelines are available online.

Finally, why not consider submitting your own article to *Science in School*? See our online author guidelines, or ask us for advice.

Eleanor Hayes
Editor of *Science in School*
editor@scienceinschool.org

Forthcoming events

December 2007 – May 2008

Life Learning Center (Fondazione per le Biotecnologie), Turin, Italy

Training course for high-school science teachers and students

The Life Learning Center organises one-day theoretical and laboratory courses for science teachers who would like to increase their knowledge of biotechnology and bioinformatics and bring modern biology into their classroom. The courses are free of charge, including printed materials and an activity booklet.

One-day practical laboratory courses are also available for high-school students. They cover biotechnology and bioinformatics topics and molecular biology techniques (PCR, digestion with restriction enzymes, gel electrophoresis). The students are guided by young scientists; after the hands-on laboratory work, the students can discuss the experiment with their teacher and the supervising scientists. These courses cost €5 per student, including printed materials.

All courses are run in Italian.

More information: www.llctorino.it

Contact: Enrica Favaro or Elena Spoldi (divulgazione@fobiotech.org)

4 December 2007 – 30 September 2008

Explor@dome, Paris, France

Exhibition: Bougez Vert: the development of sustainable transport

This exhibition invites pupils and teachers to address environmental questions related to transport. It offers an interactive and pleasant way to test their knowledge and develop an understanding of sustainable development. Among the many hands-on exhibits are the energy bike and interactive exhibits that produce hydrogen for a fuel cell or allow visitors to investigate different ways to move around a city.

Scientific and multimedia workshops are also available for children aged 7-14.

More information: www.exploradome.com

Contact: Eloise Soucours (eloise@exploradome.com)

6-9 December 2007

Cambridge University, UK

Training course: Physics update course

This course for practising teachers of physics consists of a series of talks and workshops in which participants will:

- Hear about recent developments in physics and the applications of physics
- Try new practical techniques
- Find out about developments in physics education.

Cost: £70 (non-residential) or £130 (residential).

Contact: Leila Solomon (+44 (0)20 7470 4821 or leila.solomon@iop.org)

Until 12 December 2007

Many UK venues

Lectures: Institute of Physics schools lecture series 2007

The science of light and colour is fantastically important in an enormous number of areas: from observing and understanding the Universe in astronomy; to diagnosis and treatment processes in medicine; to efficient communications and signal processing in industries.

The Institute of Physics 2007 schools lecture will be presented by Dr Pete Vukusic, a researcher and lecturer at the University of Exeter's School of Physics. He is one of the leading scientists in the world involved in broadening our understanding of how nature uses and controls the flow of light and colour.

'Light Fantastic: the Science of Colour' will open pupils eyes to the basic concepts of the science of light and colour and show how technology is making the most of light's astonishing properties. This presentation will include demonstrations, hands-on activities and movie clips to help shed light on the science of colour. The lecture lasts an hour and is suitable for students aged 14-16.

More information: www.iop.org

Until 31 December 2007

Poland

Competition: Astronomy in School

Two websites, www.astronomia.pl and www.interklasa.pl together with *Fizyka w Szkole* magazine (*Physics in School*) have organized an astronomical contest for teachers in Poland. Participants should prepare a series of lessons, an astronomy day at school or other event during which students learn about astronomy.

More information: www.astronomia.pl/konkursy

Until 4 January 2008

UK and rest of Europe

Competition: Planet SciCast Awards

Why not encourage your students to enter this competion for short films of science demonstrations – or enter it yourself? Deadline: 4 January 2008.

Competition entries must be from the UK, but – depending on demand – films from elsewhere in Europe may be included on the website. Email and ask.

More information: www.planet-scicast.com

Contact: scicast@nesta.org.uk

17-19 February 2008

London, UK

Study course: Physics in Perspective

Organised by the Institute of Physics (IOP), this study course for sixth form-

ers and college students consists of a series of 6 lectures. The course costs £20 per person for three days or £7 per day.

Contact: Leila Solomon (+44 (0)20 7470 4821 or leila.solomon@iop.org)

Until 29 February 2008

Worldwide

Competition: Catch a Star

This international competition for school students is run by ESO (the European Organisation for Astronomical Research in the Southern Hemisphere) and the EAAE (European Association for Astronomy Education).

Students can win a trip to visit the ESO Very Large Telescope on Cerro Paranal in Chile, and many other prizes. Choose from three different competition categories:

- Catch a Star Researchers: Select an astronomical object, such as a star, galaxy, comet, planet, moon, or nebula. Become astronomical detectives, forming teams to research your chosen object. Write an article about it, to learn and share some of its secrets. Projects must be written in English, and prizes are awarded by an international jury.
- Catch a Star Adventurers: As with Catch a Star Researchers, write about your chosen astronomical topic, but entries do not have to be written in English, and prizes are awarded by lottery.
- Catch a Star Artists: You can also take part by making a drawing or painting for the artwork competition. Prizes are awarded with the help of a public web-based vote.

Submission deadline:
29 February 2008

More information:
www.eso.org/catchastar

10-16 March 2008

Portugal

School activities: Brain Awareness Week – Get Connected

Brain Awareness Week is an international effort organized by the Dana Alliance for Brain Initiatives to increase public awareness about the progress and benefits of brain research. During this week, school activities (visits to scientific laboratories, school visits by scientists, science lectures at schools) will be held all over Portugal, involving students from primary, middle and secondary schools.

More information:
http://brainweek. dana.org and www.cienciaviva.pt/divulgacao/semanacerebro2007/home/

Contact: jomalva@fmed.uc.pt

12-14 March 2008

European Molecular Biology Laboratory, Heidelberg, Germany

Training course: ELLS LearningLAB

The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools.

The three-day course is designed to enable the participating teachers to explore a range of activities, which they can practice in the lab and then take back to the classroom.

The course is open to 20 European high-school science teachers and is run in English. The course, including course materials, catering and accommodation, is free of charge; participants are expected to meet their own travel costs.

More information: www.embl.de/ells

Contact: ells@embl.de

By 31 March 2008

Worldwide

Competition: Medicines from Fungi

Why not get your students to enter the Microbiology in Schools Advisory Committee's writing competition?

Patients often ask their doctor or pharmacist for information about the medicine they have been prescribed to treat their illness. They want to know how it is produced and how it works. There is a need for a range of information sheets for patients explaining the facts about different drugs.

Many of the medicines in common use today are produced by fungi. Imagine you are a medical writer and you have been asked to produce a factsheet about one drug of fungal origin. Your factsheet should be A4 in size, attractively illustrated and factually accurate.

More information:
www.microbiologyonline.org.uk

Contact: education@sgm.ac.uk

By 31 March 2008

Worldwide

Competition: *Plus* new writers award

Plus magazine is again looking for the science writers of the future, who can make mathematics lively and interesting for a general audience. There are three categories in this writing competition: school students; university students; and the general public. In the first category, secondary-school and sixth-form students are invited to write a piece of up to 900 words about the life and/or work of any mathematician, living or dead.

The winning entries will be read by an international audience of over 200,000 in the June 2008 issue of *Plus*. There

are also prizes for the best submissions, including signed copies of popular science books and an Apple iPod.

The closing date is 31 March 2008.

More information: http://plus.maths.org/competition

March – April 2008

Five venues in the UK

Training course: Advanced physics revision roadshows

The Institute of Physics advanced physics revision roadshows for students feature exciting experiments and interactive lectures summarising key information from the AS and A2 physics courses.

The courses cost £20 per student, and include revision lectures, student handbooks, lunch and refreshments. Accompanying teachers are free.

More information: http://advancingphysics.iop.org

Contact: Anastasia Ireland (Anastasia.ireland@iop.org)

4-8 June 2008

Cheltenham, UK

Cheltenham Science Festival

At the 7th Cheltenham Science Festival, events for school students of all ages include many interactive workshops and activities which bring the science curriculum alive.

More information: www.cheltenhamfestivals.com

Contact: science@cheltenhamfestivals.com

5 June 2008

Rugby School, Rugby, UK

Conference: 20th Annual Meeting of Teachers of Physics in Schools and Colleges

The day consists of three lectures (one each on research physics, physics education and both education and entertainment), plus a series of six parallel workshops and a discussion session. Dame Professor Jocelyn Bell Burnell (who, as a research student, discovered the first radio pulsars) will speak about astrophysics and Professor Peter Main (director of education and science at the Institute of Physics) will talk about the future of physics education in schools.

The meeting is open to teachers, teachers in training and technicians from all countries. It will cost £30 per person including lunch and refreshments (£15 for newly qualified teachers and trainee teachers).

More information: www.iop.org/activity/education/Events/Events%20for%20Teachers/Schools%20Physics%20Group/page_5736.html

Contact: Chris A Butlin (ChrisAButlin@aol.com or +44 (0)1904 607 169)

July-August 2008

Andøya Rocket Range, Andenes, Norway

Student course: European Space Camp

The European Space Camp is a summer camp in English for high-school students. Participants should be aged 17-20, interested in space and science, and have a background in physics and mathematics.

The participants spend a week doing technical experiments involved in a rocket campaign, working as real rocket scientists, learning how to exploit knowledge they already possess, and broadening their understanding of applied science. Working in groups, they have to use their creativity and learn to cooperate. The programme includes hands-on activities related to the rocket launch, lectures and social activities.

Participation in the European Space Camp is free, but participants must cover the cost of their own travel expenses.

More information: www.spacecamp.no

Contact: contact@spacecamp.no

9-11 July 2008

European Molecular Biology Laboratory, Heidelberg, Germany

Training course: ELLS LearningLAB

The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools.

The three-day course is designed to enable the participating teachers to explore a range of activities, which they can practice in the lab and then take back to the classroom.

The course is open to 20 European high-school science teachers and is run in English. The course, including course materials, catering and accommodation, is free of charge; participants are expected to meet their own travel costs.

More information: www.embl.de/ells

Contact: ells@embl.de

21-31 July 2008

Davidson Institute of Science Education, Israel

Seminar: Schwartz Family International Leading Science Teachers' Seminar

Are you a motivated secondary-school science teacher? Do you want to make a long-lasting impact? Do you want to help improve science education in schools?

At this 10-day seminar at the Weizmann Institute of Science, you will:

- Be exposed to cutting-edge research by top scientists
- Develop leadership in school science education
- Establish international collaborative initiatives with like-minded colleagues
- Improve your science teaching strategies.

All lectures will be in English.

More information:
davidson.weizmann.ac.il/international
Contact: Zahava Scherz
(zahava.scherz@weizmann.ac.il)

29 September – 1 October 2008

European Molecular Biology Laboratory, Heidelberg, Germany

Training course: ELLS LearningLAB

The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools.

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More information:
www.embl.de/ells
Contact: ells@embl.de

23-26 October 2008

Berlin, Germany

Science teaching festival: National Science on Stage festival

Science teachers are invited to submit proposals to participate in the first national Science on Stage festival in Berlin, organised by Science on Stage Germany and THINK ING. Three hundred teachers from Germany and other European countries will present teaching projects and experiments in a fair and discuss innovative methods in workshops. The festival programme also includes scientific talks, exhibitions at the science and research institutes in Berlin as well as on-stage performances.

All proposals should be submitted via the appropriate national steering committee. To find the national steering committee contact in your country, consult the international Science on Stage website. The deadline for proposals is 25 May 2008 and the working language is English.

More information:
www.science-on-stage.de
Contact: info@science-on-stage.de

All year

Schullabor Novartis, Basel, Switzerland

Workshop: 'Gentechnik Erleben' (Experience Genetic Engineering)

These workshops focus on practical laboratory work, but background information is given for all experiments. Secondary-school students isolate plasmid DNA from bacterial cultures and digest it with restriction enzymes. The resulting DNA fragments are separated and visualised by gel electrophoresis.

The workshops are for secondary-school students who already have the necessary theoretical background and are over 17 years of age. The workshops are free of charge, are in German or English (on request), and have a maximum of 20 participants. Teachers are invited to get in touch to arrange a workshop for their class.

More information: www.schullabor.ch
Contact: Gesche Standke
(gesche.standke@novartis.com)

All year

Schools and other venues in England

Roadshow: Cool Seas

Run by the Marine Conservation Society, the Cool Seas Roadshow will visit 150 primary schools throughout England between September 2006 and March 2008. It entertains and educates primary/junior school children about England's spectacular marine wildlife, using life-size inflatable models of whales, dolphins, sharks, turtles, seals and porpoises in dynamic presentations given by a marine wildlife education specialist. The roadshow takes a full day at each school, and is free.

Each school that is visited receives printed materials and web-based resources, including an activity booklet and bookmark for every pupil, and a poster for every classroom. The web-based resources can be viewed here: www.mcsuk.org/coolseas

The project also has funding for 37 visits to English venues other than schools, mostly in summer 2007. If you have a large and suitable audience who would like a visit from the Cool Seas Roadshow, please get in touch.

More information: www.mcsuk.org/mcsaction/education/cool+seas+roadshow
Contact: Angus Bloomfield
(angus.bloomfield@mcsuk.org)

All year

10 locations around the UK

Training courses: Science continuing professional development

The national network of Science Learning Centres, set up by the UK Department for Skills and Education and the Wellcome Trust, provides continuing professional education for everyone involved in UK science education, at all levels. With nine regional centres and a national centre in York, access to innovative and inspiring courses is within reach across the UK. The centres not only deliver hundreds of courses, but also act as a focus for all the science learning activities in their region.

More information:
www.sciencelearningcentres.org.uk
Contact: enquiries@national.slcs.ac.uk

All year

Glasgow Science Centre, Glasgow, UK

Free teacher visits

Teachers, classroom assistants, nursery teachers and technicians are invited to visit the Glasgow Science Centre, free of charge, to explore and investigate what is on offer.

More information:
www.glasgowsciencecentre.org
Contact +44 (0)871 540 1003

All year

Many Scottish venues, UK

Roadshow: Science Circus

Glasgow Science Centre's outreach team brings all the fun of the science centre directly to schools and community groups throughout Scotland thanks to its lively travelling 'Science Circus'. Science Circus activities consist of amazing live science shows and interactive exhibits delivered at your venue.

More information:
www.glasgowsciencecentre.org
Contact +44 (0)871 540 1004

All year

Pembrokeshire, Wales, UK

Field trip: Rockpools

The Pembrokeshire Darwin Science Festival invites all primary schools in Pembrokeshire to book a rockpool ramble and identification field trip. The course is aimed at Key Stage 2 pupils (ages 8-11), takes half a day and is led by three qualified marine scientists. Cost: £250 with a bus or £170 without a bus. Maximum 30 children.

More information:
www.darwincentre.com
Contact: Marten Lewis
(M.B.Lewis@pembrokeshire.ac.uk)

All year

Pembrokeshire, Wales, UK

Workshops: Primary school

The Pembrokeshire Darwin Science Festival offers a double workshop visit for a maximum of 30 Key Stage 2 pupils (ages 8-11) and costs £200. The group is split into two workshops, which run simultaneously:

- Plankton / microscopy identification workshop
- Energy workshop using dynamos, solar panels and a steam engine as hands-on props.

Also available are three 90-minute workshops, each for a maximum of 20 pupils and costing £120:

- Oil spill workshop for Key Stage 2 pupils (ages 8-11)
- Climate change workshop for Key Stage 2 pupils (ages 8-11)
- Marine litter workshop for Key Stage 1 pupils (ages 4-7)

More information:
www.darwincentre.com
Contact: Marten Lewis
(M.B.Lewis@pembrokeshire.ac.uk)

All year

Paris-Montagne, Paris, France

Science Academy

Throughout the year, Paris-Montagne runs an outreach programme in all Parisian suburbs. The programme is for high-school students interested in sciences but not confident enough to enrol in undergraduate studies, due to social and cultural hindrances. The organisation offers personal tutoring and the possibility to discover the world of research by meeting researchers in various fields and by carrying out their own research in real laboratories during their holidays (300 expected in April 2008). The most dedicated participants in the programme are offered the chance to take part in a summer camp during the Paris-Montagne science festival (July 2008). This year's summer camp will have an international dimension, with some of our students taking part in partner programmes in Hungary, Croatia and Serbia.

More information:
www.scienceacademie.org or
www.paris-montagne.org

All year

Portugal

School visits: MIT professors go to Portuguese secondary schools

Ciência Viva is organising short talks by MIT professors in Portuguese secondary schools, as part of a cooperation (MIT-Portugal) between MIT and Portuguese universities in the areas of bioengineering, sustainable energy and transport systems. The students have direct contact to MIT professors and can discuss their ideas and ask questions about these important engineering areas.

Schools are selected based on their motivation for participating in the programme and on the projects they have developed in the areas of science and engineering.

More information:
www.cienciaviva.pt/divulgacao/mit
Contact: mit@cienciaviva.pt

All year

INTECH, Hands-on Interactive Science and Discovery Centre, Winchester UK

Free teacher visits

Teachers are invited to visit INTECH, the hands-on interactive science and discovery centre, free of charge or to attend a teacher preview session to discover what is available for school visits and workshops.

More information: www.intech-uk.com
Contact: Angela Ryde-Weller
(AngelaRydeWeller@intech-uk.com)

If you organise events or competitions that would be of interest to European science teachers and you would like to see them mentioned in *Science in School*, please email details, including date, location, title, abstract, price, language, website and contact email address to editor@scienceinschool.org

Interview with Lewis Wolpert

Professor Lewis Wolpert discusses his controversial ideas about belief, science education and much more with **Vienna Leigh** from the European Molecular Biology Laboratory.

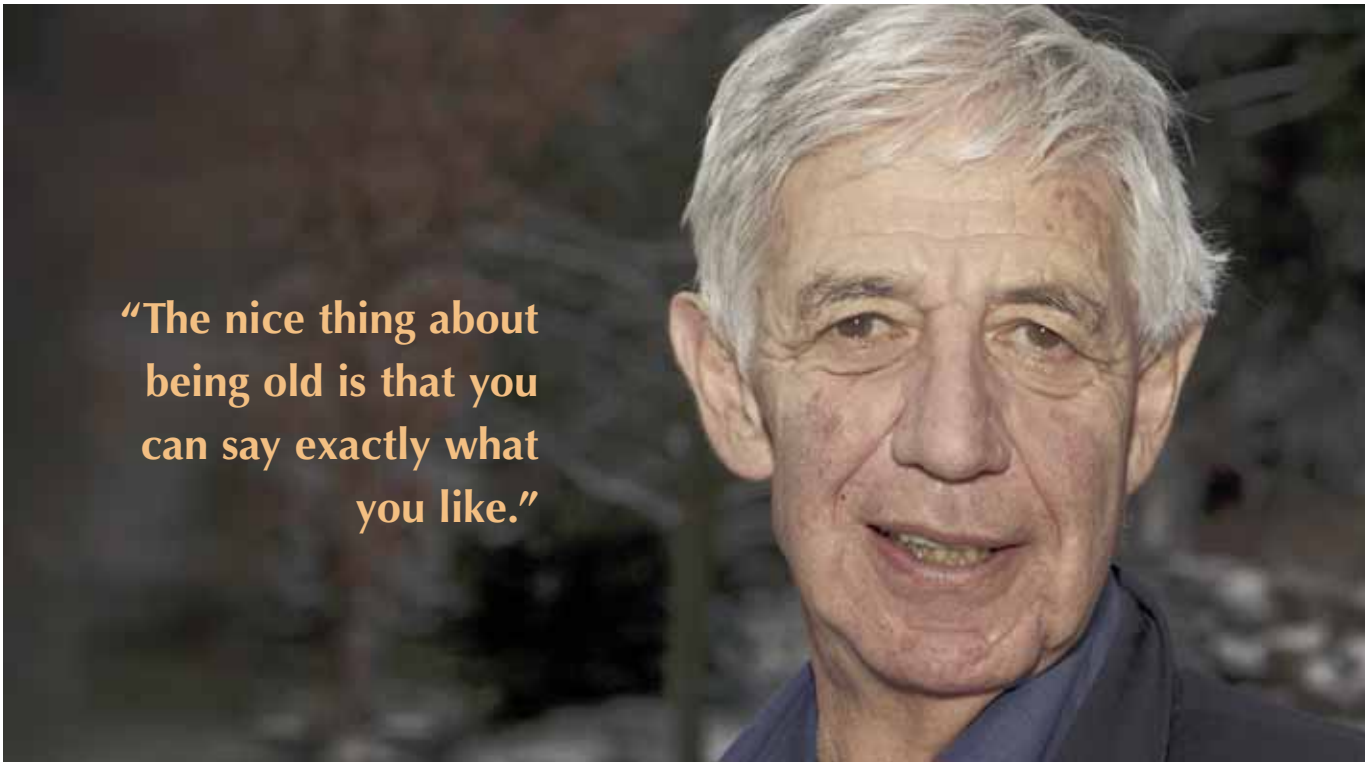

Image courtesy of EMBL Photo Lab

However you describe Lewis Wolpert, make sure you never call him a philosopher. The distinguished broadcaster and developmental biology professor from University College London, UK, has no patience with that sort of thing. "The philosophy of science is useless and gives no insight into the process of science. No scientist takes it seriously."

In fact, about most things, Professor Wolpert is not afraid to say what he thinks. "Psychoanalysis? A load of nonsense!" "A postmodernist? That's even worse than being agnostic! Oh, dear me, no!" "Telepathy... oh God, no..." "Memes? Impenetrable!" And all this in just a one-hour conversation in which he set the world to rights in a forthright, straightforward and frankly very refreshing manner.

Author of the recent bestseller *Six Impossible Things Before Breakfast: the Evolutionary Origins of Belief*, Professor Wolpert is a scientist with a life-long interest in the effective and straightforward communication of science and the study of human psychology, in this case causal beliefs. Despite his opinionated manner about subjects from religion and euthanasia to the teaching of science and the existence of ghosts, one thing is clear – he's not a bigot. "Religion, memes, the existence of UFOs – they're all sets of beliefs, and if you can understand why people want or need to believe them, then that's fine. That's what we're interested in: why people believe, rather than whether what they believe is true."

Despite the book being described in UK newspaper *The Observer* as "singularly welcome to those of us who

BACKGROUND

Lewis Wolpert

Lewis Wolpert is an author, broadcaster and professor of biology as applied to medicine in the department of anatomy and developmental biology at University College London, UK, where his research interests lie in the mechanisms involved in the development of the embryo.

Born in Johannesburg in 1929, he originally trained as a civil engineer but changed to research in cell and developmental biology at King's College London in 1955. In 1966 he was appointed professor of biology at the Middlesex Hospital Medical School. He was made a Fellow of the Royal Society in 1980 and awarded the Commander of the British Empire in 1990.

Currently, he and his research group are working on several questions. Together with Michel Kerszberg from the Pasteur Institute in Paris, France, they are investigating the extent to which diffusion determines the spatial organisation of the developing embryo. Can cells reliably recognise gradients of chemical concentrations and use this to lay down the pattern for the organism, e.g. the vertebrate limb or the wing of a fly?

Another field of interest for Lewis is the evolution of development itself. He and his co-workers have proposed a new model for the origin of multicellular organisms: in hard times the cells could eat each other, giving multicellular organisms an advantage over their unicellular competitors. He is also interested in the evolution of larval forms and the origin of gastrulation (when the surface of the embryonic ball of cells folds in on itself, giving a multilayered organism). "It is not birth, marriage, or death, but gastrulation, which is truly the most important time in your life," he is reported to have said.

He is also interested in the evolutionary psychology of depression. If sadness is an adaptive emotion (i.e. can be beneficial) and depression is pathological sadness, perhaps the negativity of depressed patients is a way of rationalising that pathological sadness?

Outside the laboratory, Lewis has presented science on both radio and TV, and stood for five years as chairman of the UK Committee for the Public Understanding of Science. He wrote about his experience of clinical depression in his book *Malignant Sadness: The Anatomy of Depression*, which was published by Faber in 1999. This was the basis for a series of programmes on UK television called *A Living Hell*, which Lewis presented himself.

His other books include *A Passion for Science* and *Passionate Minds*, both with Alison Richards, which are compilations of interviews with scientists, published by Oxford University Press in 1988 and 1997, respectively. *The Triumph of the Embryo* was published by Oxford University Press in 1991, and *The Unnatural Nature of Science* was published by Faber in 1992. *Principles of Development*, of which he is principal author, was published by Faber Current Biology in 1998. From 2001-2005, he was a regular contributor to the science and technology section of the UK newspaper, *The Independent*.

His latest book is *Six Impossible Things Before Breakfast: The Evolutionary Origins of Belief*, published in 2006. He was made a Fellow of the Royal Society of Literature in 1999.

have suffered many dreary years having God's message stuffed down our throats by the religious self-righteous", Professor Wolpert doesn't take the church-bashing stance that someone like Richard Dawkins upholds. *Six Impossible Things Before Breakfast* concludes that humans alone have a unique ability to comprehend the concept of cause and effect. This allows us to think about the world in abstract terms, design and use tools, hold beliefs and practice science, and drives us to find explanations for everything. Every culture has its set of beliefs about the cause of things, usually invoking gods who would be able to set events in motion.

"I'm not against religion," he explains. "Invoking God to explain evolution and the origin of life doesn't help one iota, but it makes people feel better. That's the point, you see? I'm only against religion when it starts to interfere with other things, like telling people they can't use contraception, or banning abortion, or stopping euthanasia. These bloody religious nuts in Parliament! Nobody else, other than the Catholic Church, ever went around saying a fertilised egg was a human being, and now people are starting to believe it. Authority plays a big role in our beliefs."

He's currently working on a new book about the cell, aimed at the

general public, and is the author of another basic science text, *The Triumph of the Embryo*.

As a proponent of the clear and transparent communication of science, Professor Wolpert has a lot to say about how science is taught in schools. "In Britain, at least, they have the lunatic idea that children should be discussing the ethics of science. How can you discuss stem cells and cloning if you know nothing about developmental biology? It's mad beyond words. It's moral masturbation, to borrow a phrase from Mark Twain!

"What children should be taught is something about the processes of science… how discoveries were actually made, the history of things, rather than being presented with a fait accompli in a textbook. They should be taught about clinical trials, peer review, and what it's all about to be a scientist, and above all, that science is a group activity, where numerous scientists try to convince each other of their theories; if history were re-run, the discoveries would remain the same but the names would not. Science teaching is very lacking at the moment.

"It would also be helpful for children to be told that science goes against common sense. It's not common sense to think that Earth orbits the Sun and not the other way around. Science is counter-intuitive, and they need to learn that, and that science is hard. It'll make them feel better."

About some things he concedes defeat himself. "This molecular stuff that you're all doing at the European Molecular Biology Laboratory, well, I'm out of my depth. That's real molecular biology, hunting for enhancers and hybrids and DNA searching… I can't do that… I don't understand it, you know," he confides in a stage whisper. "When you look at the journals now, you can fall asleep, it's all so detailed. Unless it's the system you're actually working on, you couldn't give a hoot about it, don't you agree? They're very boring, the journals! I said to one of the editors – I won't say which one – Jim, I said, 'I just throw almost all of it away! Detail! Infinite detail!' Not unimportant… but who cares? In the old days we were looking for general principles. It was great fun. Now it's very different."

Our time is up, but we could have gone on. As Professor Wolpert takes his leave, with a twinkling smile, he adds: "You know, the nice thing about being old is that you can say exactly what you like, and be as badly behaved as you like."

REVIEW

Readers who are not familiar with the work of Lewis Wolpert should read his biographical summary first and then read the interview to find out something about the opinions of this eminent scientist and science communicator. The provocative comments on science education for the real world, communication, religious beliefs and ethics should inspire debate about syllabus review and for classroom use.

This article introduces the human element of science, in this case embryology. It is applicable to many topics, for example the philosophy of science, science and ethics, science communication, science and religion or science in the future. It could be used in a debate on the differences between science and pseudoscience or as the basis of a discussion about the opinions of one scientist.

Possible comprehension questions include:

1. What are the main conclusions about humans that Lewis Wolpert reaches in his book Six *Impossible Things Before Breakfast*?
2. Do you agree with the author's assertion about Lewis Wolpert that "one thing is clear – he's not a bigot"? Give reasons for your answer.
3. In what ways does Lewis Wolpert think science education could be improved?
4. "You know, the nice thing about being old is that you can say exactly what you like, and be as badly behaved as you like." Do you agree with this statement? If everyone shared this opinion, would life become very difficult for scientists trying to help the ageing population?

Marie Walsh, Republic of Ireland

Note from the editor

What do you think about Lewis Wolpert's opinions? For example, do you agree that children are not knowledgeable enough to discuss the ethics of science? Do you think science has become more detailed and less interesting? Why not leave your comments online: www.scienceinschool.org

Resources

Lewis Wolpert's 2002 essay on the responsibility of scientists in society is available on the Nobel Prize website: http://nobelprize.org/nobel_prizes/medicine/articles/wolpert/

Mercury: a poisonous solution

Image courtesy of Andraz Cerar / iStockphoto

Sigrid Griet Eeckhout from the European Synchrotron Radiation Facility in Grenoble, France, investigates what determines the toxicity of mercury compounds – and how X-ray light is helping to solve the mystery.

Metals comprise about 75% of known elements. They can form alloys with each other and with non-metals and are widely used, for example, in cars, computers, highways and bridges. Civilisation was founded upon the metals of antiquity, namely gold, silver, copper, mercury, tin, iron and lead. Gold was first discovered around 6000 BC and mercury has been found in tombs dating back to 1600 BC. The ancient Greeks used mercury in ointments; the Romans used it in cosmetics. Since the beginning of the Industrial Age, metals have slowly entered into the environment, accumulating in soils, sediments and surface waters.

Small quantities of many trace metal elements are of ecological interest due to their necessity as nutrients or their toxicity as pollutants. Nutrient trace elements include magnesium, manganese, copper and zinc, some of which become toxic at high concentrations. Others, including the heavy elements such as mercury, cadmium, arsenic and lead, are of environmental concern due to their high toxicity and widespread industrial use. Mercury is present in the environment at concentrations of less than 0.1%, but is extremely toxic because it binds to the functional groups of various enzymes and proteins, and so inhibits or negatively affects key organic functions. Mercury is used to extract gold, and is found in thermometers, dental amalgam, thermostats, relays, switches, barometers, vacuum gauges and other scientific apparatus, although concerns about its toxicity have led to mercury thermometers being largely phased out in clinical environments.

Mercury is a trace element with both natural (native metal, Hg, and cinnabar, HgS) and anthropogenic (man-made) sources. Anthropogenic sources include agricultural (fungicides) and metallurgic (mining and smelting) uses, plastics industries, refuse disposal and landfills. Most of the mercury in soils, sediments and surface waters comes from the combustion of fossil fuels. This volatile metal can travel over long distances in its gaseous form or by attaching itself to small dust particles. Gaseous mercury can remain in the atmosphere for up to one year before being deposited onto the earth via rainfall.

Once deposited, metals and metalloids (elements with properties of both metals and non-metals) undergo dynamic biogeochemical processes in the near-surface environment, which is a mixture of rocks, soil, water, air and living organisms. Biogeochemical processes affect the metal's atomic form (speciation), and therefore its solubility, mobility, bioavailability and toxicity. As a rule, the less soluble a chemical species is, the less mobile and less toxic it is. Therefore, transforming soluble species to sparingly soluble forms, either *in situ* or in landfills after excavation, can lessen the impact of hazardous heavy metals on living organisms and the environment.

Micro-organisms can transform metals by means of oxidation-reduction or other chemical reactions. One example is another heavy metal, hexavalent chromium, Cr(VI), which is a very dangerous, water-soluble form of chromium. Ingesting large amounts of Cr(VI) can cause stomach upsets and ulcers, convulsions, kidney and liver damage, various forms of cancer and even death. Trivalent chromium, or Cr(III), on the other hand, is an essential trace nutrient that helps the body to use sugar, protein and fat. Cr(III) is insoluble in water. Reducing Cr(VI) to Cr(III) using micro-organisms makes it insoluble in water, hence limiting its availability and toxicity [w1].

This type of transformation can also occur the other way around. In soils,

Image courtesy of Klaas Lingbeek-van Kranen / iStockphoto

X-ray techniques (for advanced readers)

For a simple explanation of these two techniques, see Capellas (2007).

X-ray absorption spectroscopy (XAS)

X-rays are light with energies ranging from ~500 electron volts (eV) to 500 keV (1 keV is equivalent to 1000 eV).

When you perform an X-ray absorption spectroscopy (XAS) measurement, you vary the energy of the incident X-rays. When the energy of the incident X-ray equals the binding energy of a core-level electron (usually 1*s* electron), the electron is ejected from the atom. The corresponding X-ray absorption spectrum shows a sharp rise, also known as the absorption edge (Figure 1). The position of the absorption edge is also determined by the formal oxidation state. For instance, the absorption edge of Cr(VI) occurs at higher energy than the one for Cr(III). The outgoing electron interacts with the surrounding atoms, thus creating oscillations in the spectrum beyond the edge. These oscillations provide information on the neighbouring atoms.

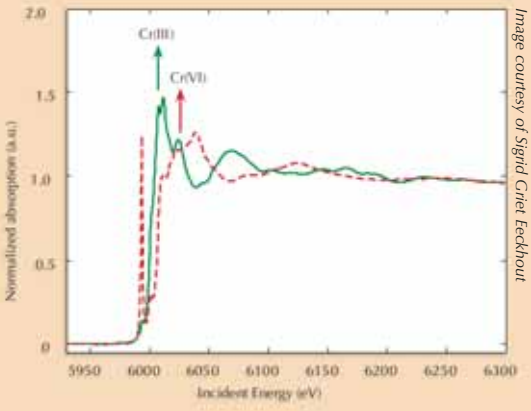

Image courtesy of Sigrid Griet Eeckhout

Figure 1: X-ray absorption spectrum of a Cr(III) sample (green) and Cr(VI) sample (red). The arrow shows the position of the absorption edge. au= arbitrary unit

Since every atom has core-level electrons with well-defined characteristic binding energies, the XAS technique is element-specific. This means that you can study a chosen element (e.g., mercury) inside heterogeneous matter, such as a soil consisting of organic matter, microbes, minerals, metals and so forth.

The XAS spectrum is sensitive to the formal oxidation state (which reflects the number of electrons available for binding to other atoms), the co-ordination chemistry (e.g., octahedral or tetrahedral co-ordination), and the distances, co-ordination number and species of the atoms immediately surrounding the selected element.

X-ray fluorescence

The well-defined characteristic binding energies of an element are used as a fingerprint in the X-ray fluorescence technique. When you change the energy and you observe a peak at a particular energy, you know that the respective element is present (Figure 2).

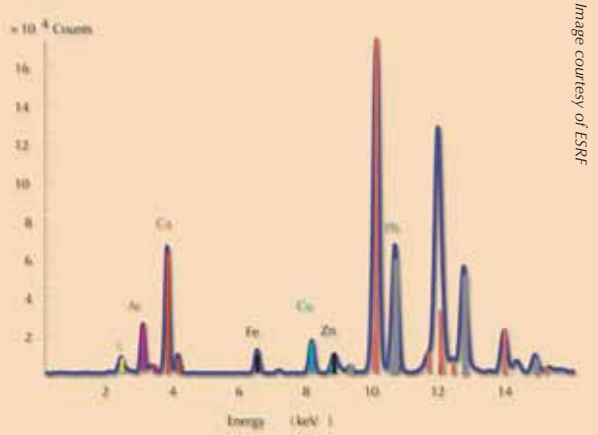

Image courtesy of ESRF

Figure 2: X-ray fluorescence spectrum showing the presence of different elements

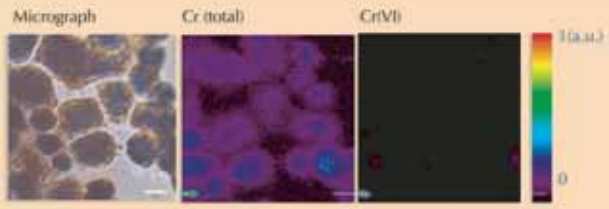

Figure 3: Micrograph of a soil sample (left), distribution of Cr(total) within the sample (middle) and of the toxic Cr(VI) (right). The colour scale reflects the concentration. au= arbitrary unit

BACKGROUND

microscopic organisms can transform the less poisonous, inorganic (non-carbon-containing) form of mercury into a poisonous, organic (carbon-containing) form. In this reaction, called methylation, an atom, usually hydrogen, is replaced by a methyl group ($-CH_3$). As a positively charged ion, methylmercury (CH_3Hg^+) readily combines with anions such as chloride (Cl^-), hydroxide (OH^-) or nitrate (NO_3^-).

Transforming mercury to a methylmercury compound produces a metal form that becomes lipophilic (i.e. can be dissolved in fat) and can thus pass through cell membranes, the blood-brain barrier and placenta. In this organic form it can enter the food chain and accumulate in fish, fish-eating animals and humans. In other words, the less poisonous, inorganic form of mercury, which would normally be safely excreted by organisms, is transformed into an organic form, which becomes available and poisonous to organisms.

So how does the less poisonous, inorganic form of mercury transform into a poisonous, organic form? Researchers from Sweden and the USA used synchrotron light at the European Synchrotron Radiation Facility (ESRF) to determine the speciation of mercury in natural organic matter at environmentally relevant concentrations, using X-ray absorption spectroscopy (XAS) techniques (see box).

They found that mercury in natural soil organic matter binds to two reduced organic sulphur groups, mainly thiols (-SH). The thiol group is the sulphur equivalent of the hydroxyl group (-OH) found in alcohols. Laboratory experiments indicate that neutral, inorganic mercury-thiol and mercury-sulphur species in solution determine the rates of methylation. This means that the binding of mercury to thiol groups in natural organic matter makes the element available for the methylating bacteria in the environment. Furthermore, since these mercury-thiol complexes are soluble, they can be mobilised and transported to places where methylating bacteria live.

The next step is to identify the role that different sulphur-containing molecules frequently found in soil organic matter play in the transformation of mercury to its poisonous form.

The use of XAS to characterise the speciation of mercury is quite new. It is a big step forward compared with earlier wet (liquid phase) biochemical methods and it is the first time that such low concentrations of mercury (0.1 gram of mercury per 1000 grams of soil) have been measured.

Deciphering the chemistry of trace metals and metalloids in the environment is difficult because natural materials are complex in composition and structure. With the advent of advanced synchrotron light sources, which provide techniques using intense X-rays and a greater spatial resolution, scientists are able to determine the forms and distributions of metals in heterogeneous systems such as soils, plants and mineral-microbe-metal interactions. To do this, three micro-analytical techniques can be applied together. The micro-X-ray fluorescence technique (see box) can map the distributions of the different metals and help identify metal associations (Figure 3). Then, the species hosting the metal (such as clay or mineral) is determined at points of interest on the chemical maps by micro-X-ray diffraction and micro-XAS. The diffraction pattern shows the inner structure of the material. The proportion of each species in the bulk material is further calculated by linear combination of the different component species (in other words, by adding up the amounts on the spectra).

In conclusion, X-ray techniques using synchrotron light are extremely valuable in determining the forms and distributions of metals in soils, sediments and surface waters. Once we know the speciation of the metal, we can look into how to limit its solubility and bioavailability. As the world's population and economies continue to grow, especially in developing countries, the need for metals will increase but their use will amplify the potential for soil and water contamination. Since this could have serious implications for human health and environmental quality, environmental studies are extremely important.

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This paper was chosen from more than 1100 articles in *Environmental Science and Technology* as the top environmental science contribution from 2006.

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w1 – For a discussion of chromium with reference to the film *Erin Brockovich*, see:

Stevens J (2007) *Erin Brockovich*. *Science in School* **4**: 67-69. www.scienceinschool.org/2007/issue4/erinbrockovich/

Resources

A short explanation of the use of synchrotron light at ESRF is available here: www.scienceinschool.org/2006/issue1/maryrose#esrf

For information about ESRF, see: www.esrf.eu

Fighting an old enemy: tuberculosis

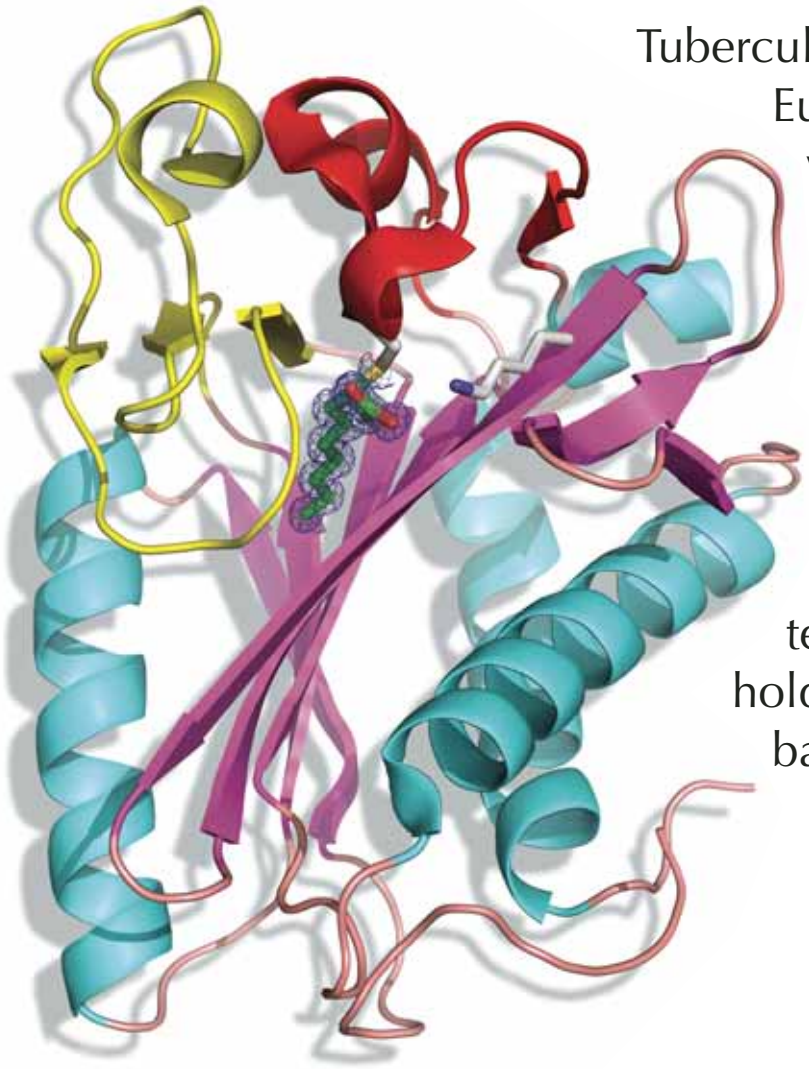

Image courtesy of Qingjun Ma, EMBL

LipB: this enzyme is essential for the tuberculosis bacterium

Tuberculosis isn't something Europeans normally worry about. But the disease is re-emerging and is resistant to many of our drugs. **Claire Ainsworth** describes how Matthias Wilmanns and his team are trying to hold the disease back.

"Che gelida manina" – *How cold your little hand is*. Rodolfo, an impoverished artist in Puccini's opera, *La Bohème*, sings a love song to Mimi, a girl he has just met. The two characters meet in a garret in 1830s Paris, enchanting the opera's audience with their touching love story. But the relationship is doomed: Mimi has tuberculosis and gradually perishes, coughing and cold. In the final scene, when a grief-stricken Rodolfo casts himself over Mimi's deathbed, crying out her name, there is scarcely a dry eye in the house.

Even so, *La Bohème*, written in the 1890s, has lost some of its impact for a modern European audience. Much as we might sympathise with poor Rodolfo, the idea of someone actually dying from tuberculosis (TB) seems a little unreal. In our modern age of

vaccines and antibiotics, it feels like a disease from a bygone age. Indeed, in the 1950s and 1960s, such was the success of antibiotic therapy that many experts predicted that TB would be eradicated worldwide.

But two things have weakened our therapeutic defences against TB. The first was that patients often failed to complete their courses of antibiotics. The second was the arrival of the global HIV epidemic, which decimated the immune systems of millions worldwide. As a result, TB had the opportunity to develop drug resistance, and did so with alarming rapidity.

Soon, strains of the bacterium appeared that resisted one or more antibiotics. Now, a highly lethal form, dubbed XDR-TB for 'extremely drug-resistant TB', has emerged, which resists nearly all antibiotics – one strain has been found that resists them all. If it became widespread, such a strain could render doctors as helpless to treat patients as they were in the 1800s. "It's alarming," says Matthias Wilmanns, head of the European Molecular Biology Laboratory (EMBL) in Hamburg, Germany. "The emergence of the XDR-TB strain is a major problem."

Matthias heads a project that forms part of biomedical science's counter-offensive against TB. The X-MTB project is run by a consortium of academic and industrial institutions in Germany, and is co-ordinated by EMBL Hamburg. It aims to discover the structures of TB proteins that are promising candidates as drug targets. And new drugs are desperately needed; no new therapies to tackle TB have been brought to the clinic for more than 40 years.

Matthias's team is part of a global effort to apply structural genomics – the science of determining the structure of every protein encoded in an organism's genome – to *Mycobacterium tuberculosis*, the bacterium that causes TB. Whereas the largest consortium, the US TB Structural Genomics Consortium, has taken a broad approach and is scanning the entire genome, Matthias and his collaborators have focused their efforts on finding structures for proteins that have already been singled out as promising drug targets. Knowing a protein's structure is invaluable to drug developers, because they can design drugs to interact with the key working parts of the protein.

The X-MTB project began in 2003, funded by the German Ministry for Science and Education. With the help of consortium member Stefan Kaufmann of the Max-Planck Institute of Infection Biology, the team selected 242 proteins to study. Of particular interest were proteins that are involved in TB's ability to survive in the body for decades.

About one-third of the world's population is infected with TB, with the majority harbouring dormant infections that are kept in check by the body's immune system. As many as three million people die each year from acute infection or dormant disease that has become reactivated. This dormancy or 'latency' is a particular problem because most antibiotics only kill bacterial cells that are actively dividing. So finding drugs that inhibit TB's long-term survival in the body is a key goal.

To date, the X-MTB project has been remarkably successful. Thanks to its experimental and technological setup, the team has disproved a long-standing dogma in X-ray crystallography that it was only possible to attain a structure determination efficiency of 10 percent. "We have shown that it is possible to get about a third of all targets selected, purified and crystallised," says Matthias.

Key to this success was the open-access, high-throughput crystallisation facility at EMBL Hamburg, coupled with the innovative system the team used to produce the proteins. "The conventional wisdom was that it was very difficult to get structures," says Matthias. "With this project, we have been able to show that if you produce a good pipeline, you can get almost too many structures."

Thanks to these efforts, the X-MTB team has produced structures for 35 key TB proteins so far. The function of many of these was unknown, but the consortium has already made good progress in working out what some of them do. In a number of cases, the

Image courtesy of EMBL Photolab

Matthias Wilmanns and Paul Tucker

structure has actually helped to reveal the function of the protein.

One such case is LipB, an enzyme involved in producing the co-factors TB needs to grow and survive. Stefan singled it out as being a key target when his team found the enzyme was extremely active in infected human cells, especially those infected with multidrug-resistant TB. So Matthias's group set to work making and studying crystals and determined its structure. This revealed, unexpectedly, that there was another small molecule called decanoic acid attached to the enzyme. Further studies showed that this formed part of LipB's active site and allowed Matthias and his team to deduce what kind of chemical reactions took place there, and from this, to work out what the enzyme does. "It's a kind of classical functional discovery, based on structure," says Matthias. Further work will be needed to see whether it is possible to block this process with drugs, he adds.

Other important avenues of attack include the sensing systems that TB uses to probe and respond to its environment. Such systems are poorly understood. One, called the PrrA-PrrB system, helps the bacterium replicate and survive inside macrophages, the immune cells it infects, and is an obvious target for drug therapy. Last year, EMBL Hamburg scientists, led by group leader Paul Tucker, published the structures of the two proteins, PrrA and PrrB, that constitute this system. This work revealed how the structures of the proteins change as they interact – information that will prove invaluable for scientists designing chemicals to inhibit that interaction.

But such discoveries will not make a difference unless ways can be found to translate them into therapies. Historically, the pharmaceutical industry has not been terribly interested in developing TB drugs as it is perceived as a disease of developing countries – countries that are too poor to buy enough drugs to allow companies to recoup the considerable costs of developing them, let alone to make a profit.

Now, says Matthias, there are encouraging signs that things might be changing. He is involved in efforts to find new ways of funding TB drug development, such as securing European Union funding and possibly collaborating with labs in India and other developing nations. Even pharmaceutical companies are starting to show more interest, he says, now that China and India are set to become major economic powers.

Because TB does not respect national borders, it would be a mistake for developed countries to ignore the threat. TB is a global disease that requires global action, lest it return, incurable, and make the sad tale of Mimi and Rodolfo strike a chord with Western audiences once more.

Image courtesy of EMBL Photolab

Some of the equipment used to study the tuberculosis bacterium

Resources

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REVIEW

The article provides a good account of the recent developments regarding tuberculosis (TB), including details of the re-emergence of the disease as a major threat to humanity, as well as the global efforts underway to find a cure. Apart from providing scientific information on the strategies and methodologies that biologists use to tackle TB, the article offers the opportunity to discuss:

- How one disease can have a drastic effect on the evolution of another disease.
- How modern science recognises no geographical borders, and therefore, solutions to scientific problems are often found as a result of collaborations between scientists from around the world.
- How different scientific groups adopt different research strategies in their effort to discover important information that will help fight a disease.
- The criteria that companies use when deciding whether or not to fund the research needed to find a cure for a specific disease.

Michalis Hadjimarcou, Cyprus

The great migration

Why are cells like wildebeest? **Laura Spinney** investigates the migration of cells and the formation of organs, using the tiny and transparent zebrafish.

Darren Gilmour, Gillaume Valentin and Petra Haas

Image courtesy of EMBL Photolab

Every year in May, vast herds of wildebeest move from the dry East African plains towards the forests in search of food. They return in November, when the short rains come to water the plain, thus completing their annual migration. Each wildebeest behaves according to its instinct for survival, which tends to push it towards the company of other wildebeest. Once a herd has formed, it behaves as a new unit, with its own rules. Cells have a similar herd instinct. They are genetically programmed to work with other cells, but there is no strict set of instructions that determines the precise behaviour of every cell in the group. "We realise now that many of the events that occur after fertilisation are somehow free and plastic, and based on self-organising principles," says Darren Gilmour from the European Molecular Biology Laboratory in Heidelberg, Germany.

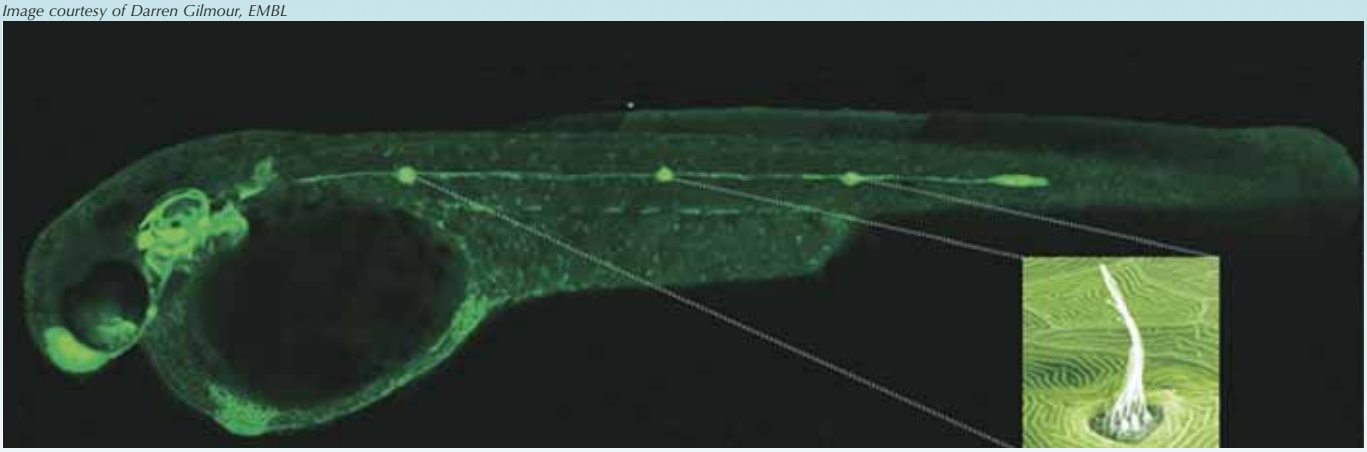
As a developmental biologist, Darren would like to understand those principles, because the mass migration of cells gives rise to the sculpting of intricate and complex systems such as blood vessels and the respiratory system. Since the cells within these migrating groups appear to be very similar in terms of the genes they express, knocking out (inactivating) or knocking down (reducing the activity of) single genes tends to block migration in the whole group. He has to take a more subtle approach, finding ways to disrupt the cells' social networks, and looking at how that affects their ability to migrate and build organs. "It's sociology, basically," he says. "We want to know who tells who what to do, and how."

Darren's group explores these principles in the lateral line primordium of the zebrafish, a transient structure that can only be seen in early development, and whose function is to equip the embryonic fish with hair cell organs – sensory organs which enable it to detect the presence of other fish based on minute changes in water pressure. "The primordium is a cluster of more than 100 cells which creeps along under the skin of the animal, like a slug," Darren explains. "It starts behind the ear, moving towards the tail, and as it goes it leaves a trail about two cells thick, punctuated by little clusters of cells that will eventually become hair cell organs."[w1]

As model systems go, the zebrafish is an answer to biologists' prayers, as it is transparent and therefore amenable to live imaging of cells which have been labelled with fluorescent proteins. The lateral line system is relatively easy to engineer genetically, and it is also a gift to those interested in cell migration, because it makes use of a signalling pathway that is very important in human health, and therefore well studied. A chemical signal called SDF1, the zebrafish equivalent of a signal also found in humans, causes a range of changes in the primordium cells. It does so by binding to a receptor, called Cxcr4b, that the cells carry on their exterior. Cxcr4b is a protein which sits across the cell membrane and, in humans, is necessary for HIV infection. As well as playing a role in normal development, it is also implicated in metastasis, or the spread of tumour cells.

In a zebrafish mutant with reduced Cxcr4b signalling, Darren's group found that the primordium loses all directionality – there is no forward movement and no slug trail left behind. Moreover, the static structure seems to stop producing cell clusters, as if it has to move and expel those clusters in order to generate more. One of the most interesting features of the mutant, however, is that even though the primordium's migration is stalled, a closer look reveals that its cells are still moving, tumbling over one another in an apparently random fashion.[w1] "It looks as if the cells are confused," says Darren. "Like monkeys in a sack." And that, he adds, is

Image courtesy of Darren Gilmour, EMBL



The microscope image of a transparent zebrafish embryo shows the lateral line primordium under the skin of the animal. It starts behind the ear, moving towards the tail, and leaves a trail about two cells thick, punctuated by little clusters of cells that will eventually become hair cell organs as shown in the box to the right.

the key to how the system works.

To find out if they could rescue the mutant and restore forward motion to the primordium, the researchers created a genetic mosaic by transplanting some normal, 'seeing' cells, which expressed the Cxcr4b receptor and could therefore respond to SDF1a, into the otherwise 'blind' mutant tissue. The normal and mutant cells were tagged with red and green fluorescent proteins respectively, so that Darren and his team could track the cells' movements. Very quickly, through the tumbling motion of the cells in the primordium, the seeing cells found their way to the front, and the primordium once again moved forward.[w1]

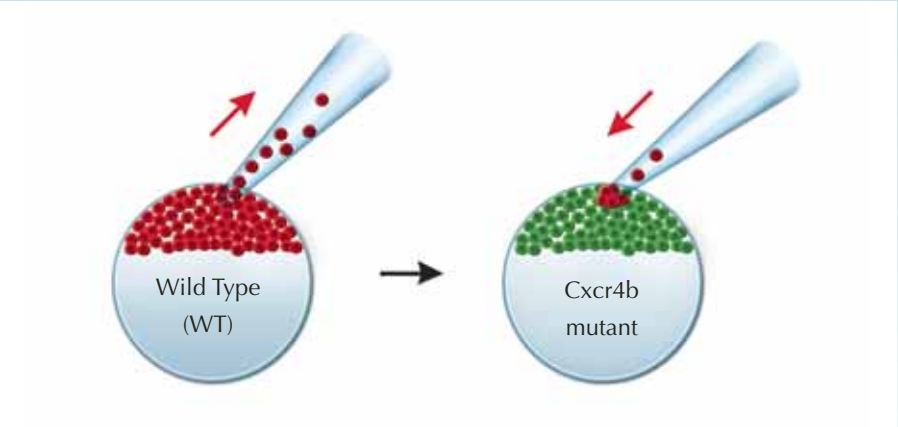
What was strange about these experiments, says Darren, was that not all of the sensing, Cxcr4b-expressing cells found their way to the front. As soon as some were there, the random tumbling motion stopped, the primordium moved forward, and those sensing cells that had not made it to the front remained where they were –"as if frozen in ice". "We think that the system finds strength in instability," he says. "It rolls around and makes random movements, and in doing so it ensures that the cells that can lead get into the position where they do lead. Whenever they pull, the others freeze."

But if not all sensing cells become leaders, what defines a leader? Whatever it is, it doesn't appear to be differences in the activity of genes. "It's not the genes that say, you're the leader, you're the follower," Darren says. "Rather the genes equip all the cells with the receptor, and after that it's a case of 'fight amongst yourselves'." He and his co-worker Petra Haas think leadership is more likely to be defined by the unstable nature of the migrating group. The random tumbling of the cells gives some a temporary bias over others, in terms of their proximity to the source of the signal. They then latch on to it, and if they are able to maintain the activation of their receptor, they move to the front. However, that is not the end of the story, by any means.

One theory of cell migration is that the leading cells somehow carry the followers, which passively allow themselves to be swept along. However Darren is sceptical of what he calls the hitchhiker model. He prefers to think that the leaders point the others in the right direction, and the primordium is internally organised such that those others then actively follow. And he believes that a similar principle will apply to the development of all organs. "If you look at the branching of blood vessels, I predict that there will be a small number of cells at the tip which sense the signals from the environment, and through cell-cell interactions they somehow influence the behaviour of the others," he says. "The others don't have to see the world." He gives the analogy of a falcon ambushing a flock of starlings. Not all the starlings have to see the falcon in order to respond appropriately by fleeing – they only have to detect the panicked response of their neighbours.

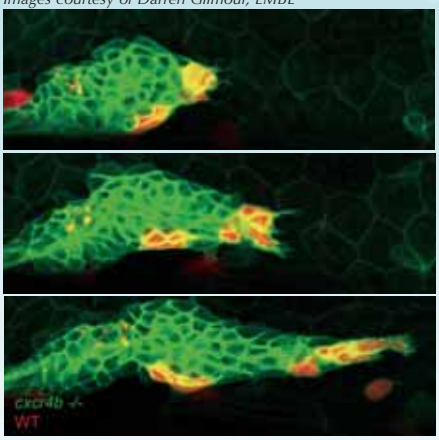
So far so good, but the story gets more complicated still, because it turns out that not all the followers behave in the same way. In their live-imaging experiments, Darren and his team have noticed that as the front of the primordium noses forward, the cells in the rear slow down, causing the tissue to stretch. PhD student Guillaume Valentin has now identified another receptor, expressed by those rear cells, which also responds to SDF1a, but which triggers a different kind of behaviour to that elicited by the SDF1a/Cxcr4b pathway – giving the cells at the back a certain degree of independence from the Cxcr4b-expressing leader cells.

Image courtesy of Petra Riedinger, EMBL



A genetic mosaic, is made by taking cells expressing the Cxcr4b receptor (red) out of a wild-type embryo and transplanting them into a mutant lacking functional Cxcr4b (green).

Images courtesy of Darren Gilmour, EMBL



In a genetic mosaic, wild-type cells (red) find their way to the tip of the primordium and project in the direction of migration, pulling mutant cells (green) with them.

When the primordium is moving forwards, depositing cell clusters at the back, the general motion of cells through the structure is backwards. As cells fall back inside it, Darren suspects they may switch on this second receptor. Perhaps, he speculates, the combination of the two cell populations expressing different receptors gives rise to a kind of caterpillar motion, in which the front and back of the primordium move forward alternately. Some evidence for this comes from experiments with zebrafish embryos in which the activity of the second receptor is reduced and the second half of that coordinated movement is lacking. "The leading edge pulls and pulls, but the back doesn't come with it, so eventually it gives up and tumbles back," he says.

If he is correct, the new findings raise questions about how dynamic information is transmitted through large groups of cells. It becomes necessary to understand not only signalling, but also the propagation of forces through cell populations, in terms of cell-cell interactions. This is where Darren now hopes to take his research. For now, though, he is excited by the discovery of a second SDF1a receptor in the zebrafish primordium. "The idea that the cells inside can also sense is entirely novel," he says. Whether the same principle applies to wildebeest is another matter.

REVIEW

I was delighted to be asked to review this paper, as I might not have read it so carefully otherwise. It is so well written, with many colourful analogies, such as linking the migration of African herd animals with the migration of cells in developing organisms. Not only is the biology fascinating, including signal proteins, HIV infection, zebra fish, cancer cells and mutant 'blind' cells, but so is the description of the research team's methodology, which reads like a detective story: coming up with theories, rejecting models, moving onto new ideas and testing them.

There is a lot of interest in this article for most biology teachers. It could also make a really good comprehension exercise or provide supplementary material for biology students aged 16 or more. Alternatively, it could be used in a discussion of embryology, vertebrate development, genetic engineering, communication between cells as opposed to communication between organisms, signal proteins, cancer, mutations, the steps in scientific investigations or modelling theories.

Sue Howarth, UK

Web references

w1 – Videos of the wildtype, mutant and mosaic primordia can be downloaded here: www.scienceinschool.org/issue7/migration

Resources

Haas P, Gilmour D (2006) Chemokine signaling mediates self-organizing tissue migration in the zebrafish lateral line. *Developmental Cell* **10**: 673-680. doi: 10.1016/j.devcel.2006.02.019

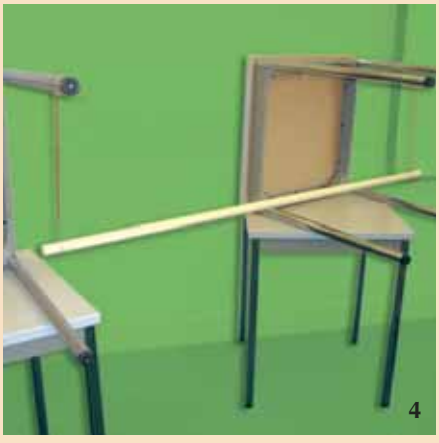
What happens next? A teaching strategy to get students of all ages talking

David Featonby, from the UK, presents some simple demonstrations to get your students thinking about scientific principles.

1


2


3


4


5


6

Images courtesy of David Featonby

Very often, meaningful discussion of science is limited to a small number of vocal students in a class. Here is a great way to get everyone in the class talking and thinking about science principles.

The following approach not only lends itself to groups of all ages and abilities, but has opened up discussions between children who normally make few positive contributions to lessons. Furthermore, it can be applied in a variety of different cultures and educational systems, so could be used in different countries. When the approach has been tried as a full lesson, teachers have been most enthusiastic about the effect that it has had on their students, and the development of their thinking skills.

David Featonby with a group of four-year-olds at Newburn Manor Nursery School, UK, discussing how the small balloon inflates the large one

Image courtesy of David Featonby

1 What happens to the egg when the bottle is knocked to the left?

2 What happens to the small beanbags when the board below is pushed sharply to the left?

3 What happens when you try and fill the second almost-full conical beaker with the water from the first beaker?

4 What happens to the broomstick (suspended on two threads) when it is struck with a second broomstick?

5 One ice cube on a pan and one on a plastic box; which will melt first?

6 What happens to the teddy bear when the truck crashes into the box?

The idea is to present to the class a series of easily demonstrated experiments, all with slightly unusual outcomes, each one presenting opportunities for discussion. These experiments are sometimes referred to as discrepant events: the scientifically slightly unexpected. One approach is to arrange the students in small groups to compete with each other to predict the correct outcome and give the correct explanation for the situation. It provides an ideal alternative to the end-of-term trivia quiz! Groups are challenged to reach a consensus as to what might happen, having been given a series of possible outcomes. Alternatively these ideas can be used at the beginning or end of lessons over a whole year, so students can look forward to finding out 'what happens next' each week. The strategy could also be used for a revision session.

Younger children can be presented with simple 'either/or' experiments whereas older children can be offered more complicated situations that require deeper understanding. The strategy has been used successfully with students aged 5-18, and in training sessions for teachers. Younger children particularly like ideas they can take home and try out.

It is important that both students and teachers are able to understand what is happening; although the ideas should be interesting, experiments should not be too complex. Science is not about mystery and magic, but about seeing, investigating, believing and understanding. Overleaf are some of the experiments that I have used. The examples illustrate mostly physics phenomena, but the strategy would work equally well with chemistry, biology or other science subjects.

With suitable questions, some of the later examples can also be used with younger children. I hope the ideas spark your imagination, and help you think of other experiments that lend themselves to this approach.

A much fuller list of suggestions is available online[w1].

Readers are invited to submit their own additions and make comments on the *Science in School* website[w2].

Web references

w1 – For a fuller list of experiment suggestions, see www.scienceonstage2.co.uk

w2 – Readers are invited to submit their own additions and make comments in the new *Science in School* forum: www.scienceinschool.org/forum/whathappens

w3 – Science on Stage is a series of international teaching festivals organised by the EIROforum, who also publish *Science in School*: www.scienceonstage.net

Example experiments

Ideas for students aged 5-11 (either/or situations)

Idea	Question	Answer
Dropping balls		
Drop a golf ball and a table-tennis ball simultaneously.	Will the balls land together or will one land before the other?	Yes The balls land together. Air resistance is not significant at low speeds.
Floating oranges		
A whole orange floats in water. Peel the orange and put it back in the water.	Will the orange sink?	Yes The skin acts as a buoyancy aid (like armbands when swimming).
Melting ice		
Put an ice cube on a metal frying pan and another on a plastic box. The box feels warm, whereas the pan feels cold.	Will the ice on the plastic box melt first?	No The ice on the metal pan (a good conductor) can obtain heat from the pan to melt it.

Ideas for students aged 11+ (offer several solutions)

Idea	Question	Answer
Sultanas in lemonade		
Put some sultanas in a newly opened bottle (or freshly poured glass) of lemonade.	What will happen to the sultanas? A. They will float. B. They will sink. C. They will dissolve. D. Something else.	D. The sultanas first sink, then bubbles attach to them so they rise again. The bubbles pop at the liquid's surface, so the sultanas sink again. This process repeats.
Basketball and tennis ball		
When you drop the basketball, it bounces. When you drop the tennis ball, it bounces.	If you place the tennis ball on top of the basketball and drop the two together, how high will the tennis ball bounce? A. It will bounce as high as before. B. It will bounce higher than before. C. It will hardly bounce. D. Something else.	B. When you hit a ball with a bat, the ball goes further if you move the bat towards the ball. Similarly, the basketball is moving upwards after it bounces, towards the tennis ball, so the tennis ball bounces higher.
Burning a candle at both ends		
Balance a candle (with open wick at each end) with a needle through its centre. One end will fall as the candle will not be perfectly balanced.	A. The candle burns but the high end stays high. B. As the candle burns the lower end eventually rises. C. The lower end rises, then falls, then rises, and so on. D. Something else.	C. As the lower end burns, more wax melts and drops off, until that end of the candle rises. The same thing will then happen to the other end. The falling wax causes the candle to oscillate quite rapidly.

CLASSROOM ACTIVITY

Falling candle		
Place a lit tea-light (small, stable candle) in a glass jar.	Drop the jar and then catch it. What happens to the candle flame? A. It goes out. B. It gets much longer. C. It stays the same. D. Something else.	A. The flame requires convection to work (the hot gases need to rise out of the way for oxygen to reach the burning wick). In a free fall, convection no longer occurs.

Ideas for older students

Idea	Question	Answer
Spouting bottle		
Prick a small hole in the bottom of a plastic bottle. Fill the bottle with water so that it spouts out of the hole.	What will happen to the jet of water when the bottle is thrown up in the air? A. No change. B. The jet is longer on the way up and shorter on the way down. C. The jet stops while the bottle is in the air. D. Something else.	C.The water is effectively weightless while the bottle is travelling (in free fall) both up AND down. (its acceleration is 10 m/s^2 downwards whether the bottle itself is moving up or down).
Eclipse of Mars		
Stare at the centre of a red disc on a white background for about 30 seconds. (This is best done on-screen with a PowerPoint presentation.)	What will happen if the disc is moved away from you, or gets smaller? A. You see the red disc as before but smaller. B. The red disc will have a yellow halo. C. The red disc will have a green halo. D. The red disc will have a cyan halo.	D.The 'red' cones in the eye become tired, so only the blue and green cones are used, producing a cyan halo around the disc.
Tin of beans		
Tie some thin string around a tin of beans (or any 450 g tin) with one loose end above and one below. Suspend the beans from a rigid point (e.g. a hook in the ceiling or a door frame) using the string.	When you pull sharply on the string hanging below, where will the string snap? A. Above the beans. B. Below the beans. C. You can't tell.	B.The inertia of the beans resists change, so the string snaps below where the force is exerted. If you pull gently the string snaps above the tin because the full force is passed above the tin as you pull.

REVIEW

Teaching science principles in primary or secondary education is essential but usually not easy.

In this article, David Featonby provides teachers from all countries with a strategy and resources to encourage thinking skills and discussion in the classroom or school lab. By involving the class in a series of simple and easy experiments, each with slightly unusual outcomes, all pupils are engaged in an enjoyable and practical framework. This useful learning tool encourages students to participate, investigate and understand science principles.

This article could be used in various ways as a teaching aid. Teachers may use the experiments presented in the article, adjusting them to their students' needs. Additionally, the article may prompt teachers to think of experiments in other science subjects, and realise them according to the successful approach presented here.

Vangelis Koltsakis, Greece

David Featonby is a recently retired physics teacher from Newcastle, UK, with 35 years experience in the classroom, now working as a Teacher Network Coordinator for the Institute of Physics, UK. David represented the UK at the last two Science on Stage international festivals[w3], and has a keen interest in unusual things connected with physics.

Primary circuses of experiments

Catch them young! **Alex Griffin**, **Tim Harrison** and **Dudley Shallcross** from the University of Bristol, UK, show how important it is to interest young children in science – and how much fun it can be!

Alex was in the final year of her chemistry PhD….

"The pressure is on: I've not finished the laboratory work yet and time is running out. I've got a million-page thesis to write and money is running out too. 'How do you relieve this tension?' I hear you ask. Well, I try and distract myself by 'reaching out'.

It's not some new-age relaxation technique but Bristol ChemLabS[w1] – a programme run by the University of Bristol's chemistry department to take science, chemistry in particular, to the masses. We want to dispel some myths about science being dull, boring, dangerous and/or harmful and also to let the general public see what we really get up to. One of the things we do is visit primary schools.

Image courtesy of Bristol ChemLabS

We start by loading all the equipment, including balloons filled with hydrogen and helium gas, into Tim Harrison's fortunately large car. On arriving at the school, we unpack and commandeer the school hall for a full demonstration. The children (4-11 years old) file in, staring in wonder and excitement. Once they've settled down, with the front rows provided with safety glasses – for effect rather than necessity – Tim gets going. He tests their knowledge by asking the pupils which constituent gases are found in the air. Then he stuns them with liquid nitrogen experiments, dumbfounds them with colourful reactions, makes them giggle with a fountain of bubbles (thank goodness for washing-up liquid) and finishes by exploding the hydrogen balloons with a flame. Of course, we have audience participation for this part. The audience cheer for the fireball, when the hydrogen balloon is set alight, and boo for the boring inert helium balloon which just pops!

The excitement is over for the moment and we clear up the hall while Tim answers questions from staff and children. We have just enough time for a cup of tea and then it continues….

For two classes of 9- to 11-year-olds, we have a set of three experiments around which the children rotate, so everybody gets a chance to do all three. I kit the children out in children-sized lab-coats, safety glasses and disposable gloves (they love this!) and get them to team up and dissolve ribbons of magnesium in different concentrations of hydrochloric acid. They measure the time taken for the metal to dissolve, then collect the gas and ignite it so it makes a 'pop'. The other experiments involve making a colourful polymer – also known as slime – and the iodine clock reaction (see overleaf). The teachers don't get off lightly either: we put them in lab coats make them join in all the experiments. It surprises me that the children are all so confident and inquisitive: I have to think long and hard when answering some of their questions.

These sessions are about having fun while learning a bit about chemistry, but we do introduce an element of competition. The team with the highest accuracy in the iodine clock experiment wins a Bristol ChemLabS Periodic Table mouse-mat or mug!

Exhausted but still buzzing, we pack up, drive back to the university and unload. What a way to relax!"

Image courtesy of Bristol ChemLabS

Primary school-university links: a win-win situation?

There are few reasons why chemistry or science workshops cannot be held for primary schools as long as funding and expertise are available. In many countries, primary schools have strong ties with higher educational establishments or their local secondary schools. It should be possible for individual or clusters of schools to seek grants for additional equipment to share or to pay for appropriate groups to come into schools[w2]. The necessary equipment for the most commonly used workshops is listed on page 32.

University science departments have resources that primary schools could use, with minor adaptation. Although there is always a financial or time investment in building up a relationship between the university and a few local primary schools, we feel this has huge benefits for both parties. Postgraduate scientists, and even academics, get the opportunity to plan and deliver activities to engage the public in science. The primary schools are introduced to new resources and role models, which has many benefits for teachers as well as pupils. Indeed, in our experience there can even be a three-way benefit in cases where secondary schools host the workshop events for local primary pupils by using a mixture of university personnel and their equipment and involving several of the school's senior science students.

"The pupils spent ages afterwards talking about their favourite demonstration (mainly the washing-up liquid foam one). They were very animated and clearly in awe of what they had seen. Even those younger children who cried [due to a minor – intended – explosion] thought it had been great."

"[Tim] did some experiments with carbon dioxide and liquid nitrogen, eggs, flowers, gloves, rubber tubing, etc., which have converted … 240 children in half an hour – including all of the 'uncool to learn' crew! We are now changing our curriculum to include more of such activities. Schools need lots more of the same. It was wonderful to see the children so motivated."

Two teachers

"I did not know that gases could freeze."

"I really want to be a scientist when I am older."

Year 3 pupils (ages 7-8)

"I had expected them to gasp in amazement at the pretty colours, steaming vacuum flasks and loud explosions that Tim created in the school hall but it was their reaction to the classroom experiments that impressed me most. Despite their obvious excitement, their behaviour was exemplary and they were a real credit to the school. Plus, by the end of the final 30-minute session, every pair in my group was able to predict to the nearest second a fairly complicated clock reaction! From the kids' point of view, we definitely succeeded in making science 'cool'!"

A postgraduate chemistry student, after helping out at a primary workshop for the first time

Practical details for the chemistry workshops

A classroom (with a sink) is easily converted into a temporary laboratory. Although we offer several experiments, the most popular ones are those designed to increase measurement, investigatory and cooperation skills and an increased awareness of chemical safety. These are described below.

Many secondary-school teachers may recognise the experiments, but the purpose of running them in primary schools is not to get the pupils to produce written records. They may do this later with their teachers, but the main point is to show the children how exciting and how much fun science can be.

Note: All chemical use should have a risk assessment made by the people conducting the experiment and must take into account local conditions. Primary teachers who do not have a background in chemistry may feel more comfortable obtaining the following solutions from colleagues in their local secondary school.

Investigating the properties of slime and polymorph

Slime is made by mixing borax and poly(vinyl alcohol) (PVA) solutions, then adding a few drops of food colouring. Changing the proportion of borax changes the physical properties of the slime. This (rather yucky) experiment is very popular with children.

Polymorph is a thermoplastic that can be moulded at the comparatively low temperature of 62°C.

Materials

For two classes of 35 pupils working in pairs, you will need 3 l of PVA solution and 2 l of borax solution.

To make 1 l of PVA solution:

1. Take 40 g of poly(vinyl alcohol) and add water until the total volume is 1 l.
2. Stir while heating from 40° to 90°C in water (allow 1 h). To speed up the process, cover the beaker in tin foil to keep the heat in.

To make 1 l of 4% borax solution:

1. Take 40 g of borax and add water until the total volume is 1 l.
2. Stir.

Note: Borax is also called sodium borate or sodium tetraborate, and is widely used in detergents, water softeners, soaps and disinfectants.

Polymorph can be bought from Middlesex University Teaching Resources, UK[w3] for about €30/kg. Allow 4-5 g per pupil (in individual tubes).

Method

Pupils should:

1. Pour PVA solution to a depth of about 1 cm into a disposable plastic beaker (there is usually a convenient marking on the beakers we use: the PVA solution is too viscous to make sensible use of a measuring cylinder).
2. Optional: add 3-5 drops of food colour and stir.
3. Add a carefully measured volume of borax and stir it in.
   Initially, tell each pair of pupils to use a fixed volume of borax – between 4 and 10 ml.
4. Wearing gloves, scoop out the slime and investigate its tactile properties by stretching it.

Introduce the pupils to the thermoplastic polymorph. This comes as colourless granules which, when put into hot water (over 62°C), can be moulded into interesting shapes such as fish, birds or – for the less imaginative – balls. The balls made from this material bounce differently depending on whether the polymer is still warm or has reformed its bonds in the coloured form.

The iodine clock experiment

With this experiment, the children investigate dilution and learn how to measure volume accurately to make the chemical reaction change colour after exactly 30 seconds. We run this activity as a competition, which adds to the fun.

The experiment uses two solutions referred to simply as solution A and solution B (see below). We do not confuse the issue with the names of the chemicals used. Students have three small beakers half-filled with solution A, solution B and water (W) and appropriately marked measuring cylinders to avoid contamination.

CLASSROOM ACTIVITY

Materials

For two classes of 35 pupils, you will need 4 l of each solution.

To make 4 l of solution A, mix the following chemicals and add water until the total volume is 4 l:

- 0.2 g soluble starch
- 30 ml ethanoic acid (glacial acetic acid)
- 4.1 g sodium ethanoate (acetate)
- 50 g potassium iodide
- 9.4 g sodium thiosulphate

To make 4 l of solution B, take 200 ml (30%, also described as 100 Vol) hydrogen peroxide and add water until the total volume is 4 l.

Method

Make sure that each pair of students has the correct equipment and can operate a stopwatch, then demonstrate the reaction without dilution. Mix 15 ml of solution A and solution B together. The mixture will turn black after several seconds.

Discuss the effect of adding water to the mixture. Use terms such as 'less concentrated' and 'more dilute' in the explanation, to give the pupils a mental model of what is happening. Give all instructions verbally to maximise the time spent doing the practical.

Set the children the challenge of making the mixture turn black at a set time – set a target that is between 30 and 60 seconds. Give each pair of children a different time to achieve.

Although the experiment is not strictly a fair test, as both the volume and concentration of the mixture changes, it does excite the pupils as well as giving them practice in measuring, investigating and how to work in a team. If necessary, you could offer a reward to the best pair.

It can be made more complex for secondary-school students, for example by insisting that solution B is diluted such that the same volume of solution B is used each time – which is of course more scientifically appropriate.

After the experiment, carefully pour the iodine solution that has been produced into a sink and wash it away. Wipe and reuse the beakers. If you do not have a sink, use a waste bucket (containing sodium thiosulphate crystals to react with the iodine) and dispose of the solution in a toilet at intervals.

Acid dilution

The pupils enjoy investigating the effect of diluting an acid on its reaction with magnesium, especially because they get to collect the hydrogen and set it alight (with a loud pop) at the end.

Materials

- Magnesium ribbon cut into 2 cm strips. Each student will need 5 pieces.
- Approximately 2 l of each of four concentrations of hydrochloric acid (HCl), see below.

Table 1: Hydrochloric acid concentrations

Approximate concentration (molar, M)	Volume of 11 M hydrochloric acid (ml)	Volume of water (l)
2.0	364	2
1.5	273	2
1.0	182	2
0.5	91	2

Method

Pupils should:

1. Measure 10 ml of one of the acid solutions and put it into a boiling tube.
2. Add a piece of magnesium, start a stopwatch and stop it when the fizzing stops.
3. Tabulate their results and convert the times into seconds.
4. Towards the end of the session, use the fifth piece of magnesium and trap the liberated hydrogen gas in a second boiling tube then use a lit wooden spill to ignite the gas safely.
5. Compare the results of their experiment with the explosion of the hydrogen balloons in the school hall.

When we do the experiment, the postgraduate scientist shows the pupils how to ignite the gas and supervises them carefully while they do it themselves.

REVIEW

This article describes visits by university students to primary schools to do chemical experiments, motivating the pupils, inspiring interest in chemistry, and provoking astonishment and joy.

There are detailed descriptions of the experiments, which could be used even by teachers without extensive experience in chemistry or access to a laboratory. I will definitely do the iodine clock experiment with my chemistry students.

Sølve Tegnér Stenmark, Norway

Web references

w1 – For more information about Bristol ChemLabS, see: www.chemlabs.bristol.ac.uk

w2 – A list of sources of potential funding for schools activities in the UK can be downloaded from the Bristol ChemLabS website: www.chemlabs.bristol.ac.uk/outreach/resources/

Editor's note: If you know of a similar list of funding sources that apply to other European countries, email the web link to editor@scienceinschool.org and we can include it on the *Science in School* website.

w3 – Middlesex University Teaching Resources website: www.mutr.co.uk

Resources

Details of some of Bristol ChemLabS's activities for secondary schools are described in:

Harrison T, Shallcross D (2006) Perfume chemistry, sexual attraction and exploding balloons: university activities for school. *Science in School* **3**: 48-51. www.scienceinschool.org/2006/issue3/perfume

Image courtesy of Bristol ChemLabS

BACKGROUND

Necessary equipment

Bristol ChemLabS's equipment for primary-school workshops includes:

- 60 lab coats in child, small adult and medium adult sizes
- 50 pairs of adult safety glasses and junior goggles
- 400 pairs of disposable rubber gloves in varying sizes
- Plastic beakers, measuring cylinders, stirring rods
- 250 disposable (non-brittle) plastic cups
- Stopwatches
- Laminated instruction sheets (wipe clean/dry)
- Glass boiling tubes and racks
- Mobile Bunsen burner (fuelled by butane), spills and matches
- Many rolls of laboratory roll or kitchen roll
- Large waste bags
- Electric kettles
- Eye wash bottle

The apparatus, storage boxes, chemicals, and other consumables for the day's visit cost about UK£4000, including the equipment for the morning presentation to the whole school.

Alex Griffen is now a postdoctoral research associate at the Synchrotron Radiation Source, UK.

Tim Harrison is the Bristol ChemLabS School Teacher Fellow.

Dudley Shallcross is a professor of atmospheric chemistry at the University of Bristol and the Bristol ChemLabS outreach director.

Learning through research: a Serbian tradition

Srdjan Verbic tells the story of the Petnica Science Center, which brings enthusiastic students (and teachers) from across Europe to a village in Serbia, where together they discover the joy and fascination of science.

Image courtesy of Petnica Science Center

There is one outcome of teenage research projects that is often undeservedly overlooked. Research not only allows self-directed learning, the fostering of critical thinking skills and thinking outside the 'classroom science' box, but also enables young people to gain very important social skills: communication, teamwork and listening to one anothers' ideas.

We all enjoy spending time in dynamic, stimulating surroundings and teenagers are no different. It is not easy being a teenage scientist these days, and it is particularly hard in the Balkans. Difficult times, lack of materials and the unpopularity of science amongst school friends prevent those interested in science from taking it further. This is where centres of excellence come in – attracting and motivating young people to take on a collaborative research project outside the standard school curriculum.

"We can do it ourselves"

Many centres of this kind proliferated throughout Europe, in particular in Eastern Europe, in the 1980s. Unfortunately, a great majority of them did not have the 'critical mass' to maintain their operation. However, one centre, established in former Yugoslavia (now in Serbia), has survived, developing its programmes and attracting more visitors each year.

Twenty-five years ago, in a village called Petnica, 100 kilometres south-east of Belgrade, an unusual science education centre was founded and soon became a hideaway for many rebellious secondary-school and university students from all over Yugoslavia. The attractive landscape and rich natural resources, such as a canyon, caves and archaeological sites, caught these students' attention. Even though they were deeply unsatisfied with the formal education system, they were truly enthusiastic

Image courtesy of Petnica Science Center

Petnica almanac

about nature and scientific work, and realised there was much more to education than school. Long before Petnica was formally established, some camps were organised for students of Belgrade University and members of a movement called Young Researchers of Serbia. Eventually, they managed to find government support to start an organisation with a few employees, a pile of books and a couple of Spectrum computers. Thanks to their efforts, an extracurricular educational centre was established for future generations of curious minds.

Since its beginning in 1982, Petnica Science Center has organised nearly 2300 programmes (seminars, workshops, camps and small conferences) for more than 40 000 secondary-school pupils, university students and teachers interested in science and technology. Today, Petnica is the largest independent, non-profit organisation for out-of-school science education in south-eastern Europe.

Programmes at Petnica help students to focus on the scientific method and to write science reports and papers. In this way they are 'learning through research'.

BACKGROUND

Examples of students' projects

The following oral presentations were given at the Petnica Students' Science Conference 2006:

- Influence of ultrasound on the electrochemical production of hydrogen on different electrodes (Chemistry)
- Simulation of chaos in an RLD circuit (Electronics)
- Boosted SMRNN: online speech recognition (Computer Science)
- Types of children's names for typical and atypical concepts (Linguistics)
- Determination of an open cluster age (Astronomy)
- The position of pronominal enclitics in constructions with infinitive (Linguistics)
- Influence of World War II on given names in the Savski Venac municipality (History)
- Numerical simulation of one-dimensional freely evolving granular gas (Physics)
- Relationship between school success, popularity, and status of 'crammer' in a group (Psychology)
- Archaeological-historical interpretation of the Vojlovica monastery (Archaeology)
- Relationship between physical characteristics of abstract visual stimuli and their connotative meanings (Psychology)
- New aspects of applying acid-base titrations for ascorbic acid determination (Chemistry)

Image courtesy of Petnica Science Center

Main building of the Science Center

Participants 'discover' various facts, relationships, structures or models for themselves, under the supervision of experienced researchers. School curricula cannot keep up with the growth of current scientific knowledge so researchers concentrate on developing a few specific skills: how to observe and access information, evaluate content and credibility and infer consequences and possible meanings.

Petnica Science Center has 15 science and technology programmes (including subjects such as archaeology and astronomy) which consist of a series of seminars. The first seminar (in winter, lasting 7 days) is a chance for students to see Petnica from inside and realise that some school subjects can be learned in unexpected ways. The second seminar (spring, 4-8 days) is dedicated to methodology of research, and concentrates on practical things like measuring, using instruments, drawing graphs and writing short reports. Students then propose a research plan for the summer seminar

Images courtesy of Petnica Science Center

Getting their feet wet

Archaeology camp

Geologists in Petnica Cave

BACKGROUND

Attending the Petnica International Science School

The Petnica International Science School gathers gifted students, unusually motivated for learning through research, from all over the world. The next science school will be in August 2008 and all students aged 17-20 are eligible to apply. Application forms and instructions are available on the Petnica website[w1]. The programme fee is €500, but financial support is always available for students from south-eastern Europe.

Field work

Taking a rest

Image courtesy of Petnica Science Center

(lasting 13 days) where they do the majority of their research. (Of course, summer seminars also have a lot of non-science activities like swimming in the lake, camp fires, barbecues and late-night guitar playing.) The fourth seminar (autumn, 4 days) is a chance to improve the drafts of their research papers and to hear some interesting new lectures. The last event in the annual cycle is Petnica Students' Science Conference (at the beginning of December) at which students present the results of their work and submit text for publication in *Petnica Papers* (see box on page 34). A selection of these papers (in English) is available online[w1].

Petnica Students' Science Conference is always the last event in the 100-seminar series for secondary-school students every year. It is the culmination of a year's work with 700 students from 200 secondary schools from Serbia and neighbouring countries, 400 senior associates, professional scientists from 70 university faculties and institutes, 120 junior associates, university students, and a core team of staff from Petnica Science Center. Involvement in the conference usually requires two years of participation in Petnica regular programmes. Submitted papers are in

Image courtesy of Petnica Science Center

"I am not quite sure about this"

Serbian, but all have summaries in English. Of course, guest participants from other countries present their work in English.

After 2000 programmes had been run in Serbian, Petnica finally started an international science school[w3] which is run in English and open to secondary-school students both within and outside Serbia (see box on page 35). The fact that international students cannot visit Petnica as frequently makes the programme concept quite different. There is no time for endless corrections of research plans, reports and final presentations. Everything should be finished in just two weeks. The basic idea behind such a school is to increase students' interest in scientific research and to give them the opportunity to practice scientific methodology. In the first two years, students (aged 17-20) from 12 countries attended this programme. In spite of the distance from their home countries, some of them have already started to come back. The third international school will end before this article goes to press. The fourth will be in August 2008.

Although it might seem that a centre like Petnica needs great human and material resources for all these programmes, it doesn't really require anything more than the proximity to an average-sized university town. There is no need for 'space-age' equipment because in order to learn through research it is more important to have stimulating surroundings, a decent library, computing facilities, a few small laboratories where students can work whenever they want and, of course, a group of enthusiastic people willing to share and discuss their interests and ideas. The main problem is trying to encourage people (such as scientists, teachers, officials and sponsors) to participate in an independent project that promotes critical thinking and a passion for science in young people – things that you cannot easily commercialise.

Petnica is particularly proud of the way everyone is frequently encouraged to share ideas, demonstrate new concepts and 'teach' younger colleagues. There are programmes for primary-school students, in which the bright instructors are only a few years older than the pupils. Programmes with secondary-school students are enhanced by the participation of university students. All students are

BACKGROUND

Practical details

Lab work

Petnica Science Center has 30-35 full-time employees. Since it is impossible for such a small number of staff to run so many programmes (130-150 per year), the staff collaborate with hundreds of professional scientists. Junior associates (university students and alumni of Petnica) also have a very special role: over 100 of them volunteer as guides and tutors for their younger colleagues attending the programmes.

The centre is in close contact with 250 secondary schools in Serbia and neighbouring countries in order to keep teachers informed and to encourage them to get their students to apply.

Finally, the cost. Students coming to Petnica for the first time are required to pay a participation fee. If they demonstrate enthusiasm and hard work, the following courses are free of charge. In the past decade many international organisations have supported Petnica programmes, and the centre receives funding from government institutions, industry and an alumni fund.

encouraged to ask questions and discuss science with others, whatever their age. There are no *teachers* and *students* because everyone learns from each other. We only have *more* or *less* experienced researchers.

The centre may have been designed for students, but Petnica is well-known for its specialised courses and workshops for schoolteachers. The centre carries out teacher training for hundreds of science, technology and humanities teachers every year in the same exciting style and by making use of the stimulating environment, which then indirectly influences tens of thousands of students. For teachers, Petnica is a meeting place, a club with a positive atmosphere where their opinion really matters.

Inadequate science education and unenthusiastic public attitudes toward science and technology seem to be problematic all over the world, not just in Serbia. However in developing countries these issues are more prominent because of such effects as the brain drain, limited accessibility of major scientific centres, and old-fashioned equipment and didactic teaching methods. Fortunately, there are some small centres of excellence, such as Petnica, which continue to work hard to break down these barriers preventing the development of budding scientists.

Cecilia (a 17-year-old from Sweden) sent this message after attending Petnica in 2005: "Today I finally managed to do something more than sleeping, eating, looking at photos, and telling my family about how fantastic you [Petnica] are and how much I want to go back (I think they're quite tired of hearing about you by now...). So, instead I went to see some friends and showed them photos and told THEM how fantastic you are and how much I want to go back..."

Image courtesy of Petnica Science Center

Teacher training

REVIEW

This article celebrates the success of the Petnica Science Center in Serbia. It is interesting to see how the centre developed and to appreciate the way it has influenced science education in the region. Science beyond the classroom is a vital way to enthuse pupils in science; this article will enable teachers to question facilities in their own country. The Petnica Center models how research can make science come alive for pupils and teachers. (I want to visit!!) This centre is a fantastic resource for science education; it would be wonderful for all pupils to have access to a centre like this. This could be a model for similar centres across Europe. I am looking forward to finding out more about the international conference in August 2008 and will be encouraging local schools to get involved.

Clara Seery, UK

Contact

For all comments, ideas or questions, or if you want to set up a similar centre in your country, you can contact the staff of the Petnica Science Center by post (Petnica Science Center, P.O. Box 6, 14104 Valjevo, Serbia) or email (pi@psc.ac.yu).

Web references

w1 – A selection of students' papers, *Learning Physics through Research*, is available in English from the Petnica website: http://pi.petnica.net

w2 – For more information on the annual Petnica Students' Science Conference, see: www.psc.ac.yu/konferencija

w3 – The Petnica international programmes website: http://pi.petnica.net

Resources

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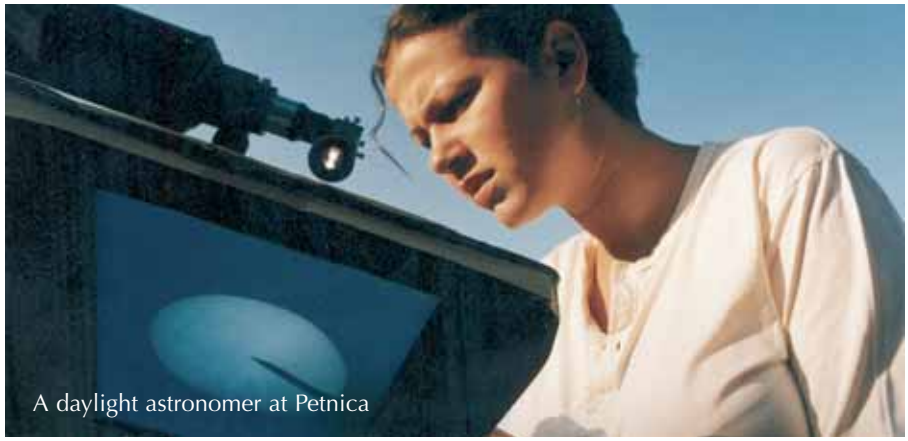
Srdjan Verbić is the head of Petnica international programmes

Halle-Bopp comet over Petnica



A daylight astronomer at Petnica

Images courtesy of Petnica Science Center

BACKGROUND

An outside viewpoint

Just before Science in School *went to press, the editor,* ***Eleanor Hayes****, visited Petnica.*

As I visited other parts of Serbia, I was struck by how well known and well-visited Petnica is. Every (English-speaking) person I met had heard of Petnica and many of them had attended one or more programmes. One consequence of Petnica's 25-year history is not only that everybody has heard of Petnica, but that Petnica alumni are to be found in almost every university, company and other organisation in Serbia.

I was impressed by how Petnica enables young people to learn for themselves how exciting science is – whatever their future careers will be. 'Science' is interpreted widely, with the emphasis on enquiry rather than topic. Programmes not only cover standard scientific subjects like biology, physics and astronomy, but also psychology, linguistics and social science. The young people are encouraged to come back year after year, attending programmes in varied subjects: physics followed by social history, or geology by psychology. Those who have attended several programmes are free to visit Petnica at other times, perhaps to help teach younger students or to use the facilities for university research projects.

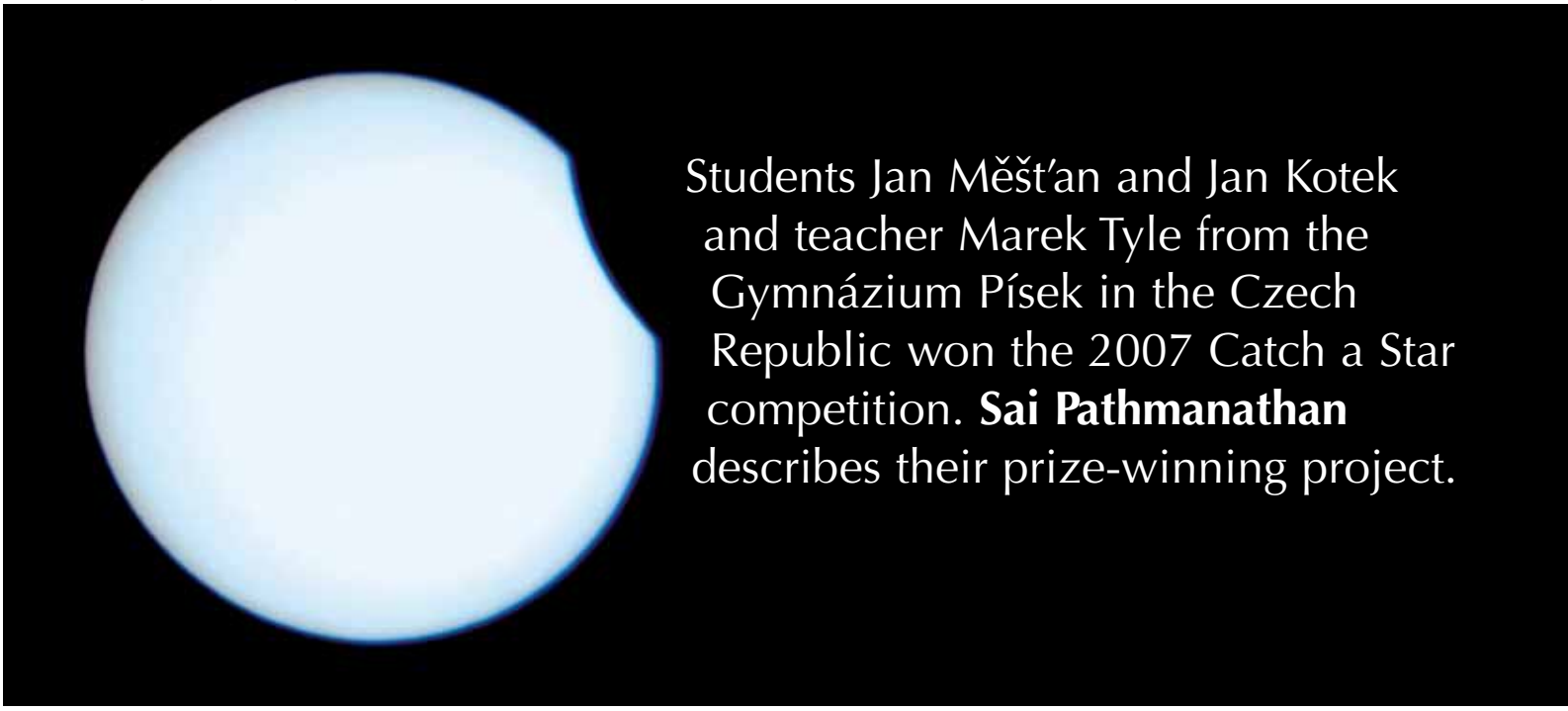
One important aspect of Petnica is that – with the exception of the final conference – it is not competitive: there are no prizes or certificates. Nonetheless, students can use the results of their research project or their conference paper to demonstrate their experience when applying to university. Another benefit is that the young people attending the programmes have direct and prolonged contact with scientists at different stages of their career (including university undergraduate students, PhD students, young scientists and professors). This gives them a good opportunity to find out about science careers.

The young people I met were definitely not the stereotypical overly-focused scientists: they were open and friendly, with wide-ranging interests. Whether they become scientists or take their enthusiasm and scientific experience into other fields, they will be a valuable resource for Serbia.

While I was impressed by the beautiful surroundings and large airy buildings, my most striking memory of Petnica is of the atmosphere of excitement and enthusiasm. I wish something similar had been available when I was at school and university in the UK.

Students Catch a Star: researching and observing a solar eclipse

Image courtesy of Marek Tyle, Jan Měšťan and Jan Kotek



Students Jan Měšťan and Jan Kotek and teacher Marek Tyle from the Gymnázium Písek in the Czech Republic won the 2007 Catch a Star competition. **Sai Pathmanathan** describes their prize-winning project.

The partial solar eclipse

Jan Měšťan has been interested in astronomy for several years. When he heard about the international astronomy competition, Catch a Star[w1], he asked his school friend Jan Kotek to take part too. With the help of their physics and information technology teacher, Marek Tyle, the two Czech 15-year-olds not only entered the competition, but won first prize. The competition is run by the European Organisation for Astronomical Research in the Southern Hemisphere (ESO)[w2] and the European Association for Astronomy Education[w3]. Their prize was a week-long visit to the La Silla Paranal observatory in Chile, operated by ESO.

Their project involved researching and observing the solar eclipse that occurred on 29 March 2006. The total eclipse was only observable in Libya, Turkey and Russia but from their school in the Czech Republic, the teenagers hoped to observe a partial eclipse. The project was not simply a chance for two enthusiastic students to enter a competition, it was an inspiration for the whole school. Jan and Jan gave a presentation to other students at their school, the Gymnázium Písek, after which the whole school observed the eclipse. Moreover, as part of the project, they hoped to carry out some scientific experiments during the eclipse.

The presentation

The main aim of their project was to show the partial solar eclipse to students of Gymnázium Písek and to share what they had learned during their research. So that everyone would be well informed on the day, Jan and Jan delivered a presentation to their fellow students 15 days before the eclipse. Their presentation included:

- General information about the solar eclipse (origin, types, significance for humans)
- Information about the total solar eclipse on 29 March (such as its path of totality and maximum duration)

Image courtesy of Marek Tyle, Jan Měšťan and Jan Kotek

Their presentation on 14 March 2006

- Details on the planned observation of the partial solar eclipse at Gymnázium Písek (observation devices, observation safety)
- A descrption of the scientific experiments to be conducted during the observation (measuring the decrease in brightness and temperature)
- How to make a filter to observe the eclipse
- Organising students so that they could all take part in the observation (644 students and teachers all wanted to watch).

BACKGROUND

Solar eclipses

Jan and Jan were interested in why solar eclipses occur, how to predict their occurrence, the characteristics of solar eclipses, and when they occurred in history. They investigated why solar eclipses are important to modern scientists, what observational methods astronomers use and how to use equipment to collect meaningful data.

A solar eclipse occurs when the Sun, the Moon and Earth are in a straight line (which can only happen during a new moon), so that the Moon casts a shadow on the Earth. Because the Moon and the Sun appear approximately the same size at this time (the Moon is approximately 400 times nearer to Earth than the Sun and has a diameter approximately 400 times smaller), the Moon can cover up ('occult') the Sun, when viewed from Earth.

A similar situation occurs during the more frequent lunar eclipse, when the Moon and Earth swap positions, so that Earth casts its shadow on the Moon. Eclipses also occur elsewhere in the Universe: total solar eclipses can be observed on Jupiter when its moon, Io, casts a shadow on it, or when Saturn's moon, Titan, comes between it and the Sun. Planetary transits (when a planet can be seen to cross the Sun) may also be observed from Earth, with the Venus transit being perhaps the most important as it was used historically to measure the distance between Earth and the Sun.

Jan and Jan were fascinated by documented appearances of the solar eclipse throughout history; their findings formed part of their project and presentation to the rest of the school. The first written record of a solar eclipse is from 2137 BC, when two Chinese court astronomers were executed because they forgot to alert the emperor to the forthcoming total solar eclipse. At the time, Chinese people believed that a dragon was coming to eat the Sun.

During their research, Jan and Jan became increasingly aware of the scientific significance of the phenomenon. During a solar eclipse, astronomers can observe properties of the Sun that are normally invisible, such as the corona or the solar chromosphere (a thin, coloured layer of the Sun's atmosphere), from which they can learn about the structure and composition of the Sun. By looking at the shape of the Moon as it crosses the Sun, they can draw conclusions about the structure of the lunar surface. Furthermore, the decreased levels of sunlight during an eclipse allow astronomers to observe stars, asteroids and comets and the other objects that are very close to the solar disc and cannot normally be seen. The low light levels also affect living organisms: many flowers close their petals and animals may go to sleep. Not only astronomers, therefore, but also botanists, ethologists and psychologists are interested in the effects of solar eclipses.

Images courtesy of Marek Tyle, Jan Měšťan and Jan Kotek

The live programme of the total solar eclipse in the assembly hall

Construction of the apparatus

Projection of the partial solar eclipse on the palm

At the end of the presentation, everybody received an information leaflet about the planned observation to pass on to other interested people. Three school noticeboards were also dedicated to information about the eclipse.

The observation

The last solar eclipse seen in the Czech Republic was on 3 October 2005, although clouds made it difficult to observe. Jan and Jan were hopeful, however, that the solar eclipse on 29 March 2006 would be more visible and that they could gather some useful data.

Jan and Jan chose a suitable terrace from which observations could be made. They and other students at Gymnázium Písek planned to use a variety of observation devices, including solar filters (made from X-ray films), binoculars with solar filters for safe observation of the Sun, telescopes, cameras and devices to measure light levels and temperatures.

The day of the eclipse dawned cloudy and the students were anxious that they would not be able to see anything. But by 9.15 in the morning, the sky had cleared up and the observation went ahead as planned. From 9.40, classes began to visit the observation platform. The live broadcast of the total solar eclipse viewed from Turkey was shown on a television screen in the assembly hall for everyone to see.

The air temperature was around 11°C and there was a strong wind

Image courtesy of Marek Tyle, Jan Měšťan and Jan Kotek

Jan Kotek during the observation

outside; sometimes the Sun hid itself behind clouds. Because of this unpredictable weather, Jan and Jan could not carry out their planned scientific experiments (measuring the decline in brightness and temperature). However, it did mean that they could spend more time helping fellow students to use their observation devices and telling them more about what they had learned about solar eclipses during their project. Even though they were disappointed by the weather, Jan and Jan learned (and taught) a lot about solar eclipses and hope that everyone enjoyed the experience as much as they did.

Acknowledgements

Jan Měšťan and Jan Kotek would like to thank the management and the director of their school, Mr Petr Pícha, for allowing the observation to take placě; their teacher Mr Jakub Cenek, who helped with the translation of the project; a professor in the Department of Physics at the University of South Bohemia in České Budějovice, Mgr Petr Jelínek, who acted as a consultant during this project; Pavel Vajík, who allowed them to borrow his Proximus 100 reflector; and the weather, for not being too cruel during the observation.

Web references

w1 – Full details of the project are available on the Catch a Star website: www.eso.org/catchastar/cas2007/

w2 – To learn about ESO's work and to view (and use) ESO's stunning astronomical images, see www.eso.org

w3 – The European Association for Astronomy Education works to improve and promote astronomical education at all levels in all European institutions involved in teaching astronomy: www.eaae-astro.org

w4 – For more details about the Very Large Telescope and the Paranal Observatory, see:

Pierce-Price D (2006) Running one of the world's largest telescopes. *Science in School* **1**: 56-60. www.scienceinschool.org/2006/issue1/telescope

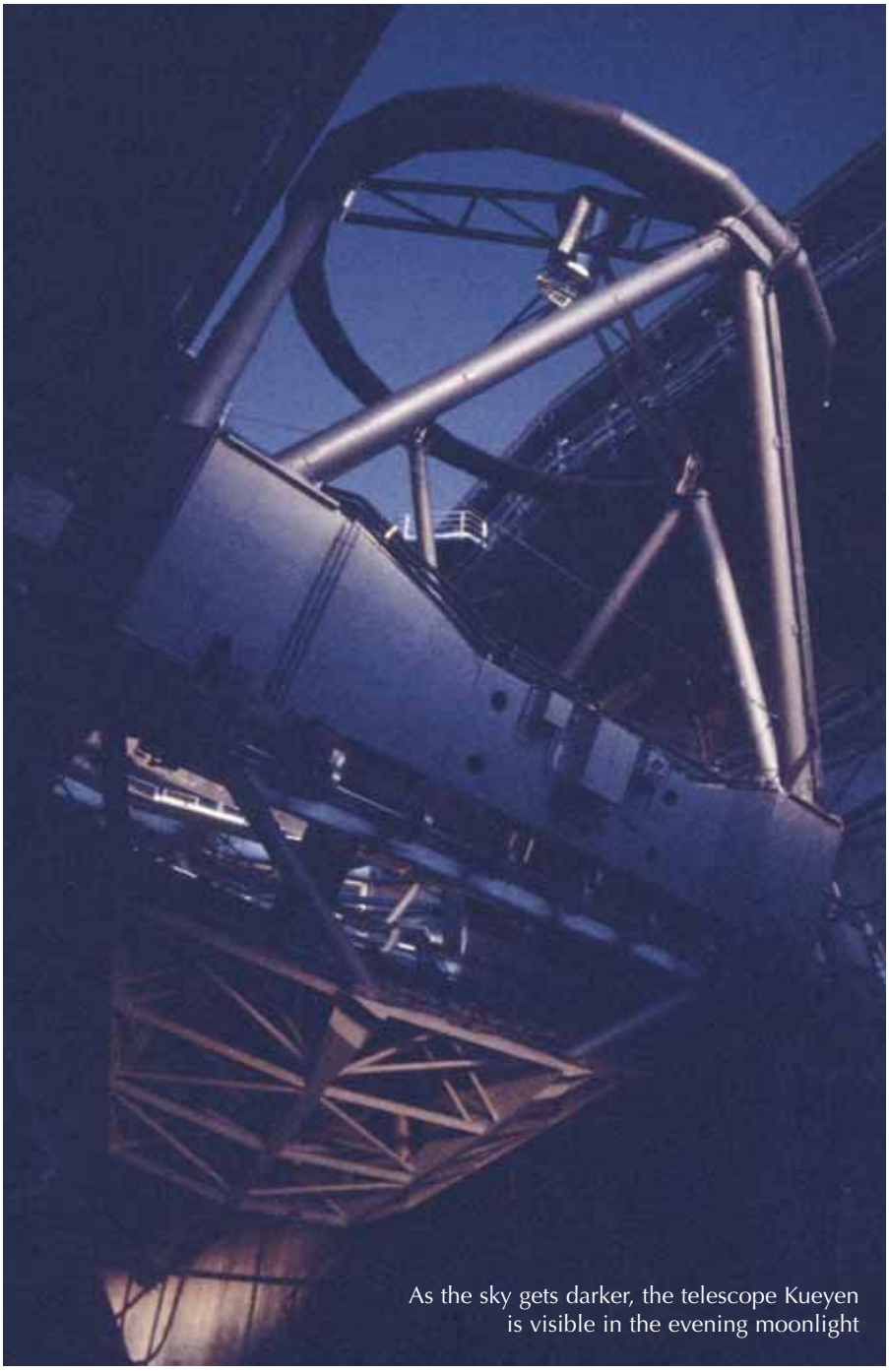
Catch a Star 2008

Catch a Star 2008 is open now! This international astronomy competition for school students returns for its sixth year, with fantastic prizes including a trip to visit ESO's Very Large Telescope on Cerro Paranal in Chile.

Image courtesy of ESO

The central region of the Large Magellanic Cloud

Image courtesy of ESO



As the sky gets darker, the telescope Kueyen is visible in the evening moonlight

REVIEW

This article is an interesting story about the development of an astronomy project by school students: the two teenagers succeeded in preparing presentations, experiments and an observation session in their school for other pupils, taking advantage of a partial solar eclipse. This could encourage teachers to consider how a local scientifically interesting event can be used to trigger a bonanza of social, cultural, educational and experimental events.

Problems with the weather during the eclipse are a rather common occurrence for experimental astronomers; the students, therefore, could fully experience a real astronomer's disappointment, which can be a daily companion to experimental scientists.

The report is suitable mainly for teachers of physics and astronomy and is presented in plain and simple language.

Marco Nicolini, Italy

As before, there are three categories in the competition. In Catch a Star Researchers, teams of students write a report about an astronomical subject of their choice, and discuss how large telescopes such as the VLT can be used to research this topic. Entries must be in English and are judged by an international jury. Catch a Star Adventurers is similar to the Researchers category, but entries do not need to be in English, and prizes are awarded by lottery. Alternatively, for Catch a Star Artists, students can make a drawing or painting with an astronomical theme. Prizes are awarded with the help of a public web-based vote.

The deadline for entries is 29 February 2008. To find out more, including competition rules and entry requirements, see: www.eso.org/catchastar/cas2008/

Report from Paranal

Just before Science in School *went to press, the prize winners sent this report.*

Paranal, Chile, is a really amazing place: it is in the Atacama desert, believed to be the driest place on Earth, and has the best astronomical technology in the world.

We visited the platform of ESO's Very Large Telescope (VLT) for the first time on 12 August. From the platform, there is a wonderful view of the Andes and the Pacific – especially beautiful at sunset. Until the third day of our visit, the sky was very cloudy, but then, at about midnight, the sky cleared and we watched the telescope domes opening. First, we visited the dome of the telescope Yepun, one of the four main telescopes of the VLT.

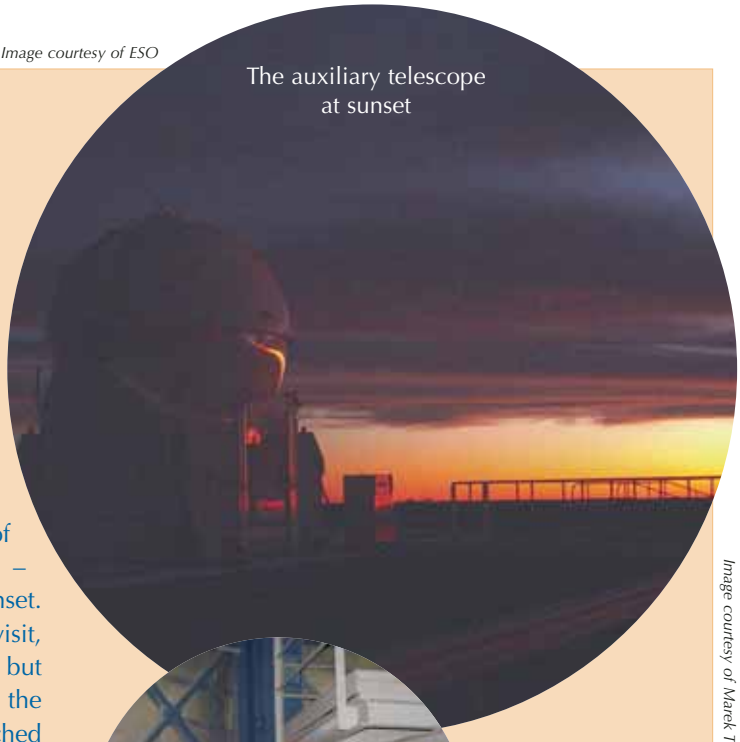
At Paranal with Laura Ventura

Image courtesy of Marek Tyle, Jan Měšťan and Jan Kotek

Next, we visited the control centre and met Stan Stefl, a Czech astronomer working at Paranal. We asked him about his work at ESO and the instruments at Paranal and he explained how the VLT interferometer works: it combines the light from the individual telescopes into a giant virtual telescope. This helped us to understand the work of the astronomers at Paranal. After our visit to the control centre, we took some pictures of the southern sky and saw the Magellanic Clouds (see image) and the Southern Cross. We would like to thank Laura Ventura, public relations manager of the Paranal observatory, who showed us other objects in the sky and helped us with our stay in Chile.

Aerial view of the Paranal summit, with the sun setting over the cloud-covered Pacific Ocean

Image courtesy of ESO



The auxiliary telescope at sunset

Image courtesy of ESO

Stan Stefl explains how the telescope works. From left: Stan Stefl, Jan Měšťan, Marek Tyle and Jan Kotek

Image courtesy of Marek Tyle, Jan Měšťan and Jan Kotek

We also investigated other features of Paranal: we went walking in the area surrounding the observatory, visited the gym and enjoyed delicious meals in the very cosy dining room. Paranal made a great impression on us: it is a very good facility for astronomers and scientists from all over the world. In addition to Paranal, we visited the ESO headquarters in Santiago and Antofagasta and made a day trip to the city of Valparaíso.

We will inform our schoolmates about our trip and use the knowledge that we gained in future physics lessons.

Marek Tyle, Jan Měšťan and Jan Kotek

Classroom@Sea: bringing real marine science into the classroom

Bringing marine science into the classroom can be challenging work for teachers. So why not take the classroom – and the teachers – to sea? **Vikki Gunn's** Classroom@Sea project does just that.

Images courtesy of NOCS / HERMES

Deployment of the remotely operated vehicle *Isis* from RRS *James Cook* to survey the mud volcanoes in the Gulf of Cadiz

Image courtesy of NOCS / HERMES

The UK's new research vessel, RRS *James Cook*, which was home to six teachers during a research cruise in Summer 2007

With our oceans coming under increasing pressure from human activities, there has never been a more urgent need to understand the marine environment and how it works. This applies not only to scientists and policy makers, but also to the general public and, perhaps most importantly, to the marine scientists of the future – school children. Classroom@Sea is a novel outreach initiative designed to bring cutting-edge marine science into classrooms across Europe. Based around real scientific expeditions on research ships, Classroom@Sea engages teachers and pupils in the journey from scientific hypothesis to investigation, discovery, analysis and interpretation.

In UK schools, as in those of many other European countries, marine and earth sciences are taught only at a very basic level, if at all. Although this is improving, the few marine or earth science concepts that exist in the curriculum are often taught in a very 'dry' fashion with few visual or practical aids to bring the subject to life.

With global change now a high priority in European research, it is essential that school children and the general public are not only aware of the issues threatening our oceans today, but also engaged in the research so that they understand the processes by which scientists obtain their results. This is particularly important now, when so many important policy decisions are being taken that will affect their future enjoyment and use of our oceans. Understanding how our oceans work is fundamental to ensuring that future generations have the tools to manage, conserve and enjoy the oceans responsibly.

As marine scientists, the most fundamental activities we undertake are expeditions to remote areas to probe the ocean's secrets, using dedicated research vessels equipped with the latest technology. For most members of the general public, the notion of boarding a ship to undertake a scientific mission in one of the most inaccessible and hostile environments on the planet – the deep sea – is the stuff of science fiction rather than science fact. Classroom@Sea invites the non-scientist to join the expedition and share in the experience, not only from a scientific perspective but also in terms of living life in the alien environment of a research vessel. It is these expeditions that provide the greatest opportunity to stimulate young minds and encourage young people to consider a career in marine science.

Image courtesy of NOCS / HERMES

The Classroom@Sea initiative is led and managed by the National Oceanography Centre, Southampton (NOCS), UK. From its conception in 2003, the project's aim has always been to enthuse and inspire school children by sharing the journey of scientific exploration and discovery. And what better way to do this than by recruiting schoolteachers to join the scientific team on board the ship? There are many scientists who are excellent at communicating their research to the wider public. However, teachers are ideally qualified and placed not only to share the excitement of being at sea on a scientific expedition, but also to communicate the ideas, concepts and theories in a format appropriate to our target audience: school pupils. Teachers' understanding of the curriculum means that they are able to apply their experiences on board the ship to aspects of their teaching where they would otherwise rely on standard demonstrations or examples. Many of the basic scientific principles taught to 11- to 16-year-olds can be demonstrated using the marine realm as an example; indeed, finding new and innovative ways to present concepts and theories provides an invigorating and rewarding experience for teachers and pupils alike. Life on a research ship is a unique experience and, we feel, best communicated to the outside world through the eyes of someone who is experiencing it for the first time.

In the summer of 2007, Classroom@Sea recruited six schoolteachers from the UK, Spain and Portugal to participate in a major multidisciplinary cruise aboard the UK's newest research vessel, the RRS *James Cook*. Equipped with the remotely operated vehicle (ROV) *Isis* and carrying an international team of marine geologists, biologists, geochemists, geophysicists, ecologists and oceanographers, the cruise set out to investigate the exotic mud volcanoes in the Gulf of Cadiz, the vast submarine canyons off the shores of Portugal, and the mysterious Whittard Canyon off the shores of Ireland. As such, the cruise was divided into three legs of two to three weeks' duration, with two teachers on board for each leg.

In the run-up to the cruise, the teachers documented their preparations for sea-going, including the indignity of hauling themselves into a life-raft during the compulsory sea survival course! They also researched material to add to the ever-growing archive of background science information available on the Classroom@Sea website[w1], and designed simple experiments with their students to carry out on board.

Once at sea, the teachers composed daily 'blogs' of their experiences for the Classroom@Sea website, relating tales of the trials and tribulations, anticipation, successes and occasional disappointments that are an integral

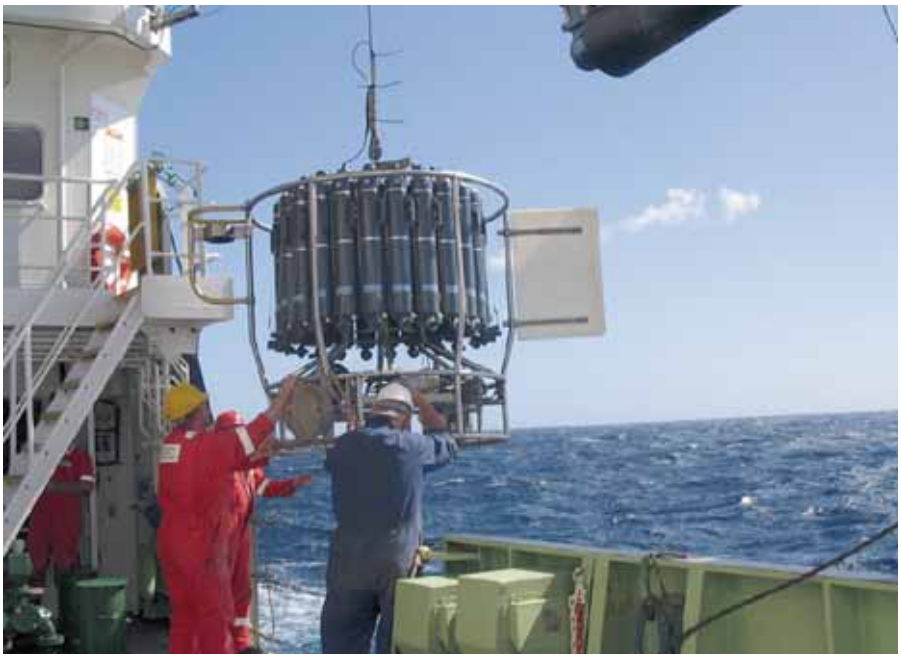
Images courtesy of NOCS / HERMES

The inside of the ROV control van – the hub of activity during an ROV dive. Live feed from the ROV cameras can be seen on the upper monitors

Teachers Eduard Vives Mayol (Barcelona, Spain) and Gillian McGahan (Berkshire, UK) enjoy a break from the heavy work schedule on board RRS *James Cook*

part of a scientific expedition. Online feature articles on the roles of crew members and the scientific team, and how the ship's cook caters for the masses without a supermarket nearby, a video tour of the ship and ROV video footage of a shipwreck served to draw in even the most non-scientifically minded pupil in the audience. Those following the progress of the cruise on the website were able to communicate with the team on board via an interactive question and answer session, in which the team were tested by a range of questions

Image courtesy of NOCS / HERMES



Work at sea is varied and often multidisciplinary – here the conductivity-temperature-depth probe is being deployed over the side of the research ship to measure changes in the salinity and temperature of seawater through the water column – invaluable information for both geologists and biologists

varying from the predictable "How deep is the sea where you are?" to the more taxing "Do fish break wind?", which sparked a lengthy debate amongst the marine biologists on board!

As well as providing the obvious benefits to teachers and schools, the involvement of teachers on a cruise is also a positive experience for the scientists on board. When faced with the need to explain their research at its most basic level, scientists must often view problems from new and unexpected angles. Teacher Gillian McGahan, who participated in the first leg of the cruise (the Gulf of Cadiz, 14 May – 2 June 2007), says, "As a teacher it is probably the best professional development I could have had. This experience has made me think of new ways to approach the curriculum. I have been given so much interesting support material and made aware of many resources that have been developed to enable us to teach science through oceanography, and I hope to be able to encourage colleagues to use this to develop their teaching as well. I feel that I now have a much better and deeper understanding of biodiversity along the European margin and I am really looking forward to sharing this with my pupils."

Fellow teacher Eduard Vives Mayol agrees: "Classroom@Sea has been one of the best educational experiences I have had. I have learned more than I could possibly imagine during the cruise. Working on the project and sharing ideas with scientists has been a hugely positive experience, particularly devising ways in which to share our experiences over the Internet. The atmosphere and the excitement on board the ship have increased my enthusiasm for teaching science."

Unfortunately, funding is not always available to finance the participation of teachers in NOCS's expeditions, but if there are no teachers taking part, a small team of shipboard correspondents are recruited from the onboard scientific team. For the most part, these individuals tend to be PhD

Image courtesy of NOCS / HERMES

students or young researchers, many of whom are going to sea for the first time. With communication skills becoming an increasingly valuable and essential asset, the exercise greatly benefits the researchers as well as the audience.

Share the excitement of scientific discovery online[w1].

Joining the team

When funding is available to include teachers on the cruises, the places are advertised on the Classroom@Sea website[w1].

Web references

w1 – The Classroom@Sea website includes many resources for teachers, such as activities for teaching biology, chemistry, physics and geology/geography. To learn how to demonstrate osmoregulation with a piece of potato or to show how submarines work using lemon peel, see: www.classroomatsea.net

Other useful resources on the website include posters to download, questions from children (and answers), a daily diary written by the teachers involved and plenty more information about oceanography.

Resources

Other school resources from NOCS include:

Oceans4schools web magazine for secondary-school students: www.oceans4schools.com

Ocean Zone magazine: www.noc.soton.ac.uk/nocs/ocean.php

What do we know about climate? The evidence for climate change

In the first of two articles, climate researcher **Rasmus Benestad** from the Norwegian Meteorological Institute examines the evidence for climate change.

In recent years, climate change has become a considerable international political issue, involving the Kyoto Protocol and discussions at high-level meetings such as the G8 summits. The recent fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) states that the global warming recorded over recent decades is very likely caused by human activity (with more than 90% probability).

International scientific societies have called for actions to mitigate global warming caused by emissions of greenhouse gases such as CO_2; the IPCC and former US Vice President Al Gore shared the Nobel Peace Prize 2007 for disseminating knowledge about man-made climate change; there was an Academy Award for Gore's documentary *An Inconvenient Truth*; and the *Stern Review Report* views climate change as a major challenge for the world.

At the same time, the media has provided reports giving the impression that the science behind anthropogenic (man-made) global warming is controversial, and debates now range from scientific issues concerning climate change to questions about how to deal with climate change. So what do we *really* know about climate? Here we examine the evidence and arguments concerning climate and climate change.

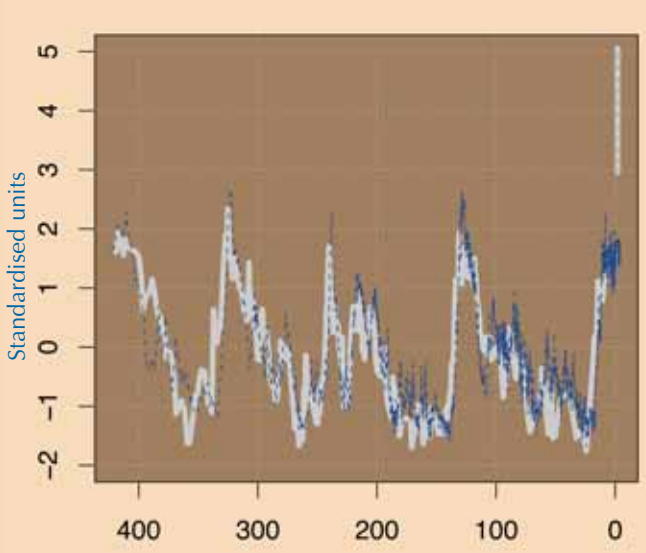
The history of climate research

It is useful to put the notion of climate change into a historical context, and note that it has been a topic of debate before. In the late 19th century, scholars discussed whether the local climate was affected by deforestation, or whether sunspots had any influence on the weather. At the end of the 19th century, the Mount Haldde aurora observatory in northern Norway was founded – based partly on the belief that Aurora Borealis, or Northern Lights, may affect the weather.

Some scholars believed that climate follows certain cycles, and by looking to the past, one could see patterns that could be used to predict the future. Around the same time, there were also scholars who studied the effects of increases in the atmospheric concentrations of CO_2. They thought that variations in the CO_2 concentrations might help explain the pronounced temperature variations associated with the ice ages, since the effects of changes in the Earth's orbit around the Sun were considered too weak to be involved. 'The Discovery of Global Warming'[w1] is an excellent website on these historical aspects.

Image courtesy of Rasmus Benestad

Fossil ammonite



CO_2 (grey) and temperature (blue) reconstructions from the Vostok ice core. On the far right are the present CO_2 concentrations

Image courtesy of Rasmus Benestad

How do we know that there were ice ages in the first place? The theory of glacial and interglacial periods was inspired by early geological findings and other geological evidence. Geologists asked what had carved the valleys in the mountain ranges, caused rock scouring and glacial moraines, and came up with the only plausible explanation: ice. There was also palaeontological evidence, such as remainders of vegetation and animals associated with warmer climates, which suggested that the local climate had been warmer, and fossils suggesting that previous sea levels were different from current levels.

More recently, firmer chemical evidence has been drawn from ice cores drilled in the Antarctic and Greenland ice sheets (see graph above). Air bubbles trapped in the ice, at depths representing the time when the layer of ice was formed, provide clues about the temperatures and the concentrations of atmospheric trace gases.

Our understanding of the ice ages relies on two pillars: the *Milankovitch theory* explaining how the timing of the ice ages was related to changes in Earth's orbit around the Sun, and *Arrhenius*' explanation of how variations in CO_2 levels could influence the mean global temperature.

The debates continue; but in hindsight, were the scholars of the past wrong about the climate?

Facts about our climate

The natural variations tell us that our climate is sensitive to changes in external conditions, such as the energy that the Earth receives from the Sun. We also know that the average surface temperature of Earth should be lower than it is, if we just consider the balance between the energy received from the Sun and the heat that escapes into space.

There is already a natural greenhouse effect keeping the Earth's surface ~30°C warmer than the energy balance would suggest. How do we know this? This notion is based mostly on the laws of physics (which have been successful in all other circumstances), which state that our planet receives energy only from the Sun in the form of light, measured by the solar constant of ~1370 W/m^2. If the planet doesn't warm up or cool down over time, then the energy input from the Sun must be in balance, or equilibrium, with the amount of energy that Earth loses to the Universe.

This energy loss follows a well-established physical law (Stefan-Boltzmann law), which has been confirmed by laboratory experiments and states that heat loss (black-body radiation) is temperature-dependent. It is also important to take into consideration the proportion of light reflected from the planet (from clouds and ice, for example).

The energy balance can be used to predict the surface temperature of other planets in our Solar System, and the verification by empirical measure-

Image courtesy of NASA

A view of Earth from space

ments hence constitutes a scientific test. The intensity of the sunlight is easily calculated from the solar constant and the planet's distance from the Sun.

In general, the surface temperature of planets decreases as the distance from the Sun increases, as expected from a radiative energy balance. But some planets – such as Earth – have higher surface temperatures than those predicted by the pure radiative energy balance model. These are the planets with an atmosphere that contains greenhouse gases (GHGs). For example, the surface of Venus, which has an atmosphere containing GHGs, is hotter than that of Mercury, which is closer to the Sun but has no GHG-containing atmosphere.

Laboratory experiments confirm the greenhouse gas properties of CO_2. GHGs such as CO_2 have one important physical property: they are transparent in visible light but opaque in infra-red light (heat radiation).

The greenhouse effect can also be understood from the perspective of quantum physics, where photons are absorbed by increasing the rotation or vibration of certain molecules. When the molecules subsequently lose the energy received by the photons, they radiate about half of the energy back to the ground. When this radiation is added to the sunlight received from the Sun, the net effect is a surface warming.

In summary, the theory behind the greenhouse effect is solid and based on both empirical evidence and theoretical physics. It has also been established from several different lines of evidence that Earth's climate has undergone variations in the past. These variations can be explained in terms of changes in factors that affect Earth's energy balance.

In the next issue of *Science in School*…

What do we know about climate? Anthropogenic global warming

Image courtesy of NASA

A view of the Earth from on board the International Space Station

Web references

w1 – The Discovery of Global Warming: www.aip.org/history/climate/index.html

Resources

Climate Change Education is a website for students, teachers and many more: http://climatechangeeducation.org

RealClimate is a commentary site on climate science by active climate scientists for the interested public and journalists. It aims to provide a quick response to developing stories and the context sometimes missing in mainstream commentary. The discussion on RealClimate is restricted to scientific topics and does not include any political or economic implications of the science. See www.RealClimate.org

REVIEW

Everyone has heard about climate change. The subject is frequently addressed by the media, but the information given is often incomplete or biased by political views. As science teachers, we have to provide students with correct information and instruments to develop critical attitudes based on facts and aimed at active citizenship.

Rasmus Benestad's two-part article is very useful because it presents the topic clearly and objectively, addressing its history, available evidence, anthropogenic contribution and controversial issues. Moreover it gives the reader valuable web references for further deepening his or her knowledge of the subject.

I recommend this article to science teachers who are willing to update their knowledge and to secondary-school students interested in the facts and scientific evidence at the heart of this debate. The material is also particularly suitable for classroom discussion and for an interdisciplinary approach to environmental education in secondary schools.

Giulia Realdon, Italy

Image courtesy of Rasmus Benestad

Fusion in the Universe: gamma-ray bursts

Henri Boffin from ESO[w1] in Garching, Germany, follows the mystery of gamma-ray bursts from their first discovery to the most recent research on these dramatic astronomical explosions.

Image courtesy of ESO

It all started just like a James Bond movie. During the 1960s, in the midst of the Cold War, the United States launched a series of satellites sensitive to gamma radiation to monitor the Soviet Union's compliance with the Nuclear Test Ban Treaty, which banned nuclear tests in the atmosphere, underwater and in space. No explosions were detected in the Earth's atmosphere. Instead, mysterious bursts of gamma rays were seen that appeared to come from space, as if – as it was later written in the sensational press – aliens were conducting a massive intergalactic war!

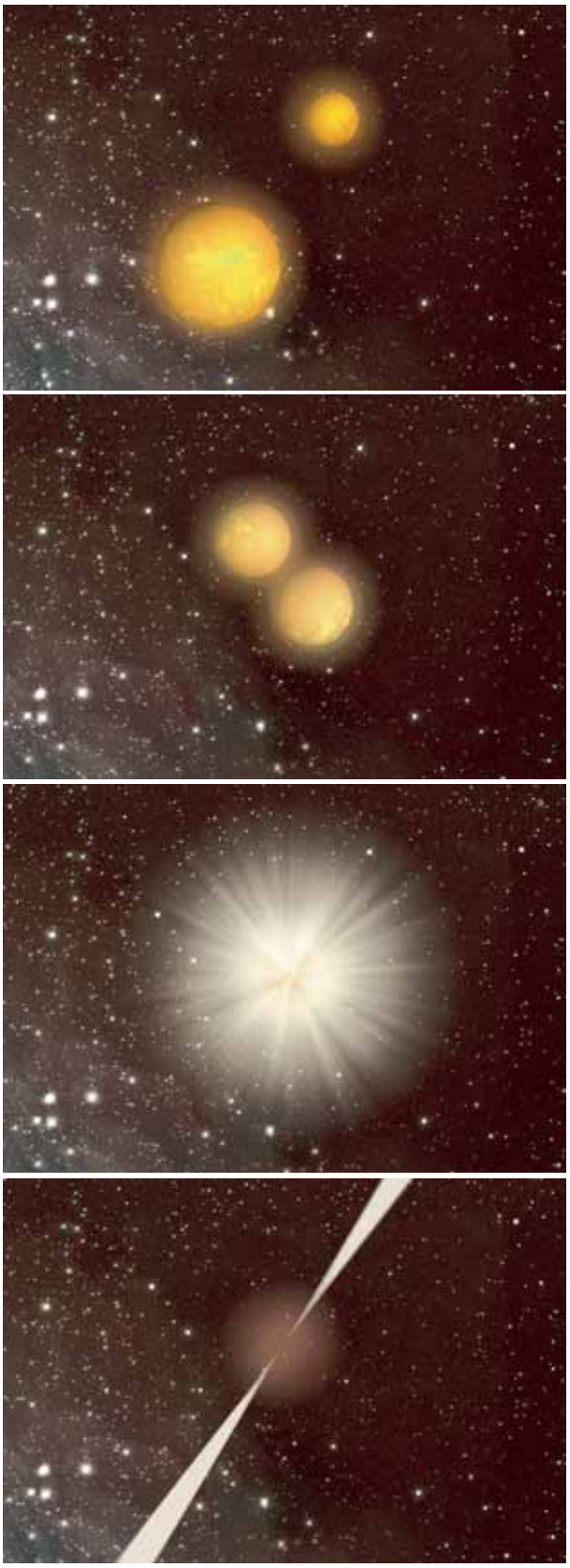
Because the few scientists who had access to the (military) data wanted to check all the details, it wasn't until 1973, six years after their first detection, that the discovery of these enigmatic explosions was announced to the scientific community. Unfortunately, the early gamma-ray detectors couldn't locate the source of gamma rays in the sky very accurately, leading to a long-standing controversy surrounding their origin.

Flashlight or lighthouse?

Scientists not only did not know where they were, but also could not even tell how far away these explosions were. Did they happen in our neighbourhood – in the Solar System or in our galaxy – or were they much further away? Without knowing the distance, it was not possible to determine the power of these events: were they just 'sparks' on the surface of comets, comets falling onto compact stars, or gigantic explosions that challenged our knowledge? The situation was not unlike one in which a person walking at night sees a light in the distance: is it a flashlight (torch) from somebody across the street, the lights of a car far away or the reassuring signal from a distant lighthouse?

Astronomers let their imaginations go wild. At one time, there were

Images courtesy of ESO



The merging model: short gamma-ray bursts are thought to be produced when two very compact objects (neutron stars or black holes) merge to produce a black hole

about a hundred theories to explain the new phenomenon – more than the number of observed events! As is often the case, advances were made when new technologies emerged, in particular with the launch of scientific satellites dedicated to gamma-ray research.

The BATSE instrument on board the NASA Compton Gamma Ray Observatory revealed that, on a typical day, two or three gamma-ray bursts occur somewhere in the Universe. BATSE also showed that gamma-ray bursts appear from all directions. This seemed to contradict the idea that they originate only in our Milky Way galaxy, because in that case they would show the typical flattened distribution of faint stars. This is because our galaxy is a strongly flattened disc of stars, as shown by the appearance of the Milky Way itself – a band of stars crossing the whole night sky.

Although crucial, these observations did not settle the debate fully and at the end of the 1980s, astronomers were still divided into two fiercely opposed camps: the first believed that gamma-ray bursts were due to 'local events' – such as comets falling onto neutron stars – and were located in a halo surrounding our galaxy. The other group dismissed this hypothesis and contended that gamma-ray bursts are dramatic ones, linked to the death of stars and the birth of black holes, and that they occur everywhere in the Universe.

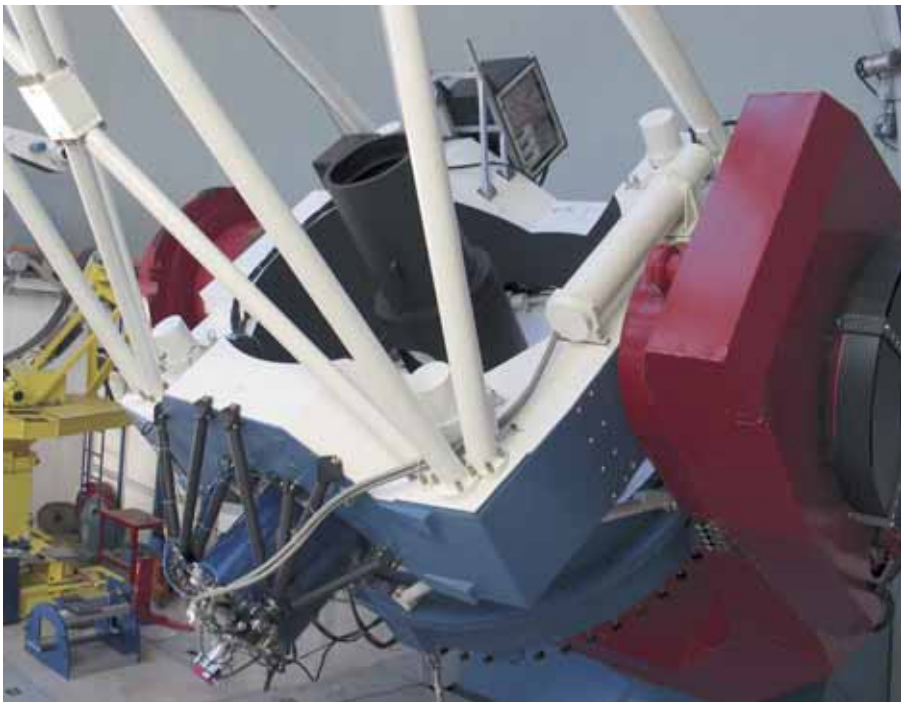
The dispute raged until the Italian-Dutch BeppoSAX satellite[w2], launched in 1996, used a combination of X-ray cameras and gamma-ray detectors to show that gamma-ray bursts originate in very distant galaxies. Since then, the most distant gamma-ray burst was found to be located more than 12.8 billion light-years away, which means that we observe it in the state in which it was when the Universe was less than 900 million years old[w3].

The most powerful events since the Big Bang

For gamma-ray bursts to be detectable from Earth, they must release tremendous amounts of energy. The energy released during a gamma-ray burst within a few seconds is thought to be more than the Sun will release during its entire lifetime (about 10 000 million years). In other words, these events are so bright that, for a brief moment, they almost rival the whole Universe in luminosity! However, they last for only a very short time, from less than a second to a few minutes.

Apart from the Big Bang itself, gamma-ray bursts are by far the most powerful events known in the Universe. Astronomers have also been able to determine that the explosions disturb a very large region around them – in one case, about 5 500 light-years, which is more than one-fifth of the distance between the Sun and the centre of our galaxy. All the material in this region of space will be ionised; that is, the atoms will be stripped of most, if not all, of their electrons. If there is any life in this region of the Universe, it will most probably be eradicated. In fact, some scientists claim that the Ordovician-Silurian mass extinction, which took place approximately 450 million years

Image courtesy of ESO



The GROND instrument at ESO's La Silla Observatory is dedicated to the study of gamma-ray bursts

ago and in which about 70% of all species on Earth were wiped out, was caused by a nearby gamma-ray burst.

Gamma-ray bursts are thus incredible events that wreak havoc in their galaxies and liberate extremely large amounts of energy. The question of course is which kind of 'engine' can trigger such events. The formation of a black hole is a very powerful event, so astronomers began to investigate whether the two – gamma-ray bursts and black holes – could be linked.

Although the details are still far from clear, scientists now believe that the best model to explain gamma-ray bursts is the 'fireball'. According to this model, during the creation of a black hole, the energy released by the explosion is stored in the kinetic energy of a shell of particles – a fireball – expanding at close to the speed of light. Initially, the density of the exploding material is so high that not even particles as evanescent as photons and neutrinos can escape. As the fireball expands to a diameter of 10-100 billion kilometres, the photon density drops enough for gamma rays to escape unhindered: some of the kinetic energy of the fireball is converted into electromagnetic radiation, resulting in a gamma-ray burst.

Long and short

The wealth of observations on gamma-ray bursts has revealed that they come mainly in two types: long (lasting more than two seconds) and short (lasting from a few milliseconds to two seconds). The difference between the two is not only in their duration: short bursts also consist of higher-energy photons than do long bursts. Clearly, although both types of gamma-ray bursts are associated with black holes, the precise physical origins of the two types must be different.

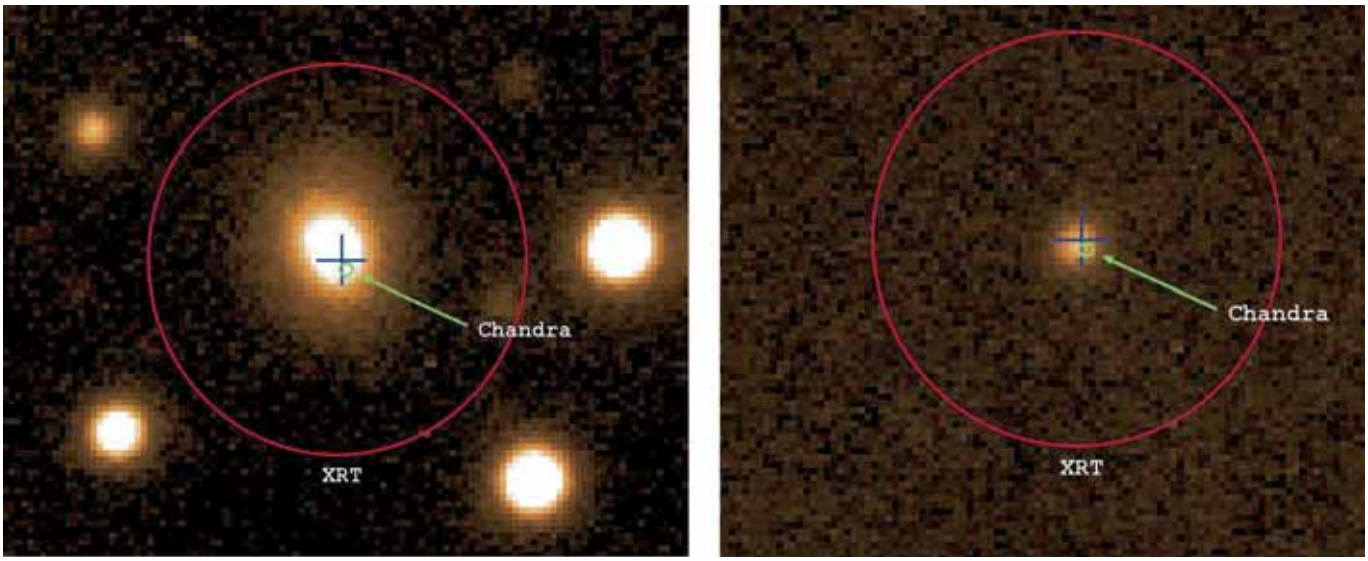
In recent years, a large international effort has convincingly shown that long gamma-ray bursts are linked with the ultimate explosion of very massive stars (hypernovae), with an initial mass more than 30-40 times the mass of the Sun, as they collapse into a black hole. Key evidence was provided with the help of ESO telescopes in 2003[w4]. Using the ESO Very Large Telescope[w5], astronomers obtained, over one month, spectra of the fading afterglow of a gamma-ray burst. This allowed them to observe the gradual emergence of a supernova-type spectrum, revealing the extremely violent explosion of a star.

Several other events have allowed astronomers to connect long gamma-ray bursts with hypernovae. One such event occurred on 11 December 2001 and was observed by the ESA XMM-Newton satellite[w6], only eleven hours after the burst was detected. At that time, the object was emitting seven million times more X-rays than a normal galaxy! This allowed XMM to take detailed spectra of the burst, permitting astronomers to detect the telltale signature of several elements, such as magnesium, silicon and nickel, which are typically ejected by an exploding star (for more details of the formation of heavy metals, see Rebusco, Boffin & Pierce-Price, 2007). Astronomers were detecting matter recently ejected by a supernova.

Merging stars

What about the short gamma-ray bursts? Until recently, astronomers

Image courtesy of ESO



Observations of a short gamma-ray burst in a very distant galaxy, by ESO's VLT. The left image was taken on 24 July 2005, 12 hours after the gamma-ray burst, showing the position of the gamma-ray burst GRB 050724 as measured by the Swift X-Ray Telescope (XRT) and the Chandra X-ray satellite. The blue cross is the position of the optical afterglow. A further image was taken on 29 July 2005 and one image was subtracted from the other, giving the image on the right. This reveals the afterglow, which indicates the presence of the gamma-ray burst

were unable to detect an afterglow. It was therefore not possible to precisely locate them and thus to deduce the environment in which they formed, or to characterise them by their light curve (variation of brightness over time) or spectrum.

Things changed on 9 May 2005 when the NASA/ASI/PPARC Swift[w7] satellite detected a gamma-ray burst lasting 40 milliseconds and located it with enough precision to allow astronomers to point ESO's Very Large Telescope towards it and take images. The burst, named GRB 050509B, was found to sit in a luminous, non-star-forming elliptical galaxy lying 2700 million light-years away.

This makes it difficult for the hypernova model to be invoked because a core-collapse supernova is unlikely in this kind of galaxy, which no longer produces stars and is thus generally devoid of the short-lived massive stars that collapse in hypernovae. On the other hand, luminous, non-star-forming elliptical galaxies host many tight binary systems (two stars orbiting each other closely) composed of compact stars. This supports the other prevailing model, in which gamma-ray bursts are caused when two neutron stars in a binary system merge to form a black hole. To be sure that the hypernova model could be ruled out, astronomers observed the burst for another three weeks, until they were confident that even the faintest supernovae would have been detected. But none were found.

A few months later, astronomers detected, for the first time, the optical afterglow of a short gamma-ray burst. Images obtained at ESO's La Silla observatory in Chile showed a fading source at the edge of a galaxy. Astronomers observed the burst, named GRB 050709, for 20 days but did not detect any supernova-like signal. This gives further support to the hypothesis that short gamma-ray bursts occur not as a result of a hypernova but when two very compact stars merge to form a black hole.

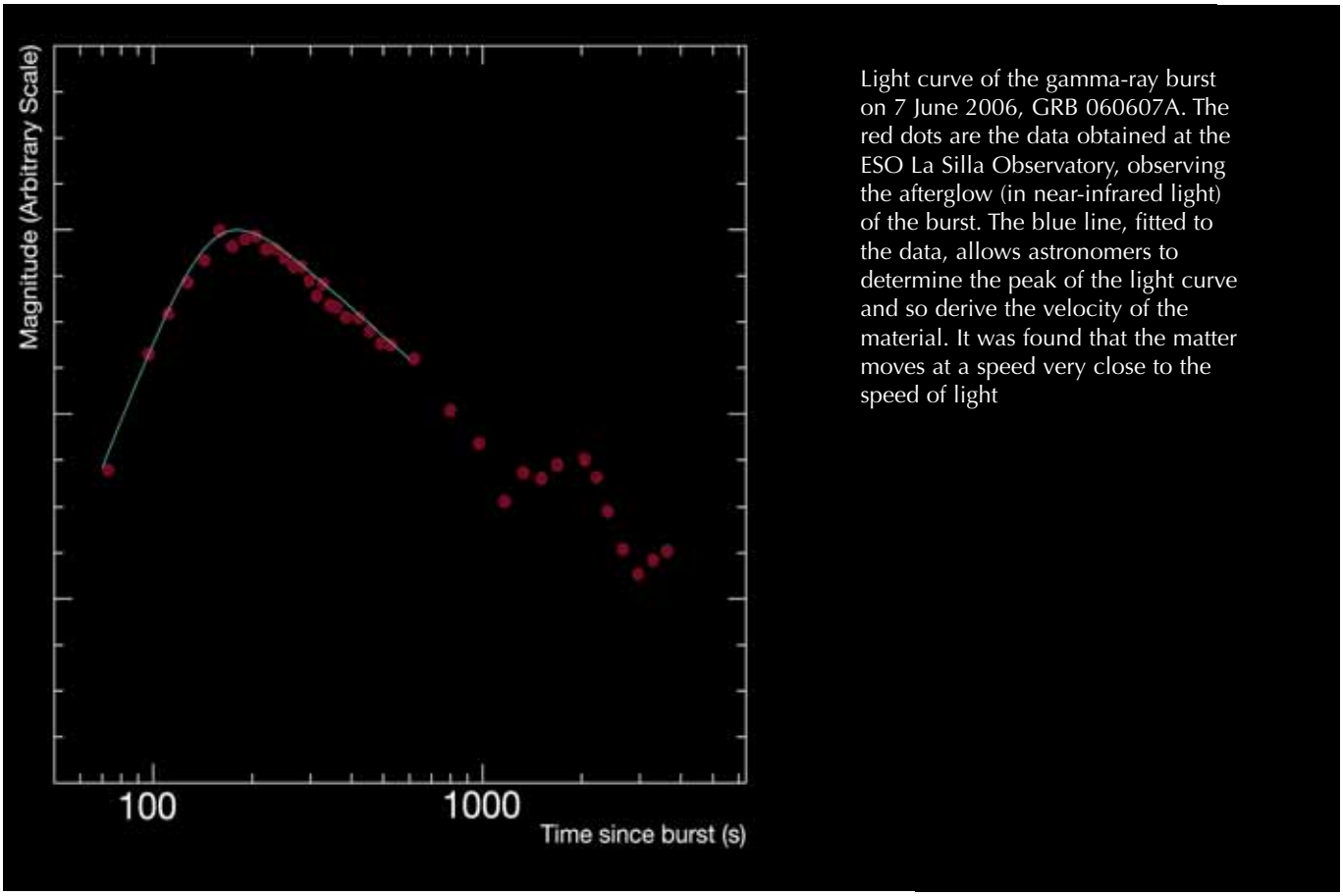
In the merging model (see image on page 53), two massive stars orbiting each other burn their fuel in about 100 million years and collapse into highly dense neutron stars about 10-20 kilometres in size. Over another 100 million to a few billion years the two objects continue to lose energy, and as they do, their orbit shrinks. Eventually they collide and produce a short gamma-ray burst. The theory also works if one star becomes a black hole, instead of a neutron star, that eventually devours its neutron star partner.

Forty years after gamma-ray bursts were discovered, we now know that they appear everywhere in the Universe, from its farthest edge to neighbouring galaxies. We also have an explanation for the two most common kinds of burst discovered. But nature is often more complicated than we tend to believe: with advances in observation techniques, astronomers continue to discover new types of gamma-ray bursts, and the story is thus far from finished.

References

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

Image courtesy of ESO



Light curve of the gamma-ray burst on 7 June 2006, GRB 060607A. The red dots are the data obtained at the ESO La Silla Observatory, observing the afterglow (in near-infrared light) of the burst. The blue line, fitted to the data, allows astronomers to determine the peak of the light curve and so derive the velocity of the material. It was found that the matter moves at a speed very close to the speed of light

Web references

w1 – ESO, the European Organisation for Astronomical Research in the Southern Hemisphere: www.eso.org

w2 – BeppoSAX: www.asdc.asi.it/bepposax/

w3 – *Star Death Beacon at the Edge of the Universe* (ESO press release): www.eso.org/public/outreach/press-rel/pr-2005/pr-22-05.html

w4 – *Cosmological Gamma-Ray Bursts and Hypernovae Conclusively Linked* (ESO press release): www.eso.org/public/outreach/press-rel/pr-2003/pr-16-03.html

w5 – To learn more about ESO's Very Large Telescope, see www.eso.org/public/astronomy/teles-instr/paranal.html

or Pierce-Price D (2006) Running one of the world's largest telescopes. *Science in School* **1**: 56-60. www.scienceinschool.org/2006/issue1/telescope

w6 – XMM-Newton: http://sci.esa.int/science-e/www/area/index.cfm?fareaid=23

w7 – The NASA Swift homepage: http://swift.sonoma.edu/about_swift/grbs.html

Resources

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

GCN, the Gamma-ray bursts Coordinates Network: http://gcn.gsfc.nasa.gov/review

REVIEW

This is a very exciting article that introduces and discusses a phenomenon involving a tremendous amount of energy: gamma-ray bursts. The article could be used to stimulate a discussion about the origin and mysteries of the Universe, as well as scientific discoveries and technological advances in research. It could also encourage young students to become interested and involved in astronomy.

Alessandro Iscra, Italy

Chemistry: a career catalyst

Gemma Guilera tells **Montserrat Capellas** about the joys of her rollercoaster approach to life. Fearlessly, she has started a new life more than once, making her home in very different European cities in the pursuit of a scientific career. Today, she faces a new challenge: motherhood.

Gemma Guilera

Image courtesy of ESRF

Noa's eyes are open, watching her surroundings attentively. Only a month old, she grasps Gemma's finger and smiles. She seems to be longing to discover the world. Her mother smiles back, perhaps thinking of how far curiosity has already taken her in life.

Gemma, a chemist from Barcelona, Spain, started her career a bit "unexpectedly". "I was in my last year in secondary school when I made up my mind, thanks to a great chemistry teacher I had. He was very passionate about chemistry, and he transmitted that passion to his students. His explanations were very clear, and his examples were taken from real life experiences rather than coming from textbooks. I chose chemistry just because I like life sciences and thought chemistry would give me a broad view of this discipline with the possibility of changing to biology if I was disappointed," she explains. In Spain, chemistry students can switch to biology after two years, but the opposite move is not allowed. Gemma combined her interest in chemistry with a desire to discover other cultures, and the fact that she was studying English at the same time led to the first destination in her career adventure: London, UK.

Gemma planned to stay at King's College in London for a year to do a master's degree on an ERASMUS/SOCRATES exchange[w1]. "I wanted to learn other ways of living, and I loved it because everything was so different from what I was used to," she says. She felt that the teaching methods in the UK were a breath of fresh air after what she had been used to in Spain. "During my time in London I realised that Spanish students approach their university teachers with fear, whereas Britons have a completely different relationship with the lecturers: they treat each other more as equals." Science in Gemma's new country placed much more emphasis on creativity and working independently. "In the UK they encourage you to try out an idea and let you develop your research by yourself," explains this 32-year-old Catalan. "In Spain, your professor has a field of research and you basically have to follow it," she adds.

A love of challenge led her to stay in London to carry out a PhD in organometallic chemistry at King's College. The Anglo-Saxon style (demonstrated by how easy it was to start scientific collaborations in the pub) and the fact that results in a PhD don't pop up on day one made Gemma feel as though she was on a

"rollercoaster, with lots of ups and downs". There were some moments of despair and stress, such as when a crystal that took a year to make broke on a plane to Germany, where it was going to be analysed; or when the X-ray crystallography machine broke down when she needed it towards the end of her PhD. Today Gemma can appreciate the positive side of her experience: "I can see how much I progressed scientifically and I have matured as a researcher since the beginning of my thesis, and this is really rewarding."

After her PhD, Gemma faced the real world: the two obvious options were dedicating her time to research or lecturing. "For a lecturer, the responsibility towards the students is huge, and I am not sure I could do a good job," she explains. On the other hand, research sounded tempting but some fields can be very isolating. "I am a social person, so I wanted to combine research and interaction with people. When I found the job advertisement at the European Synchrotron Radiation Facility [ESRF[w2]] I was fascinated by it as it was exactly the kind of work I was looking for," she explains. Of the three CVs she sent to France and three to the UK, only three responded positively: all in France. She was told she was too old for the UK jobs; in Spain it is common to finish a PhD at 28, which was her age at the time.

The career move to the alpine city of Grenoble coincided with the beginning of a new stage in Gemma's private life: marriage. Her husband, a lecturer in telecommunications, moved with her and found a job as an engineer soon after. Three years later, she is still enjoying her position as a scientist at the ESRF, where she is devoted to research on catalysts for cars, in collaboration with two Japanese car manufacturers. The aim of this research is to transform toxic gases in automobiles into harmless ones. "The subject is very motivating because it will one day have an application, although it may take several years," she says.

Gemma is developing and performing new experiments in chemistry, mainly using X-ray absorption spectroscopy[w3]. For example, she is exploring how new types of three-way catalysts function under real working conditions. These catalysts simultaneously trigger three reactions:

1. The reduction of nitrogen oxides to nitrogen and oxygen:
   $2NOx \rightarrow xO_2 + N_2$
2. The oxidation of toxic carbon monoxide to less harmful carbon dioxide:
   $2CO + O_2 \rightarrow 2CO_2$
3. The oxidation of unburnt carcinogenic hydrocarbons to carbon dioxide and water:
   $2CxHy + (2x+y/2)O_2 \rightarrow 2xCO_2 + yH_2$

By simultaneously using X-ray absorption spectroscopy and other complementary techniques, she can tell something about the mechanism of these reactions, such as how the metal particles interact with the gases, and how this differs with temperature and gas composition.

In addition to her own research, Gemma gives technical and scientific support to visiting users who perform experiments at the ESRF.

The interdisciplinarity of the institute, which combines research in physics, chemistry, biology and other disciplines, its international character and the teamwork are the values she most cherishes in her professional life.

"It is very demanding, and your whole timetable is upside down with respect to the rest of the world (because of long experiments that can keep you awake all night), but if you learn how to manage your time and be efficient when you are working, it is a great job," Gemma explains. She defines her feelings as a dichotomy: "You get exhausted from it because it is too much work but at the same time you love it because there is so much activity going on."

Now, Gemma is starting from scratch once more. In June 2006, she became a mother. Maternity is not an easy matter for scientists, and some think it can stop or slow down a

Image courtesy of ESRF

REVIEW

"Life is a wheel" – that's what Cypriots used to say, but as Gemma points out, it's more like a rollercoaster. It turns in different directions, taking you from Barcelona, Spain, to Grenoble, France via London, UK. It has its ups and downs, successes and disappointments; it spins fast, taking you from student life to a PhD; it changes destination, from a scientific career to motherhood. But somehow it all fits together, in a challenging and fulfilling way, in Gemma's life. To be inspired, to want to learn, to love what you are doing, to be challenged, to choose, to dare, as Gemma says, makes your life fantastic! That's how we can all be inspired.

Myrto Pouangare, Cyprus

career in research. "Coming from Spain, where maternity is frowned upon by employers, and being a first-time mum, I was worried about the reactions of my colleagues. I believe that if I was in Barcelona I may have been passed over for promotion, but here in France everyone respects your family choices and people recognise that you can be a serious scientist and a parent," she explains.

Gemma's boss, also a mother, understands her situation perfectly and if she has to leave the lab to take the child to the doctor, for example, it won't be a problem. Gemma also believes that fathers should not be forgotten: "There should not be any difference between men or women. Both father and mother should have the same rights to be with their child when it is born, but unfortunately it is still not the case in many countries."

Although Gemma did not move country when she entered this new stage in her life, she feels that motherhood has opened a whole new world to her. "I have to learn a new language; I feel silly because sometimes I do not understand the baby, but it is fun," she says. "It is difficult to start from scratch, and it gets even harder as you grow up, but it is a challenge that I enjoy."

Web references

w1 – To learn more about the ERASMUS exchange programme for students and university teachers, see: http://ec.europa.eu/education/programmes/llp/erasmus/erasmus_en.html

w2 – For more information about the European Synchrotron Radiation Facility, see: www.esrf.eu

w3 – A simple explanation of X-ray absorption spectroscopy can be found in:

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

A more advanced explanation can be found in this issue:

Eeckhout, SG (2007) Mercury: a poisonous solution. *Science in School* **7**: 12-15. www.scienceinschool.org/2007/issue7/mercury

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Montserrat Capellas is the editor of the *ESRF Newsletter*. This biannual magazine publishes the latest news in research carried out at the European light source. Read or subscribe to the *ESRF Newsletter* here: www.esrf.fr/UsersAndScience/Publications/Newsletter

Teaching in the Ukraine: Halyna Yagenska

Halyna Yagenska is no ordinary woman. Devoted mother of two and a teacher for 18 years, she works hard to improve science teaching in her home country, was named Best Ukrainian Biology Teacher in 2004 and was awarded the title 'Honour Teacher of Ukraine' by the president of the Ukraine. She tells **Sai Pathmanathan** what she loves about teaching science, describes her efforts to link teachers with each other, and shares her hopes for science education in the Ukraine.

"There are no teachers in my family," says Halyna. "As a child I dreamed of working at school. But then I also played a lot of sports and wanted to win an Olympic gold medal or even become an astronaut. Above all, I always loved learning new things and was lucky to have a biology and geography teacher who influenced me and trained me to win the all-Ukrainian school competition in science." Halyna also remembers the input of her parents, who taught her to appreciate the natural world; this was one of the main reasons that she chose to study biology and geography at university. But it was during her studies, on the first day of her school placement (a compulsory part of all university degrees in the Ukraine – not just for future teachers), that she knew she had found her dream career: to be a teacher.

"I realised that teaching and especially interacting with kids suited me best. My first pupils were 11-12 years old and their natural curiosity

Halyna and her students

Image courtesy of Halyna Yagenska

inspired me. We used books on the history of science to write plays for school performances, presenting tales ranging from ancient Phoenicia to Columbus and Magellan."

Teachers are naturally proud of students who do well, and Halyna remembers two students particularly clearly. "Two girls, Maria and Olena, had never previously stood out in lessons," she recalls. "But in one of the first hands-on activities I organised in their first year of biology, something grabbed their attention. The task was to observe a drop of pond water under the microscope. They found not only the usual algae, *Spirogyra* and *Chlamydomonas*, but also two examples of Protozoa: *Stentor* and *Vorticella*. This was a greater variety than any of the other students had in their samples. Additionally, Maria and Olena observed fertilisation in *Chlamydomonas* in their sample: their bench became a 'site of pilgrimage', which they loved."

This motivated Halyna too and she wanted to sustain their interest. The girls worked very hard for the next few months, also out of school hours, to breed plankton and identify the species they found. They even devised an experiment to test whether a washing powder advertised as the 'least harmful washing powder to organisms in natural ponds' really was. Maria and Olena prepared dilutions of four brands of detergents and added them to containers with two species of Crustacea. They collected results all through the night. It turned out that the least harmful detergent wasn't the one advertised as such. Surprise, surprise. The girls presented a paper in Lutsk and in the capital, Kyiv, at the National Ecology Congress for School Students. Halyna continues to be proud of her students, both of whom are now studying biology at prestigious universities in the Ukraine.

Of course, no teacher's job is without its challenges. Halyna finds there is still a huge gap between education-

Image courtesy of Halyna Yagenska

Halyna teaching

al reform and society's attitude to education. "Parents still have an old-fashioned view about education. They make their children memorise and recall facts and knowledge, without really getting involved in their education. Also, students have different needs and interests: in the Ukraine, even the older school students cannot choose which subjects they learn, which can make it difficult to interest them in a subject they will not need for their chosen career. In the same class, I have students asking me 'why do I need to study this?' and others who want to study concepts in more depth. It's a real challenge to keep the balance – to make sure one half doesn't lose their interest in biology, and the other half is not deterred from a scientific career." Halyna tries to involve her students – all of them – in the scientific world by making them researchers, not only of science but of the world around them.

"The reason why parents don't appreciate the need to develop their children's scientific reasoning is probably because they only remember their own education. Ten years ago, the state education system in the Ukraine was very different. The task was to overload students with data, offer very little practical work and make them memorise scientific terminology." The system is still rigid, but things are getting much better. "Nowadays every teacher can modify up to 30% of the content approved by the Ministry of Education and Science. In my opinion the optimal format is if the state authority sets up general guidelines with clear criteria of what is needed for exam success but then leaves it to the teacher to work out ways to achieve it."

Halyna is also optimistic about other changes being made by the Ministry of Education and Science. They are now more receptive to teachers' and students' needs and are testing new formats and approaches to encourage competence rather than knowledge accumulation in classroom science. These days, for example, new school books and programmes are written by teachers: the plans are submitted in a competition. Halyna is enthusiastic about this way of motivating students and many of her ideas have been accepted.

A significant breakthrough in the last five years has been the all-Ukraine tournaments for school teams to debate the most advanced scientific theories and unsolved problems. They begin at a local level, with the winning teams going on to regional games and finally to the national level. The list of topics is distributed by the Ministry a few months in advance and teams of students (guided by their teacher) prepare for 'battle' using all the sources they can find. Every member in the team plays a different role – presenting, defending and opposing particular ideas – but no one knows which role they will be assigned until the day of the competition. Example topics include:

- Imagine a situation in which gravity increases by 25%. How would mammals adapt?
- A gene associated with alcoholism (GABRA 2) is found in populations around the world, but the prevalence of alcoholism differs between nations. Explain this phenomenon.

"I see how much enthusiasm it sparks among my pupils and I am very glad they can realise their potential," says Halyna. "They work hard, reading complex material and extracting the essentials to build up their argument whilst all the time developing teamwork and presentation skills and even learning to control their emotions when debating." These tournaments have also shown Halyna the value of being able to meet and swap ideas and experiences with teachers from other parts of the Ukraine.

Halyna is still in contact with many of her former pupils. At the beginning of their university degrees, many of them come back to school to ask for books, advice or support but she has noticed that, after a while, the relationship changes: they bring new books and materials to update the school. Some even choose the school for their compulsory teaching placements.

Halyna encourages her former students to give talks to older teenagers in the school's science club, even on such complex subjects as secondary signalling pathways in mammalian cells. "Pupils love interesting facts and cutting-edge science and they are receptive to the 'word of the scientist'. Real scientists can show them how scientific knowledge is acquired: how an original hypothesis evolves into solid knowledge. Scientists can also give us contemporary examples of wrong assumptions that were ruled out, helping our pupils to develop critical thinking." Her former students also benefit from the visits: "They learn skills such as how to present material in an easily understandable manner and how to illustrate their points clearly using diagrams and tables."

But it's not all about the students, past or present. Adequate support facilities for teachers are also needed. Two years ago Halyna took part in a three-day workshop for teachers, organised by the European Learning Laboratory for the Life Sciences (ELLS)[w1] based at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, and felt it was one of the best she had ever attended. "First of all it was the feeling of being exposed to true cutting-edge science. Not only did the very advanced facilities impress me, but the realisation dawned on me that the life sciences have become more and more influential in shaping our civilisation."

After the workshop, Halyna and her colleagues organised a series of workshops in the Ukraine with help from ELLS to pass on what they had learnt to other teachers and education pro-

fessionals and to share materials and experiences. "Being a trainer is much more challenging than being a participant," says Halyna. "We felt a greater responsibility as we had to teach our colleagues, some of whom hold senior positions. These people can influence the curriculum and it felt like a chain reaction: scientists talking to teachers, who talk to local union managers… all to help students. It was so different to my daily routine of teaching."

Halyna has also created the learning network for biology teachers in the western Ukraine using knowledge and skills she picked up in Heidelberg. More than 20 teachers in seven regions of western Ukraine form the backbone of this network, and share information with colleagues through seminars. In Halyna's Volyn region, materials and practical experiments (e.g. DNA extractions) were presented to over 150 biology teachers. Halyna values the support of scientists in establishing this network; "In particular, one Ukrainian scientist then working at EMBL, Tetyana Klymenko, launched the process of knowledge sharing and the creation of the national network", she explains.

If Halyna was able to put European Union (EU) money to good use for the benefit of teachers and students, what would she do? "The most important part of any project would be the exchange of experience. If the best teachers, scientists and policy-makers from the EU could share their experiences with Ukrainian teachers and students it would be great, and would also improve teachers' and students' English skills."

Halyna feels that one of the biggest problems in the Ukraine is the lack of fluency in English. "In the Soviet Union, it was state policy to restrict our ability to communicate with people from other countries. The policy in the Ukraine is now very different but it will take a while for the language skills to catch up." Halyna is keen to help: together with English teachers at her school, she runs biology lessons in English. "This integrated approach motivates students to learn both biology and English," she explains.

Like most teachers, Halyna is not afraid of hard work. Especially if it means getting involved in award-winning projects. She organised a school scientific club, which has now been running for more than ten years. Students choose the research they are interested in carrying out, and as a result they have won regional and national research competitions – with some of the data being published in scientific journals and scientific conferences as far away as Prague (Czech Republic), Milan (Italy), and Washington DC (USA). Studies investigated, for example, blood pressure in school children, autonomic regulation in adolescents, and the impact of pollution on river plankton. This is a particularly proud achievement for Halyna, as many members of the club went on to choose science as their career.

Clever pupils? Probably. Inspiring teacher? Definitely.

Web references

w1 – The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into a research laboratory. Based at the European Molecular Biology Laboratory in Heidelberg, Germany, ELLS welcomes European teachers to its free three-day practical workshops. See www.embl.org/ells/ for further details.

Image courtesy of Halyna Yagenska

Kitchen Chemistry

By Ted Lister and Heston Blumenthal

Reviewed by Tim Harrison, University of Bristol, UK

Why do some people find that their urine smells horribly after eating asparagus? Should green beans be cooked with the lid on or off? How hot are chilli peppers? What affects the colour and texture of cooked vegetables? These are a few of the questions that the *Kitchen Chemistry* book and CD-ROM aim to answer with a range of experiments and other activities.

As the front cover states, "This resource for schools and colleges demonstrates the role of chemistry in the kitchen and highlights the wide applicability of chemical principles." The back page continues: "Although not directly part of most [UK] school's curricula, this topic provides an exciting context for some familiar chemistry and a way to engage students with the topic." The book consists of class practicals, demonstrations, comprehension exercises and paper-based activities. The activities are presented as teachers' notes and student worksheets.

If selected carefully, food chemistry experiments can be conducted by students from primary to pre-university level. Indeed, a helpful index categorises the *Kitchen Chemistry* activities by age: 5-11, 11-16 and post-16 (pre-university). Most topics are for post-16 students but even these could be used for younger, more able students, particularly if they were adapted accordingly. Each topic describes the learning objectives, targeted age group, approximate timings, a description, teaching notes and details of the student activities. Notes on the risk assessments for food experiments, and for the handling of liquid nitrogen in the chapter on making ice-cream, are also included.

There are three activities aimed specifically at younger students. These include investigating several of the variables that affect how jelly sets in contact with fresh fruit, as well as ice-cream making. For 11- to 16-year-olds, there are several experiments investigating salt and the use of salt in cooking. The post-16 activities make use of skeleton formulae of compounds and high-pressure liquid chromatography (HPLC) chromatograms. Experiments include the titration of sodium chloride solutions to see if vegetables absorb salt when cooked, and the chemistry of baking powder. Other exercises examine the structure of ice and water, the chemistry of flavour and why pans stick.

A CD-ROM, to be used alongside the book, lists resources by book chapter. These resources include the worksheets (as Microsoft Word® documents or PDF files in colour or black and white), a presentation on salt, some rotatable Chime structures of ice, and links to 16 video clips that can be downloaded from the Internet. To view the video clips, a PC must be connected to the Internet. The clips, featuring Heston Blumenthal from the Discovery Channel TV series 'Kitchen Chemistry', are available in three formats:

- 2MB Windows Media Video (wmv)
- 15MB Windows Media Video
- 35MB MPEG.

Adobe Acrobat Reader and Chime plug-ins are available on the CD-ROM. (Chime is needed to visualise the 3D structures of molecules.)

Ted Lister has written several publications for the Royal Society of Chemistry. Heston Blumenthal is one of the UK's top chefs whose restaurant, The Fat Duck, has the distinction of three Michelin stars. It was also voted the best restaurant in the world in April 2005. Heston is noted for his scientific approach to cooking.

Resources

Teachers who wish to see the worksheets before purchasing this resource may download them from www.chemsoc.org/kitchenchemistry.

For more information on activities of The Royal Society of Chemistry, including those designed for students, see: www.rsc.org

Details

Publisher: The Royal Society of Chemistry
Publication year: 2005
ISBN: 9780854043897

Ordering

The resource can be ordered from the Royal Society of Chemistry: www.rsc.org

Clockwork Genes: Discoveries in Biological Time and *Evolution: Constant Change and Common Threads*

Reviewed by Michalis Hadjimarcou, Cyprus

These two DVD sets, produced by the Howard Hughes Medical Institute as part of its Holiday Lectures on Science programme, address two highly interesting subjects which directly or indirectly affect our everyday lives: biological clocks and evolution.

Each DVD contains four full-length presentations by expert scientists, complemented by a variety of special features. The DVDs are easy to use, and provide direct access to the lecturer's biographies, interviews and the animations and video clips used in their presentations. Especially useful are the ideas for classroom activities. The scientists present to a high-school audience; they interact with the students and respond to their questions, making the presentations lively and interesting to view.

Clockwork Genes: Discoveries in Biological Time

This DVD contains four presentations conducted by two biomedical scientists who have made groundbreaking discoveries in understanding the molecular basis of biological clocks and specifically circadian clocks. The speakers explain in detail what circadian clocks are, how they work, and why it is important for human health to study them. The audience consists of students who attended the presentation or watched and participated by video conference both within and outside the USA.

The lectures start with the basics of what biological clocks are. From there, the speakers go into detail about the genetic mechanisms that are responsible for the appearance of this phenomenon. Therefore, the DVDs are best suited for biology teachers and advanced biology students with a strong background in molecular genetics.

In their presentations, the speakers include a variety of interesting topics, such as: a short historical account of experimental methodologies and strategies used in biological research; how the application of modern molecular techniques helps biologists acquire deep knowledge about organisms and their systems; how experimental results can be used to draw conclusions; how science can reveal information that allows us to understand how various biological phenomena affect our everyday lives; how real life events and phenomena are explained in terms of biological principles; and how knowledge from relatively simple organisms can be used to obtain valuable information about more complex organisms, such as mammals and, eventually, humans.

It is interesting to note that the vast majority of species studied so far exhibit circadian rhythms, which are set by Earth's rotation around its axis. This leads to the realisation that the planet is home to all its inhabitants, and reminds us that we must preserve Earth and share it with all living creatures. This issue would make a good topic for class discussion.

Evolution: Constant Change and Common Threads

Anyone with the slightest interest in evolution will love this DVD set. In fact, the language is so simple and the scientific content so basic that even individuals with no scientific background will appreciate and enjoy this product. Simple instructions and ideas on how to use the DVDs in the classroom and how to take advantage of their many features make this product even more useful.

The presentations include lively animations, graphics and models to captivate the audience's attention. They cover not only pure evolution topics but also relevant material from geology, genetics and other science disciplines. Some of the issues addressed include the pioneering work of Charles Darwin and the issue of human origins and evolution. And for those concerned that believing in the process of evolution is in conflict with religious beliefs, a discussion on evolution and religion between two theological experts will attempt to prove otherwise.

Darwin's 'The Origin of Species'

By Janet Browne

Reviewed by Dean Madden, National Centre for Biotechnology Education, UK

The choice of examples is quite successful as they bring evolution into our homes and lives. They show that evolution is not something from the distant past but an ongoing process which is closely related to human activity. Human fate is at least partly determined by evolution in other species; at the same time, humans actively determine the evolution of other species. The realisation that common human practices like hunting and fishing drive many species to extinction is especially shocking. This issue should be addressed in debates in science and non-science classrooms.

Details

Clockwork genes: Discoveries in Biological Time

Publisher: Howard Hughes Medical Institute

Publication year: 2000

Evolution: Constant Change and Common Threads

Publisher: Howard Hughes Medical Institute

Publication year: 2005

Ordering

These and other DVDs can be ordered free of charge from the Howard Hughes Medical Institute: www.hhmi.org/biointeractive/

This short book describes the development of Charles Darwin's *The Origin of Species* and examines its wider impact.

Janet Browne is the author of a large and highly acclaimed two-volume biography of Charles Darwin. Her new volume is slightly different – it is a biography of Darwin's most famous book, rather than the story of Darwin's life or indeed the development of evolutionary ideas. At times, the distinction is blurred because to understand the genesis of *The Origin* it is necessary to understand Darwin's personal journey. The book therefore includes much of the material from Browne's earlier works, but in far less detail. Curiously, it does not mention the meticulous way in which Darwin promoted *The Origin*, by sending copies and carefully worded covering letters to influential people. Also missing is any mention of the purchase of a substantial proportion of the first edition by Mudie's Select Circulating Library, which did much to encourage readership of the (then expensive) book in Victorian England.

The final chapter deals with *The Origin*'s fall from grace in the early part of the 20th century, only to be revitalised in the 1940s by the modern synthesis of genetics and natural selection. It also describes the somewhat surprising resurgence of opposition to Darwinism by fundamentalist religious groups in the United States. As Browne points out, although Darwin's ideas were hotly debated in Victorian England, organised opposition from fundamentalist religious groups is very much a late 20th century phenomenon.

This an enjoyable book which a teacher could read from cover to cover, but if you've read Janet Browne's biography of Darwin it might prove disappointing; I suspect that the format of this short book is more to blame than the author.

Details

Publisher: Atlantic Books, London

Publication year: 2006

ISBN: 9780802143464

Free online teaching materials

It can be difficult and time consuming to develop materials for really good science lessons. Many scientific research organisations, however, provide teaching resources, often designed together with teachers. Researchers provide scientific expertise and the teachers bring years of experience in the classroom.

These materials include pictures and videos as well as ideas for scientific experiments in the classroom. Some institutes even develop computer games for an interactive learning process. **Sabrina Graß** from the European Molecular Biology Laboratory reviews some online materials to help you to enliven your lessons and excite students about science.

Resources in English

The Association for Science Education

www.schoolscience.co.uk

The UK's Association for Science Education provides many online teaching resources and links covering all science subjects and all student age groups. The interactive resources provide information and brief online tests on topics as diverse as Viagra®, the Periodic Table, and the Big Bang.

Biotechnology and Biological Sciences Research Council

www.bbsrc.ac.uk/society/engagement/schools/resources/Welcome.html

These teaching materials for primary and secondary schools may be viewed online, downloaded or ordered. They include interactive presentations, information sheets, online exhibitions and materials for running workshops. Topics covered include the structure of DNA, biodiversity, physiology, animal welfare, plants, agriculture, food biotechnology, spiders and genetics.

Cancer Research UK

www.cancerlessonplans.org.uk

These online lesson plans address the biology of cancer, ethical issues surrounding the use of human tissues in research, how to lead a healthy life, and the role of viruses in cancer and the possible impacts of a vaccine for cervical cancer. The lesson plans are tailored to the English key stage 4 (ages 14-16) curriculum, but elements could be adapted by teachers in other European countries.

CERN (English, French, German and Italian)

http://public.web.cern.ch/Public/Content/Chapters/Education/OnlineResources/OnlineResources-en.html

CERN, the world's largest particle physics laboratory, provides online lectures, games, demonstrations of experiments to do in the classroom, movies, pictures, posters, and presentations about high-energy physics. Topics include particle physics, antimatter and special relativity as well as the functioning of bubble chambers and technological applications of CERN's research. The games about CERN's Large Hadron Collider and the microcosm are available in English, French, German and Italian.

Cold Spring Harbor Laboratory

www.dnai.org

Teaching materials on the *DNA interactive* website include interactive applications, information modules, lesson plans and student worksheets. All materials relate to DNA, but cover subjects as varied as the Romanov family, DNA fingerprinting in human identification, genes and medicine, and human origins. The accompanying DVD can be purchased online.

The DNA interactive DVD was reviewed in Issue 1 of Science in School: www.scienceinschool.org/2006/issue1/dnainteractive

European Fusion Development Agreement (EFDA) and ITER

www.efda.org, www.iter.org and www.jet.efda.org

The websites of EFDA, JET (the world's largest nuclear fusion research facility), and ITER (its successor) answer many common questions about fusion. Teachers can download or order free booklets, articles, pictures, movies and interactive modules to support their lessons.

European Initiative for Biotechnology Education (German, English, French, Italian, Dutch, Estonian)

www.eibe.info

The European Initiative for Biotechnology Education, now finished, generated teaching materials for 16- to 19-year-old school students. Among the many topics are transgenic animals and plants, immunology, and the production of biscuits. The material consists of experimental protocols, practical activities, role plays, information and debates designed for immediate classroom use. Some of the material is rather out of date.

European Learning Laboratory for the Life Sciences

www.embl.de/ells

Based at the European Molecular Biology Laboratory, the European Learning Laboratory for the Life Sciences brings secondary-school teachers together with scientists in a research environment. The teaching material that they develop together is available online and includes a stem-cell game, a virtual microarray, a bioinformatics activity, and a role play about genetic testing.

European Organisation for Astronomical Research in the Southern Hemisphere (ESO) / European Association for Astronomy Education (EAAE)

www.eso.org/public/outreach/eduoff/info-solsys/

Designed for astronomy teachers and students, the *Journey across the Solar System* information sheets use diagrams, images and texts to explain the main facts about the Solar System, the Sun, planets, moons, asteroids and comets.

Astronomy Exercises: www.astroex.org

Together with the European Space Agency (ESA), ESO has also developed a series of astronomy exercises for secondary schools. They can be downloaded or ordered online.

European Space Agency (ESA)

ESA Kids (German, English, Spanish, French, Italian, Dutch): www.esa.int/esaKIDSen/

Aimed at children in primary and lower secondary school, the ESA Kids website includes information about space and ESA's activities, quizzes, competitions, and instructions for building space models.

Instructions for building yet more models – this time of ESA spacecraft – can be downloaded here: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=35013

ESA Education (English and other European languages): www.esa.int/esaED and www.esa.int/esaHS/education.html

ESA provides a range of online materials for primary and secondary school, developed in collaboration with teachers. Including lesson plans, facts sheets, ideas for projects, satellite images, animations, analytical software, movies, exercises, games, quizzes and cartoons, they can be used to enliven geography, biology, physics, chemistry and mathematics lessons.

Some topics covered are Earth observation (water, volcanoes, atmospheric pollution, satellites, major disasters, weather and agriculture), the Universe and our Solar System, and humans in space (the International Space station, Newton in space and human physiology).

Howard Hughes Medical Institute (HHMI)

www.hhmi.org/biointeractive/

To support biology teachers, the HHMI has developed *Biointeractive*, an extensive website with animations, slide shows, videos and lectures by leading research scientists. The lectures can be downloaded as podcasts or ordered on DVD, and are supported by lesson plans and activities for the classroom – all developed together with secondary-school teachers. Online slide shows cover evolution and medicine, RNA interference, human origins and many other topics. Also online are interactive biomedical laboratory simulations including a bacterial identification lab, a cardiology lab and a neurophysiology lab.

Institute of Physics

www.iop.org/activity/education

The UK's Institute of Physics (IOP) provides online ideas and resources for teaching advanced physics to students aged 16-19. For younger students, there are interactive games (SimPhysics), with advice for teachers on how to use the games in lessons. Readers can also order a series of CD-ROMs to support non-specialists who teach physics to 11- to 14-year-olds (note that these materials are not free of charge).

The IOP also (co-)produces several other good websites:

- physics.org, with online games and physics experiments, career information and much more: www.physics.org
- Practical Physics, for physics teachers to share their skills and experience of making experiments work in the classroom: www.practicalphysics.org
- The Joint Earth Science Education Initiative supports non-specialists teachers of earth sciences by providing classroom resources for students aged 11-16. Instructions for practical experiments, teachers' notes, student materials and video clips can all be downloaded. See www.esta-uk.org/jesei/
- Secondary Online Science provides online games together with suggestions for incorporating the games into science lessons for 11- to 14-year-olds.

Montana State University

http://btc.montana.edu/ceres/

Scientists from Montana State University have worked with secondary-school teachers to create a library of online and interactive education materials for teaching astronomy. These web-based lessons incorporate online NASA resources, data and images.

National Aeronautics and Space Administration (NASA)

NASA Education: http://education.nasa.gov

The US National Aeronautics and Space Administration provides educational material for all student ages and a broad range of subjects: earth science, history, life science, mathematics, physical science and space science, technology and engineering. Materials include podcasts, videos, classroom activities, posters, pictures, puzzles and instructions for building models of space shuttles and gliders. The materials can be browsed by student age or science subject.

NASA Space Place (English and Spanish): http://spaceplace.nasa.gov/en/kids/

For primary-school children, this website offers online games, animations and facts about space. The 'teacher's corner' includes ideas for classroom activities, podcasts, posters and high-resolution images.

National Human Genome Research Institute

www.genome.gov/Education/

This website provides materials for secondary-school teachers in the form of videos, animations, articles, classroom activities, lesson plans and games about the genome and the Human Genome Project.

An online education kit, *Understanding the Human Genome Project*, examines genetic variation and what it means to be a human, how a genome is sequenced, the ethical implications of the Human Genome Project, and much more. There is also a detailed guide to using the website *DNA from the Beginning*: www.dnaftb.org

Science in Public Areas (English, French, German, Italian, Spanish, Portuguese, Arabic, Chinese and Bulgarian)

www.scienceinpublicareas.org

Why is the sky blue? Why does the setting Sun appear to be red? The European Physical Society asks 50 questions related to physics and relevant to everyday situations. The online answers are short, informative and scientifically correct and therefore suitable for children in both primary and secondary schools. The website can be used as it is, or posters with the questions and answers on can be ordered online.

Science Learning Centres

www.sciencelearningcentres.org.uk

The Science Learning Centres not only offer many courses for UK teachers, they also provide nearly 500 teaching resources on topics as diverse as biology, chemistry, ethics, earth science, ICT, general science, physics and psychology. Resources are available for all ages of school students, and include podcasts, teaching ideas, websites with background information, and films. You need to register to download the resources, but registration is free of charge.

Science on Stage

www.esa.int/SPECIALS/Science_on_Stage or www.scienceonstage.net

In a series of national events culminating in an international science teaching festival, Science on Stage offers European teachers the chance to exchange successful and innovative teaching methods and materials. Details of many of the best teaching ideas presented at the festivals - covering all areas of science – can be downloaded or viewed online.

Seeing Science

www.seeingscience.cclrc.ac.uk

This website, by the UK's Science and Technology Facilities Council, provides interactive resources to support science teaching at key stage 3 (11- to 14-year-olds) and key stage 4 (14- to 16-year-olds). They include teachers' notes (with links to original research), lesson plans, student worksheets, video clips, animations and images. Topics include anthrax, the history of astronomy, nanotechnology, chocolate manufacture and nuclear radiation. A supporting CD-ROM can be ordered online free of charge.

Resources in German

Deutsches Elektronen Synchrotron (DESY)

KworkQuark: www.kworkquark.net

DESY's KworkQuark portal explains research topics in particle physics with aid of information pages, an online encyclopaedia and games.

Media catalogue for physics teachers:

http://zms.desy.de/arbeiten__lernen/schueler__lehrer/medienkatalog/index_ger.html

From the *Medienkatalog für Physiklehrer*, you can download overhead transparencies about particle physics, particle accelerators, photon research and other topics.

Deutsches Zentrum für Luft- und Raumfahrt (German and English)

www.dlr.de/Desktopdefault.aspx/tabid-634/1061_read-1451/

The German Aerospace Centre *School Information on Space* booklets are aimed at students and teachers in primary and secondary schools. Topics covered include 'the dream of flights', German astronauts and the Solar System. The booklets can be downloaded or ordered online. English equivalents of the materials are available on the ESA Education website, see page 69.

European Particle Physics Outreach Group (German)
http://www.teilchenphysik.org/schulmaterial.htm

The teaching material *Teilchenphysik in der Schule* provides interactive animations, quizzes, videos, experiments and lessons for secondary-school teachers on physics topics such as particle physics, radioactivity and matter.

Helmholtz Gemeinschaft

www.helmholtz-campus.de

From the 'student campus' (*Schülercampus*), you can download games about scientific topics, including magnetism, glaciers, radiation, the nervous system, fusion energy, volcanoes, bacteria and virtual scientific laboratories.

The brochure *Involvement in Helmholz School Laboratories* (*Broschüre zur Machmit-Aktion der Helmholtz-Schülerlabore*) describes some scientific experiments to carry out with easily obtainable resources, for example how to measure acidity using red cabbage or how to build a thermometer. The brochure can be downloaded or ordered online.

The Helmholtz Gemeinschaft consists of several research institutes working in different scientific fields. Some of these research institutes provide their own additional teaching material. See www.helmholtz.de/de/Allgemeines/Zielgruppen/Schueler_und_Lehrer/Ergaenzende_Angebote_fuer_Lehrer_und_Schueler.html

Examples include:

- The National Research Centre for Environment and Health (*GSF-Forschungszentrum für Umwelt und Gesundheit*), which organises a 'transparent laboratory' (*Gläsernes Labor*) offering laboratory courses for school students. The protocols of some of the experiments carried out can be downloaded online: www.gsf.de/neu/gsf-lab/experimente.php
- The German National Research Centre for Geosciences (*GeoForschungsZentrum*), which provides teaching material in the form of overhead transparencies, texts and flyers. See http://schule.gfz-potsdam.de
- The Hahn-Meitner-Institute provides online resources to support the teaching of materials science in secondary schools. Topics include cryomagnets, neutrons and solar panels. See www.hmi.de/bereiche/info/index.html

Max Planck Gesellschaft

The Max Planck Society provides three German-language publications (Biomax, Techmax and Geomax) that present recent science findings in an understandable manner, and link them to the senior secondary-school curriculum. They can be downloaded or ordered online, and additional materials for teachers are available here: www.max-wissen.de

Resources in French

Palais de la Découverte

www.palais-decouverte.fr

The Palais de la Découverte is a science museum which provides online teaching materials.

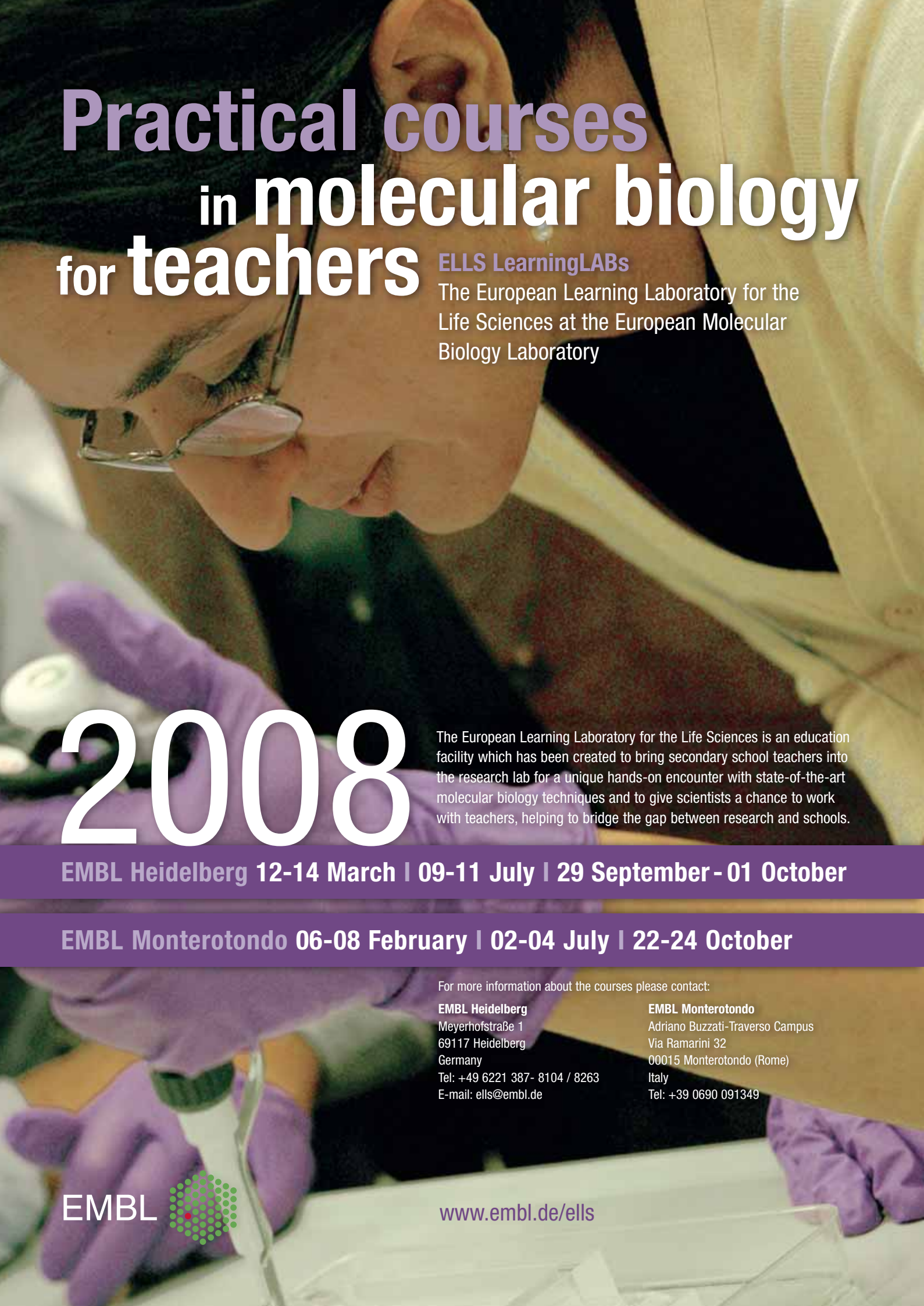
Centre National de la Recherche Scientifique

www2.cnrs.fr/multimedia

The Centre National de la Recherche Scientifique (National Centre for Scientific Research; CNRS) is a research centre which provides online teaching materials.

Why not tell other readers about your own favourite online teaching resources via the new *Science in School* online discussion forum: www.scienceinschool.org/forum

To suggest other types of websites that you would like us to review, email editor@scienceinschool.org. In the subject field of the email, please include the text 'Website review'.



Practical courses in molecular biology for teachers

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The European Learning Laboratory for the Life Sciences at the European Molecular Biology Laboratory

2008

The European Learning Laboratory for the Life Sciences is an education facility which has been created to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques and to give scientists a chance to work with teachers, helping to bridge the gap between research and schools.

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For more information about the courses please contact:

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Meyerhofstraße 1
69117 Heidelberg
Germany
Tel: +49 6221 387- 8104 / 8263
E-mail: ells@embl.de

EMBL Monterotondo
Adriano Buzzati-Traverso Campus
Via Ramarini 32
00015 Monterotondo (Rome)
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www.embl.de/ells

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

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Science in School is a non-profit activity, part of the NUCLEUS project supported by the European Union.

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Published by EIROforum:

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ISSN: 1818-0353