Summer 2007 Issue 5

SCIENCE in SCHOOL

In this Issue:

Down to Earth

Astronaut Thomas Reiter talks to *Science in School*

Also:

SCIENCE on Stage

The international science teaching festival

Highlighting the best in science teaching and research

Publisher
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Editor
Dr Eleanor Hayes, European Molecular Biology Laboratory, Germany

Assistant Editor
Dr Sai Pathmanathan

Copy Editor
Dr Caroline Hadley, European Molecular Biology Organization, Germany

Composition
Nicola Graf, Germany
Email: nicolagraf@t-online.de

Printers
ColorDruckLeimen, Germany
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Layout Designer
Vienna Leigh, European Molecular Biology Laboratory, Germany

Web Architect
Francesco Sottile, European Molecular Biology Laboratory, Germany

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European Schoolnet
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The starry flowers
Image courtesy of Aleksandra, Poland (aged 12)

Contents

Welcome to the fifth issue of *Science in School*

The most exciting recent education event for me was Science on Stage, EIROforum's international teaching festival. I enjoyed meeting many of the 500 teachers attending from 28 countries – listening to their suggestions, hearing about their experience and marvelling at their innovative teaching ideas. We have two articles in this issue to tell you more about the festival and the European Science Teaching Awards that were presented there.

For our feature article, we were lucky enough to speak to Thomas Reiter, an ESA astronaut, shortly after he returned from 177 days on the International Space Station. He told us what it feels like to leave the Earth's atmosphere, what experiments he carried out in space, and how to become an astronaut.

Also looking to the heavens – this time, as far as the stars – is the third part of our 'Fusion in the Universe' series. Paola Rebusco, Henri Boffin and Douglas Pierce-Price examine how heavy elements were formed in the early days of our Universe, and what it was that mediaeval alchemists overlooked. Probing further still into the mysteries of the Universe is dark-matter scientist Jenny List, interviewed by Barbara Warmbein.

Young people sometimes wonder why they need to learn science, or what its use is in 'real life'; we asked some scientists to help you provide the answers. For a very practical application, Darren Hughes demonstrates how understanding stress lets us build safer railways and more efficient wind turbines. Ben Parker demonstrates the everyday applications of statistics – and what to watch out for in unscrupulous advertisements. Lastly, what could be closer to home than our family? Paul Tafforeau shows how X-ray studies of fossils can tell us where our hominoid ancestors evolved.

Does education always need to be so serious? We think not, especially with the help of Johan Leveau's Mycomuncher DNA puzzle – a stimulating and entertaining way to learn how scientists discover the DNA sequence of a gene, and find out what the gene is for. You can even build the puzzle yourself. In a similar

vein, Caroline Molyneux demonstrates the benefit of playing music in science lessons.

Two important topics in the news – and in the classroom – are climate change and renewable energy. Elisabeth Schepers from the Deutsches Museum in Munich, Germany, describes a school project to allow students to discover the important facts and debate what they can do themselves to protect the environment. One way is of course to use more sustainable materials; David Bradley discusses advances in the manufacture of bioplastics – and our teacher reviewer suggests many uses for the article in the classroom.

Several of the articles in this issue relate to developments in the UK – an experimental new curriculum (Twenty First Century Science); an ambitious network of Science Learning Centres for teachers; and INSPIRE, a programme to combine post-doctoral research with school teaching. We selected these as stimulating examples of developments in European science education, but we are convinced that similarly impressive ideas are being developed elsewhere in Europe. Please write and tell us about fundamentally new curricula, innovative teaching-training programmes or other large-scale changes to science education in your countries. Did they work well? Why? Why not? We would be interested to hear both the teachers' and policy makers' perspectives.

There are plenty of other opportunities for teachers and pupils to get involved. The charity Sense about Science is looking for teachers to test their classroom resource on peer review. Meanwhile, Diana Schimke is busy linking schoolgirls with professional female scientists through the CyberMentor programme. Isabel Plantier describes some of her fun classroom projects, and her ideal space project – if you share her dream, you can help make it reality.

In our recent events section are the results of the *Catch a Star!* competition which some of you entered, and a report on WONDERS, the spectacular Carousel of Science. If you missed these events, you can join in next year – or take a look at our list of other forthcoming European events in science education.

Finally, we would be delighted to hear your feedback about *Science in School*. It's still not too late to fill in our questionnaire and tell us what you like about the journal, what could be improved, and which are your favourite articles. See http://www.surveymonkey.com/s.asp?u=686913395017

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

Forthcoming events

3-9 June 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Germany (Rheinland-Pfalz, Baden-Württemberg) and takes place in German.
Contact: Mike Storr (mick.storr@cern.ch)

Until 4 June 2007
UK
Competition: Making a Mint
Send off for a free pack of mint seeds, a balance sheet and a wall chart of growing tips. Grow your own mint and then, if you like, devise some good ideas of how to sell it and let Planet Science know your total turnover. If you are in the top 50 money earners, your ideas will be considered for a prize of £1000 of gardening vouchers (£250 for each of the four runners up).
More information:
www.planet-science.com/outthere/mint/

3-24 June 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Finland and takes place in Finnish.
Contact: Mike Storr (mick.storr@cern.ch)

7 June 2007
Rugby School, Rugby, UK
Conference: 19th Annual Meeting for Teachers of Physics in Schools and Colleges
Organised by the Institute of Physics, this is a one-day meeting for teachers of physics in schools and colleges, and for teachers in training. The main purpose is to bring together physics teachers from both state and independent schools to learn about the latest developments in physics and physics education. Three lectures are given by leading research physicists and by physics education experts, together with a series of six hands-on workshops, discussion sessions and a teacher exchange of news and information. The meeting also provides an opportunity for equipment suppliers, publishers and awarding bodies to communicate their new products.
Most participants come from England and Wales, but teachers from further afield are very welcome. Conference fee: £30 including lunch (concession for new and trainee UK teachers: £15).
Contact: Chris A. Butlin, Chairman of the Institute of Physics School Physics Group (ChrisAButlin@aol.com or +44(0)1904 607 169)

14 June 2007
Technopolis, Mechelen, Belgium
Conference: PENCIL Final Science Teachers' Conference
Science teachers are invited to participate in workshops and debates on how schools and science centres can come together at the forefront of science education. The conference will give concrete examples of best practice from the 14 European PENCIL pilot projects, covering a wide range of topics and student age groups. These projects have been tested and evaluated in schools, as well as in science centres and museums. Using these results, the conference offers teachers pragmatic guidelines on the

following key areas:
- The introduction of new topics in science
- New approaches to teaching and learning traditional subjects
- Building relationships between schools and science centres and museums.

Teachers will have the chance to network and exchange their experiences with colleagues from all over Europe. The working language is English and participation in the conference is free.
More information: www.xplora.org/xplora/pencilconference07/
Contact: Michael Creek: mcreek@ecsite.net

Until 20 June 2007
Germany
Competition: Science on Stage Deutschland 'Spannung in die Schule'
Secondary-school teachers in Germany are invited to enter this year's Science on Stage Deutschland competition, 'Spannung in die Schule' (Excitement at School). Entries should consist of exciting and practical teaching ideas, school projects or activities. They may include any subjects, but should be relevant to science.
Prizes worth up to €3000 will be awarded in September 2007 by Nobel prize-winner in physics, Professor J. Georg Bednorz.
More information: www.science-on-stage.de
Contact: info@science-on-stage.de

23 June - 17 July 2007
Göttingen, Germany
Training course: International science camp
Organised by XLAB, the international science camps are open to interested high-school students and undergraduate college and university students, about ages 17-22, from all over the world. Courses are offered in biology, chemistry and physics and held by scientists from the University of Göttingen and affiliated research organisations. The scientists are assisted by experienced technical assistants.
More information: www.xlab-goettingen.de

July 2007
Moscow, Russia
Workshop: Space Development, Theory and Practice
It's 50 years since Sputnik 1 was launched by the Soviet Union, so what better way to celebrate than a trip to Russia?
The Space Development, Theory and Practice workshop is run by the Youth Space Centre, part of one of Moscow's best universities. You will visit the companies that made all the groundbreaking space hardware and learn about the past, present and future of space activities. Closing date: 8 April.
More information: http://ysc.sm.bmstu.ru
Contact: russia@uk.seds.org

2-21 July 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Europe and the USA and takes place in English.
Contact: Mike Storr (mick.storr@cern.ch)

4-6 July 2007
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 participant teachers to explore a range of activities, which they can practise 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

10 July 2007
Madrid, Spain
Workshop: Active Learning of Physics and Chemistry
Physics and chemistry teachers of different education levels are invited to a workshop organised by the Real Sociedad Española de Química (Spanish Royal Society of Chemistry) and the chemistry didactics group at Universidad Politécnica de Madrid, about cooperative learning, conceptual maps, problem-based learning, laboratory activities, and other educational tools for active chemistry and physics learning. It is also an opportunity to discuss the European credit-transfer system used at universities. All papers presented will be published in a book. The working language is Spanish but teachers from outside Spain are warmly welcome.
More information: www.etsii.upm.es/ieducativa/Jornada2007.htm
Contact: Prof. Gabriel Pinto (gabriel.pinto@upm.es)

21-25 July 2007
Ecole Normale Superieure, Paris, France
Science festival: Festival Paris Montagne 'Sur les traces des chercheurs' (Following the footprints of research)
This annual summer science festival is dedicated to children and teenagers from underprivileged backgrounds. It takes place at the prestigious Ecole Normale Superieure, a university at the heart of the scientific area of Paris. The science festival opens the world of science and research to its 3000 visitors, aged 9-17.
More information: www.paris-montagne.org

22-28 July 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Spain and takes place in Spanish.
Contact: Mike Storr (mick.storr@cern.ch)

4-28 August 2007
Göttingen, Germany
Training course: International science camp
Organised by XLAB, the international science camps are open to interested high-school students and undergraduate college and university students, about ages 17-22, from all over the world. Courses are offered in biology, chemistry and physics, and held by scientists from the University of Göttingen and affiliated research organisations. The scientists are assisted by experienced technical assistants.
More information: www.xlab-goettingen.de

18-30 August 2007
Petnica Science Center, Serbia
Training course: Petnica International Science School 2007
The summer programme of the Petnica Science Center gathers gifted and motivated school students from south-east Europe and beyond. This intensive and stimulating course on scientific research methods includes lots of practical exercises and real research projects under the supervision of experienced science educators and professional scientists.
All students aged 17-20 are eligible. The main selection criteria are motivation for out-of-school learning and a demonstrated interest in science. Although school grades are important, they are not the deciding factor. Open-mindedness and willingness to work are much more important.
More information: www.psc.ac.yu/pi
Contact: pi@psc.ac.yu

19-25 August 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Hungary and takes place in Hungarian.
Contact: Mike Storr (mick.storr@cern.ch)

22-24 August 2007
Gembloux Agricultural University, Gembloux, Belgium
Conference: Congrès des Sciences (Belgian Science Teachers' Congress)
This congress for secondary-school science teachers includes lectures in science and didactics, workshops, demonstration experiments, a textbook and science-hardware fair, plus visits to various labs, industries and places of scientific interest. The working language is French and the congress fee is €10 (or free for many teachers).
More information: www.congres-des-sciences.be
Contact: accueil.information@fsagx.ac.be or presidence@congres-des-sciences.be

26-31 August 2007
Opatija, Croatia
Conference: GIREP-EPEC: Frontiers of Physics Education
For the first time, the GIREP (International Research Group on Physics Teaching) Seminar is organised as a joint event with the European Physics Education Conference (EPEC). Whereas GIREP traditionally gathers experts and practitioners in educational physics, EPEC is a young conference organised by the European Physical Society, which attracts the top physicists in Europe. The joint conference will bring together physics teachers from schools and universities across Europe, encouraging dialogue and the exchange of best practice in physics education.
Teachers are invited to join this conference. (Theme to be arranged, the working language will be English.)
More information: www.ffri.hr/GE2/
Contact: ge2@ffri.hr

1-8 September 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Germany (Bavaria, Nordrhein-Westfalen) and takes place in German.
Contact: Mike Storr (mick.storr@cern.ch)

9-15 September 2007
York, UK
Science festival: The BA Festival of Science
In September, the University of York, the city of York and the surrounding area will experience an explosion of science. From excursions and hands-on family days to debates on current hot topics and unique opportunities to question the UK's top scientists, the BA Festival of Science offers something for everyone.
Schools can be involved through a programme of specifically designed activities for students of all ages, their teachers and their supporters. As Europe's largest celebration of science, it offers the opportunity to find out about latest developments in an exciting and informative way by connecting with a range of scientists, engineers, technologists, museums and businesses. There is also a strand of education events specifically aimed at science teachers.
Local UK schools will receive full details and booking information in the summer term. To make sure you are on the mailing list, email or call the contact details below, mentioning the schools programme.
More information: www.the-ba.net/festivalofscience
Contact: festival@the-ba.net or telephone +44 (0)20 7019 4963

9-15 September 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Portugal and takes place in Portuguese.
Contact: Mike Storr (mick.storr@cern.ch)

14 September 2007
Universität Kassel, Germany
Workshop: English-language biology and chemistry lessons in German schools
Biology and chemistry teachers who teach in English are invited to a workshop organised by the Verband deutscher Biologen and the Vereinigung der Schulen mit deutsch-englisch bilingualem Zug in gymnasialen Bildungsgängen in Hessen.
Participants who already have experience in bilingual teaching are requested to submit worksheets or teaching ideas for a joint collection of teaching materials. Teachers from outside Germany are warmly welcome. Workshop fee: €10
Contact: Matthias Bohn (mbohnde@aol.com)

14-20 September 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and participants are expected to pay for their travel expenses and accommodation.
This course is for participants from Germany (Baden-Württemberg, Sachsen and Sachsen-Anhalt) and takes place in German.
Contact: Mike Storr (mick.storr@cern.ch)

10-12 October 2007
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 teachers to explore a range of activities, which they can practise 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

31 October - 2 November 2007
CERN, Switzerland
Training course: CERN high-school teacher programme
CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students of ages 13-16.
The courses are free of charge, and the participants are expected to pay for their travel expenses and accommodation.
This course is for participants from France and takes place in French.
Contact: Mike Storr (mick.storr@cern.ch)

Until 30 November 2007
Italy, Austria and Switzerland
Competition: Junge Forscher gesucht! – Giovani ricercatori cercansi! (Wanted: young researchers!)
In this search for talented young researchers, young people are required to develop scientific projects on many topics, including art and music. Regional finalists, selected on the basis of a report they submit, present their project to an international jury and the public. Prizes of €1500-3000 are awarded.
The competition is open to people aged 16-20, living in South Tyrol (Italy), Trentino (Italy), Tyrol (Austria) or Grisons (Switzerland) and is held in the regional languages German and Italian.
To enter the next competition, register before 30 November 2007. The final event will take place in March 2008 at the University of Innsbruck, Austria.
More information: www.explora-science.net/wettbewerb

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

Throughout 2007
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. Students isolate plasmid DNA from bacterial cultures and digest it with restriction enzymes. The resulting DNA fragments are separated and visualised by gel electrophoresis.
Students should already have the necessary theoretical background and be over 17 years of age. The workshops are free, are in German or English (on request) and have a maximum of 20 participants.
More information: www.schullabor.ch
Contact: gesche.standke@novartis.com

Throughout 2007
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)

Throughout 2007
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

Throughout 2007
Glasgow Science Centre, Glasgow, UK
Free teacher visits
Teachers, classroom assistants, nursery teachers and technicians are invited to visit the Glasgow Science Centre free to explore and investigate what's on offer.
More information: www.glasgowsciencecentre.org
Contact: +44 (0)871 540 1003

Throughout 2007
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 their 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

Throughout 2007
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)

Throughout 2007
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) at a cost of £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)

Throughout 2007
Paris Montagne, Paris, France
Science Academy
Paris Montagne runs a year-round outreach programme in all Parisian suburbs. The programme is for high-school students who are interested in sciences but not confident enough to enrol in undergraduate studies, due to social and cultural hindrances. The organisation offers students 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 (100 in April 2007, and many more expected in August and October 2007). The most dedicated participants in the programme are offered the chance to take part in a summer camp during the Paris Montagne science festival (21-25 July 2007).
More information: www.scienceacademie.org

Throughout 2007
INTECH, Winchester UK
Free teacher previews
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, website and contact email address, to editor@scienceinschool.org

Science teaching flies high at Science on Stage 2

Science on Stage 2 took place during the first week of April and brought together some of the best science teachers in Europe. **Montserrat Capellas** describes some memorable moments.

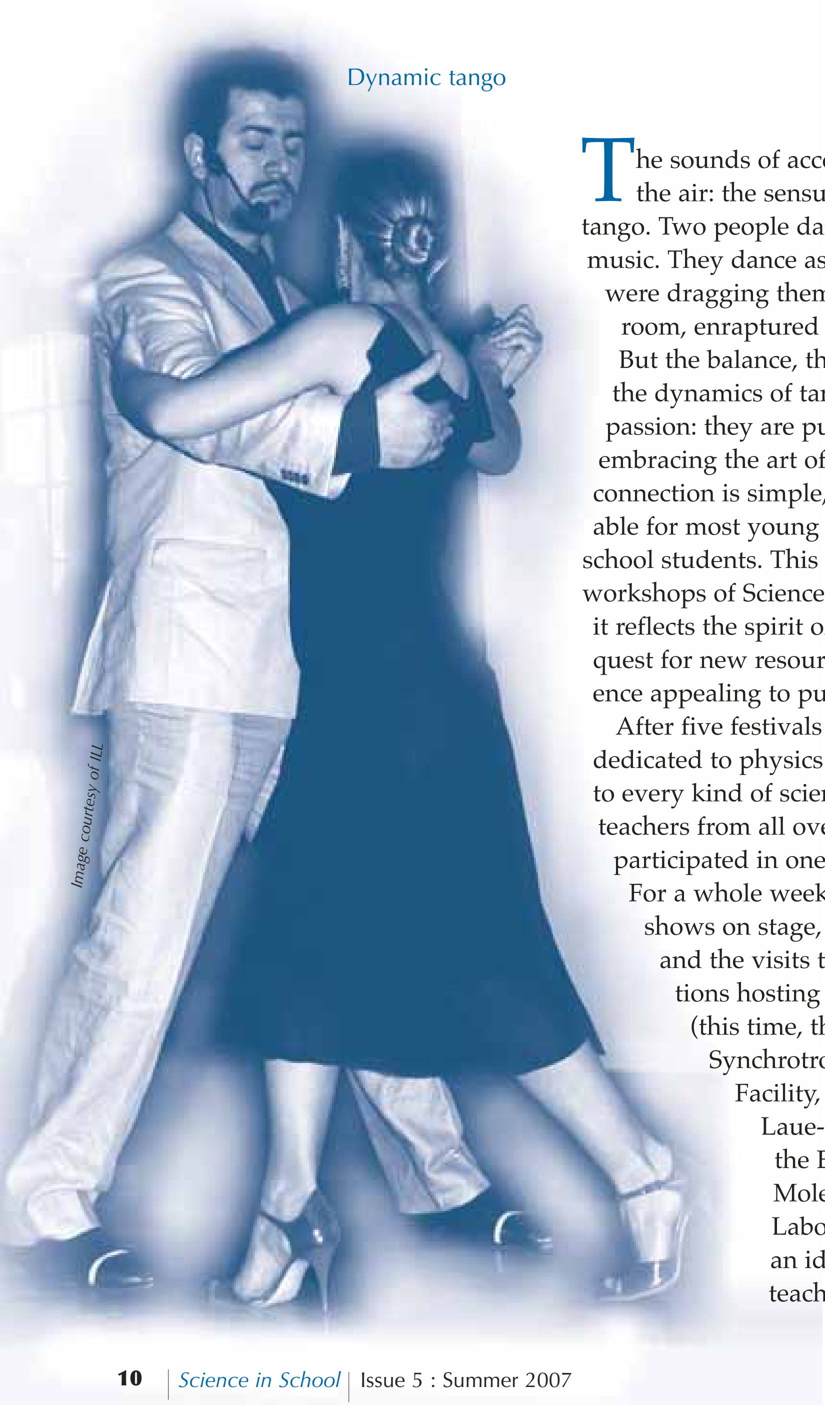
Dynamic tango

Image courtesy of ILL

The sounds of accordion music fill the air: the sensual tune of a slow tango. Two people dance to the music. They dance as if their spirits were dragging them across the room, enraptured by the music. But the balance, the signals and the dynamics of tango go beyond passion: they are pure physics embracing the art of dancing. The connection is simple, yet unimaginable for most young secondary-school students. This is one of the workshops of Science on Stage 2 and it reflects the spirit of the event: the quest for new resources to make science appealing to pupils.

After five festivals (the first three dedicated to physics and the last two to every kind of science), about 2000 teachers from all over Europe have participated in one of the events. For a whole week, the fair, the shows on stage, the workshops and the visits to the organisations hosting the festival (this time, the European Synchrotron Radiation Facility, the Institut Laue-Langevin and the European Molecular Biology Laboratory), provide an ideal scenario for teachers to exchange views with each other and with scientists. During a round-table discussion at Science on Stage 2, the 500 teachers participating from 28 countries could also pose their questions to leading decision-makers, including EU Commissioner for Research, Janez Potočnik. The million-dollar question is: does Science on Stage accomplish its purpose?

David Richardson, a physics teacher in Bristol, UK, says it does. "The best thing is to see how other countries present the same principles with a different cultural approach." For him, it is not only about being a spectator, but also about learning from other teachers. "I attended Physics on Stage 3 and I got so many ideas from it that I based a show in the UK on what I had seen. It was called 'Physics to make you go wow'."

Not far from the UK stand is the Spanish stand. Juan Miguel Suay, a physics teacher in a city near Alicante in Spain, is building kites using paper and kebab sticks with a peculiar shape. The aim is to explain geometry and aerodynamics. He shares David's vision about the value of the event: "I am getting lots of ideas for my lessons," he explains. The most attractive experiment he has noticed demonstrates pressure with very simple and available tools.

EU Commissioner for Research Janez Potočnik (left) and Michel Destot, the Mayor of Grenoble (right), join in the fun in the Dutch Science Truck

Tetrahedral kites

Didier Robbes, a university teacher from the University of Caen, France, is focused more on business. His experiment on electromagnetism, based on the Maxwell and Faraday equations, will soon be commercialised by a company he is setting up "with the aim to teach", he explains. Science on Stage has allowed him to find a group of Italian potential partners for his project. Despite being a university professor, Didier is still actively linked to secondary schools and defines the festival as "a fabulous eclecticism".

With a wide variety of imaginative and sometimes wild experiments, Science on Stage could make people change their minds about science being boring. According to Juan Miguel, "pupils – and even parents – think science is for freaks. However, science is about finding out how the world works, and why things are one way and not another." He has almost finished the kite now. He will let it loose in the Grenoble wind to fly high – in the same way that his (and the rest of the teachers') ideas have flown high for the last week.

Resources

Science on Stage is organised by EIROforum, the publishers of *Science in School*, with the support of the European Commission. The international science teaching festival in Grenoble was the culmination of national events in 28 countries.

For more information and to find your national contact, see: www.scienceonstage.net

To find out more about EIROforum and its seven member organisations, see www.eiroforum.org

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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

Image courtesy of ILL

The science teaching fair

Awards, rewards – and onwards!

At Science on Stage 2, the European Science Teaching Awards 2007 were presented for the 12 best projects. **Eleanor Hayes**, editor of *Science in School*, describes how the jury made their difficult decisions.

The *unbelievable* noise of 500 science teachers demonstrating their experiments, their materials and their ideas in the science teaching fair: the most intriguing, explosive and multilingual marketplace you've ever seen! The nose-tingling smell of innumerable chemical reactions. And the unforgettable sound of one Romanian delegate singing a song composed specially for the occasion.... It could only be Science on Stage!

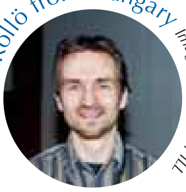
At the Science on Stage 2 festival in Grenoble, France, the eight-person jury spent a week prowling around the fair: the heart of the event. We had €18 000 worth of European Science Teaching Awards to allocate: four cash prizes and eight organisational prizes (including sponsored visits to research institutes, laboratory equipment and books). Twelve prizes, 30 countries and 500 delegates – selected by their countries to represent the very best in European science education. How could we possibly choose?

Our key criteria were innovation, relevance in school and reproducibility: was it new, could other teachers copy it, and did it matter? Sounds easy, but the competition was impressive. So much inspiration, such professional student-made equipment – and above all, such enthusiasm for science and education!

Mario Mitov from Bulgaria

Image courtesy of ILL

Our search for innovative teaching led us to Per Kornhall, from Sweden, with his ambitious project to 'Teach Science in a Different Way' (EPS Prize). As tired of basic physics as his students were, he had jumped straight in with molecular orbitals, relativity, stereochemistry, the Big Bang and quantum theory. The result? Students' attendance and their respect for science rose noticeably.



Zoltán Köllö from Hungary

Image courtesy of ILL

The very small and the very large can be particularly challenging to teach, especially without expensive equipment. We were therefore happy to be pounced on by Zoltán Köllö, from Hungary, who had created a number of clear and simple models, including a demonstration of nuclear fusion and the Coulomb barrier using a couple of drops of water! Impressed by his ideas and enthusiasm, we awarded him the fourth-place cash prize (€1000). Also a fan of the simple simulation, Panayiota Neophytou from Cyprus (EMBL Prize) and her students created an innovative 3D model of the animal cell, using cheap and readily available materials. What an effortless and fun way to learn difficult words like 'mitochondria'.

Moving from the minute to the immense, Ida Regl, from Austria, encouraged her primary-school students to pose questions about the Sun and then design and perform their own experiments to answer them. And what questions! The ambitious 'Sunny Side Up' project covered not only light refraction, colours, heat and gravity, but also Sun flares, Sun granulation, sunspots and photovoltaics. Ida received a well-earned third-place cash prize (€2000).

The Sun played a vital role too in Mario Mitov's Bulgarian demonstration of an ecological energy system. Energy from a solar panel or wind turbine was used to electrolyse water, and the resultant hydrogen and oxygen produced electricity in a reversible fuel cell. Designed by students, the modular apparatus will be commercialised to provide Bulgarian teachers with inexpensive and flexible equipment – and won Mario the second-place cash prize (€3000).

In our hunt for interdisciplinary work, we were bowled over by Angela Köhler and her 'Chemistry Under the Pyramids' project (ESRF Prize), in which she and her students rediscovered chemistry used by the ancient Egyptians. On the German stand, Angela showed us how to mummify an apple, synthesise Egyptian Blue pigment, and recreate ancient Egyptian cosmetic recipes – one of the jurors claimed the marigold (*Calendula*) salve was very effective.

Herbs were particularly important in Nils Bernt Andersen's 'Juicy Greens' student enterprise (EFDA Prize). Algal waste from a local factory-together with suitable school refuse – was used to investigate the most effective way to make compost. That done, the students grew organic herbs and vegetables – and sold them to local restaurants from their green-painted bicycle.

Ida Regl from Austria

Image courtesy of ILL

Continuing the theme of a healthy diet, we came across Gianluca Farusi from Italy. His 'Looking for Antioxidant Food' project (ILL Prize) encouraged students to eat more healthily by introducing them to the many diseases associated with free radicals and getting them to compare the antioxidant activity of different foods. The conclusion? Drink more espresso!

One criterion for the jury was whether the project could be easily used in other European schools. And what could be more useful than the books, DVDs and CD-ROMs developed by Patric Pacella from Luxembourg (CERN Prize)? Dissatisfied with the available textbooks, he has created a resource for all chemistry teachers – and has

Image courtesy of ILL

Per Kornhall from Sweden

Image courtesy of ILL

Angela Köhler from Germany

Image courtesy of ILL

Gianluca Farusi from Italy

filmed just about every chemical reaction you would want to do at school, plus plenty that you could never do yourself because they are too expensive or dangerous.

Not only fascinating and instructive but also beautiful: Vincent Devaux, Michel Merlange, Jean-Paul Chamozzi and their French students (ESA Prize) designed underwater bubble machines. The students developed several different submarines powered by effervescent tablets,

Image courtesy of ILL

Claudia Bezzina and her colleague from Malta

Image courtesy of ILL

Vincent Devaux, Michel Merlange and Jean-Paul Chamozzi from France

which used Archimedes' principle and cleverly shaped components to roll, bob or rotate through a tank of water. These were accompanied by bilingual films telling the story of the submarine captain's daring manoeuvres.

Storytelling was also central to Claudia Bezzina's Maltese project (ESO Prize), which linked historical stories with simple scientific experiments, capturing the imagination of students and jury alike. Her student booklet will be published soon.

Finally, our top prize of €4000 went to Finn Skaarup Jensen from Denmark for 'Robots in Real Life'. His build-it-yourself robot kits not only look appealing, but demonstrate mechanics, hydraulics and electronics to students aged 13 and upwards.

During the week, we heard with delight about the continuing work of the CERN prize-winners from Science on Stage 1. After winning their prize for using lichens to measure water quality, Maria das Mercês Silva e Sousa and Maria Joao Carvalho not only convinced two universities and a factory to join their school project but also succeeded in changing

Finn Skaarup Jensen from Denmark

Image courtesy of ILL

Portuguese national policy on water quality! We look forward to hearing from our latest batch of prize-winners: how have you developed your ideas and did the award help?

Although the noise, smell and music may fade, the longer-lasting benefits of Science on Stage will remain: the international collaborations and friendships that were forged, the ideas that were shared and developed, and the motivation of all participants. Congratulations to our 12 prize-winners, but also to everyone who brought and shared such impressive projects and made science so much fun!

Resources

More information about the festival and the awards is available on the Science on Stage website: www.scienceonstage.net

Many of the projects demonstrated at Science on Stage 2 will be published in forthcoming issues of *Science in School* – watch this space!

Starry Night by Veronika, Czech Republic (aged 12)

School students *Catch a Star!* in an astronomical competition

In Issue 3 of *Science in School* we invited you to join an international competition for school students and *Catch a Star!* Later, some of you helped to select winners by voting online for your favourite pictures. **Douglas Pierce-Price** from ESO reports on the results.

Catch a Star! is an international astronomy competition for school students, organised by ESO, the European Organisation for Astronomical Research in the Southern Hemisphere, together with the European Association for Astronomy Education (EAAE). In this year's competition, students from 22 countries submitted hundreds of written projects and pieces of artwork on astronomical themes. The winning pictures can be seen on the front cover of this issue of *Science in School*, as well as in this article.

The standard of entries was most impressive, and made the jury's task of choosing winners both enjoyable and difficult! We hope that everyone, whether or not they won a prize, had fun taking part, and learned some exciting things about our Universe.

The top prize, of a week-long trip to Chile, was won by students Jan Mestan and Jan Kotek from Gymnazium Pisek in the Czech Republic, together with their teacher Marek Tyle. Their report on 'Research and Observation of the Solar Eclipse' described how they had studied solar eclipses, and involved their fellow students in observations of an eclipse in 2006. The team will travel to Chile and visit the ESO Very Large Telescope (VLT) – one of the world's most powerful optical/infrared telescopes – where they will meet astronomers and be present during a night of observations on the 2600 m high Paranal mountaintop.

"It's fantastic that we will see the VLT in action. I'm also looking forward to my first view of the southern sky!" said Jan Mestan. His fellow student is also excited about the trip. "I am very happy that we'll visit the Paranal observatory, because this is one of the best astronomical observatories in the world, in the amazing scenery of the Atacama Desert," said Jan Kotek.

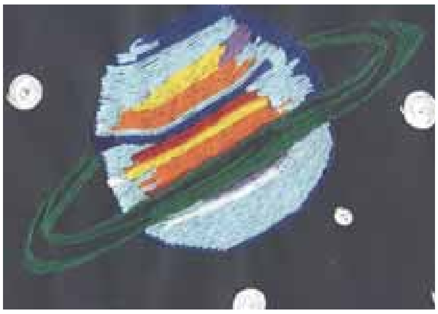
This was a very well-written project, and we particularly liked the way in which the students involved the rest of their school. The team's hard work was also helped by some good fortune, as it seemed at first that bad weather might block their view of the eclipse.

Mysterious comet by Lazar, Russia (aged 12)

"It was cloudy, overcast, and a strong west wind was blowing in Pisek. The meteorological situation was nearly hopeless, and we thought we might have to cancel the observation. But luckily, the sky cleared up and we could see the eclipse!" said the students.

Other *Catch a Star!* participants won exciting trips to observatories across Europe. Emilio Rojas, Angel Sanchez, Javier Ortiz and their teacher Roberto Palmer from Spain won a trip to Koenigsleiten Observatory in Austria for their project 'Jupiter on the Radio'. Bogumil Giertler, Ammar Ahmed, and their teacher Richard Burt from Italy won a trip to Wendelstein

Touch 1 by Kristina, Lithuania (aged 15)



Saturn by Edyta, Poland (aged 13)

The Shining Mars by Justyna, Poland (aged 16)

project 'Determining the Relative Radiant of the Geminid Meteor Shower'. Victor Raimbault, Remi Takase, Thomas Salez and their teacher Michel Faye from France won a trip to Calar Alto Observatory in Spain, a prize kindly donated by the Spanish Council for Scientific Research, for their project 'Light on Dark Matter'.

Forty other teams won prizes, which included astronomy software and sets of posters of stunning astronomical images taken with ESO telescopes. In the artwork competition, 60 winning pictures were chosen with the help of a public vote. The beautiful pictures created by students of all ages can be seen in the gallery on the *Catch a Star!* website[w1]. The full list of winners is also available online.

The competition is over for this year, but why not encourage your students to *Catch a Star!* next year? Information will be available later this year on the competition website[w2].

Web references

w1 - For further information about *Catch a Star!*, including a full list of winners and the art gallery, see: www.eso.org/catchastar/CAS2007/

w2 - Information about the next *Catch a Star!* competition, and also about previous competitions, will be available here: www.eso.org/catchastar/

Resources

Information about ESO's other education initiatives is available here: www.eso.org/outreach/eduoff/

Second European Science Festival: WONDERS 2007

Peter Rebernik from the WONDERS project describes a ride in the Carousel of Science from Moscow to Lisbon, Reykjavik to Jerusalem. Perhaps even in your town!


Image courtesy of pixelquelle.de/Michael Berger

French science shows in Estonia; Swedish science theatre in Sofia, the capital of Bulgaria; mechanics designed by the Catalan architect Gaudí demonstrated in Budapest; mathematical balls travelling from Perugia, Italy, to Reykjavik, Iceland - what kind of a carousel is that? It is WONDERS!

WONDERS, the first European Science Festival, came to an end at the Heureka science centre, Finland, in December 2006. Over the course of the year, 21 science organisations from 18 countries exchanged an impressive 63 science shows. Among many other exciting activities, visitors could cycle at the speed of light, track a white stork using a satellite, or isolate DNA from tomatoes in the kitchen. From all those science shows, two of the best science communication presentations were chosen in the Finnish finals.

The jury's favourite was 'Dr Molecula', a lively science show from the Bloomfield Science Museum in Jerusalem, Israel. "When you combine theatre and science, the result is really moving," says Ori Weyl, alias Dr


Image courtesy of Peter Rebernik

Molecula. "I was the worst science student myself, so I know that if I understand the things I am performing, the audience will understand it too!"

"Dr Molecula really showed how the language barrier becomes irrelevant when the performance is such fun and so vivid," says a jury member, Finnish high-school student Roosa Jokiaho.

The Finnish audience selected Joachim Lerch's 'Blue Light' project, a simulated factory from Germany in which visitors could assemble their own flashlights. Both adults and children were taught how to drill, countersink, tap, punch, solder, band, assemble, rivet and adhere.

Image courtesy of Peter Rebernik

Image courtesy of Peter Rebernik

Science shows are lively presentations by scientists, students, teachers and pupils, who communicate science through direct contact with the audience; volunteers are invited to join in, visitors to science cafés can discuss topics with scientists in the field, pupils can shout and scream at scary experiments. Most shows are just 15 minutes; some last 45 minutes including discussion. Visitors go from show to show, to experience the breadth of science. And most shows take place in public places: railway stations, shopping malls, tents on the main square, and so forth.

All the science shows in the Carousel of Science try to stimulate the interest of European citizens in science, encouraging them to become more curious about European science and, in the case of young spectators, to think about a future science career.

The science shows are organised by the science communication institutions of the participating countries and are sent to each other during their science festivals or science weeks. In that way, not only do the visitors to this 'foreign' show learn something in an amusing way, but also the hosting organisation can experience how other countries conduct their science shows.

In 2007, the second European Science Festival, WONDERS 2007, will see 31 organisations from 24 states participate in the Carousel of Science, exchanging science shows between cities as distant as Moscow and Lisbon, Reykjavik and Jerusalem. The Estonian university town of Tartu, for example, will send scientists to the Greek city of Thessaloniki, while the Greek researchers will in turn go to Madrid, Spain. Why not join the dizzying ride?

Resources

EUSCEA, the European Science Events Association, is the co-ordinator of this project, the European Commission is funding it, and the partners in 2007 are the European Schoolnet (www.eun.org) and EUSJA, the European Union of Science Journalists' Associations (www.eusja.org).

For more information about WONDERS and to find out about science shows in your country, see: www.euscea.org

Getting involved

Teachers who want to find out how to take their pupils to the shows can email EUSCEA General Secretary and WONDERS Co-ordinator, Peter Rebernik: office@wonders.at

Looking through the Earth's atmosphere from the ISS

Image courtesy of ESA/Thomas Reiter

Down to Earth: interview with Thomas Reiter

Shortly before Christmas 2006, German ESA astronaut Thomas Reiter returned from the International Space Station. A month later, **Barbara Warmbein** asked him about his trip, the experiments he did – and how to become an astronaut.

Thomas Reiter, German astronaut for the European Space Agency (ESA)[w1], is a true veteran of space flight. The 49-year-old father of two boys has spent more hours in space than any other ESA astronaut – almost a year in total, with 179 days on the Russian MIR space station in 1995 and 171 days on the International Space Station (ISS) in 2006. A few days before Christmas, he returned to Earth, having successfully completed a six-hour spacewalk (or extravehicular activity), collecting data for many European experiments on board the ISS, and helping to prepare the station for the arrival of the European module *Columbus*, due for launch later this year. I spoke to him by telephone at the European Astronaut Centre in Cologne, Germany.

Image courtesy of NASA

Thomas Reiter during the spacewalk on 3 August 2006

How long did it take you to recover from your long trip into space?

The first severe effects were still perceivable the morning after landing, but then recovery progressed very nicely. Right now, four weeks after landing, I don't feel anything. So within three to four weeks the effects are almost over.

What kind of effects did you feel?

There are basically three systems in the body which are affected: the vestibular (balance) system, which shows the most pronounced effect; the orthostatic system, which controls blood pressure and becomes apparent after landing, when you stand upright for a long time and get dizzy easily; and the muscles, which need to re-adapt to gravity. Of course I did a lot of physical exercise in orbit. This helps a lot in accelerating the recovery process. You need to keep your muscles trained while weightless, otherwise they would disappear. But in the first hours after landing, the effects are pretty pronounced.

What do astronauts do when they are on Earth? What are you doing at the moment, apart from giving interviews?

At the moment, the most important task is to prepare all the technical

Image courtesy of NASA

Thomas Reiter works on a cooling line on the International Space Station

debriefings for the scientists, operations people and management.

Does that mean giving them results of the experiments?

Not only results. I don't work on results of scientific experiments because that is done by the scientists themselves. But they like to know under what conditions the experiments were executed. And of course there are a lot of technical questions from our systems and operations people, for example about how they can improve the scheduling to make work on the ISS as efficient as possible – to get as much time as possible for scientific work. These kinds of debriefings are done with every agency. I started that in Houston with NASA[w2], now this whole process is taking place here at ESA, and in two weeks I will have the debriefings with our Russian partners[w3].

Did you find anything specific that could be improved?

Of course, there is always something to be done. Our intention was to prepare the operations team for the arrival of the European experiment module *Columbus* and especially the immediate start of an operation to make full use of *Columbus*. Based on the last six months that I have been on the ISS, I think we can improve a few things, squeezing a few hours in here and there by streamlining the scheduling process. It is interesting to look at these multitudes of systems that are necessary to make a space station. These include life-support systems, altitude controls, thermal-control systems and so forth. And the experience we have gathered can be used to improve these for future space exploration, in which ESA certainly will take part... going back to the Moon, or then further in the future, going to Mars.

What did you find most impressive during your latest mission?

The most exciting moments are certainly the launch and doing an extravehicular activity.

Isn't that scary?

It's not scary, no. But it's really very, very exciting and everyone who has the chance to be up there looks forward to leaving the station for a few hours at least. There are interesting moments inside as well, catching beautiful views of the Earth or of the starry sky. And there's the re-entry. Those are the main highlights from a personal, emotional point of view.

But the work is of course the most important thing. Doing all these great experiments, and working at the frontier of all these research projects, is really very exciting. Being on board a space station itself is already something very special. It takes a lot of systems to keep the ISS running, and, even with three people, we have to work hard to maintain these systems so that the station is a place where people can live. But with each additional crew member, the relationship between maintaining the station and producing scientific results will shift much more towards the scientific work.

Which specific experiments spring to mind?

In general, I was performing experiments in the areas of life science, biology, physics and astrophysics. We also had some educational projects, which was interesting because I remember very well when I was a school-child and followed all these space-flight activities.

We had a biological experiment on the growth of plants, to help us understand the processes that happen at the molecular level. The objective is not only to grow plants in weightlessness, but to enhance agricultural output by analysing how plants grow and by improving these processes and making them resistant to particular conditions.

We also had a physics experiment called 'Plasma Crystal', which has a huge range of possible applications. At the moment it is still at an experimental stage, with scientists trying to understand how dynamics are affected by weightlessness. There could be applications in a lot of areas, like the production of semi-conductors or building fusion power plants, so this is a very interesting field.

For me as an engineer, it's interesting to see that even today there are a lot of processes in our body that are not very well understood. We had experiments on our immune system: how it or certain functions of it work. Another area of study was the cardiovascular or vestibular system. So I worked on a really wide variety of activities.

You said you also had educational experiments. Can you describe these?

We had an experiment called the 'Oil Emulsion Experiment'. It was a plastic tube containing water and oil; the oil was coloured red, and of course the water was colourless. You can observe how these two liquids – which do not mix with each other – behave in weightlessness. Here on Earth, the water is at the bottom of the tube and the oil, which has a lower density, is on top. In weightlessness, the oil forms bubbles in the water. The experiment consisted of shaking the tube to try to make an emulsion and then observing how the oil behaves over time. All this was filmed. A lot of school students all over Germany performed the experiment more or less at the same time. They made hypotheses about how the water and the oil would behave and then they watched the video from the ISS. They could then test their hypotheses.

Together with my university, University Neubiberg, we carried out some small experiments showing the stability of rotational motions. For this purpose I had a little aluminium cube with me. It had different moments of inertia, and I rotated this cube around the three different axes. All of this was filmed. You can clearly see that if you rotate this cube around two of its axes, the rotation is stable, but around the third axis the rotation is instable. That experiment was intended for school students in grade 10 (ages 15-16) and above, and for first-year university students.

I think it's interesting for pupils and students to see these practical applications of weightlessness, which would be very hard to demonstrate here on Earth.

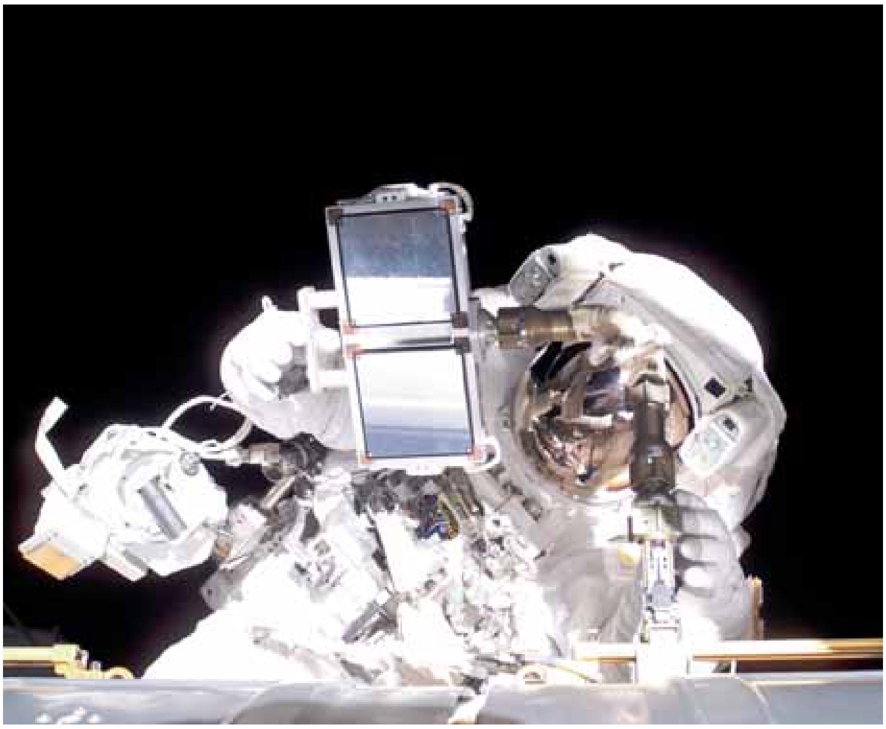


Image courtesy of NASA

Thomas Reiter during the spacewalk on 3 August 2006


Image courtesy of NASA

Exercising on board the ISS

How did you prepare for your stay in the ISS? What did you do to prepare for weightlessness and for the cramped conditions there?

The training takes a lot of time. For me, the immediate preparation for the mission took almost two years. On top of that there's the initial preparation or basic training that lasts at least another year or a year and a half. You have to learn all the different systems that keep you alive and that you depend on once you are in orbit. You also have to prepare for all the scientific work you are going to do up in space.

You don't do a lot of preparation for weightlessness. There are few occasions, like parabolic flights, just to experience this feeling for a few seconds, but it's not really preparation in the real sense, it's more a familiarisation. For extravehicular activities, however, there is quite a lot of preparation. We use big pools for this purpose. NASA has a huge pool in Houston, where you prepare for extravehicular activities. Usually for each hour you spend in space you have to spend six hours in the pool.

You have two sons. How do they cope with their father being an astronaut? What kinds of questions do they ask you?

You know, just by being with them, they already have a lot of information. It is very rare that they have an additional question. Whenever I'm home, which unfortunately doesn't happen very often, I talk about the training and about what I did. And when I am in training and away from the family, I usually try to call at least once a day and then I tell them, "I was in the pool today to prepare for my extravehicular activity." My younger son, who is nine years old now, occasionally has some additional questions, like why a rocket only has three stages.

What made you want to become an astronaut?

That was a dream I had as a child. I followed all the space activities when I was six, seven, eight years old. When I was 11, I watched the first Moon landing. Even then, I dreamed of becoming an astronaut. At the time, getting into this profession was not very likely in Europe, but I was lucky. When there was a selection process – in 1986, I think – I was just the right age and had the right prerequisites. I didn't think twice about whether I should take part. And it worked out!

You are an engineer and you are also a pilot. Would you say that these are classical qualifications?

To a certain extent, yes. Quite a lot of the Russian cosmonauts and the astronauts on the NASA flights have a similar background. But it's not the only combination. In all agencies, in ESA, in NASA and also in the Russian space agency, you also find engineers or scientists who do not have a flying background. I think, talking now for the European Astronaut Corps (ESA astronauts who are currently considered active), that the mix of different professions is crucial. We have a very nice mix: some scientists, doctors, engineers, and even teachers. Some are pilots like myself.

Can you give a general recommendation to children who want to become astronauts?

If they are thinking of becoming an astronaut, they should consider studying physics, engineering, biology or something like that. And they should get some experience in a profession: no astronaut is selected directly from university.

Web references

w1 – European Space Agency website: www.esa.int

w2 – The website of NASA, the US National Aeronautics and Space Administration: www.nasa.gov

w3 – The website of the Russian Federal Space Agency: www.federalspace.ru

Resources

More information about Thomas Reiter's Astrolab mission, including fact-sheets on all the experiments he performed, is available here: www.esa.int/SPECIALS/Astrolab/

ESA have also produced many educational materials relating to the International Space Station (ISS):

- A printed ISS education kit for both primary- and secondary-school teachers is available in all 12 ESA languages. The kits are based on all the fascinating activities involved in building, working and living on board the ISS, and provide background information and exercises for classroom teaching. They are available to all school-teachers in ESA member states and can be ordered free online: www.esa.int/spaceflight/education
- An interactive version of the ISS education kit is available here: www.esa.int/spaceflight/education
- A series of ISS DVD lessons cover topics relating to European school curricula. The second in the series, entitled *Body Space*, explores the effects of weightlessness on the human body, for example on the vestibular (balance) system. The DVDs can be ordered free by teachers: www.esa.int/spaceflight/education
- *Robotics*, the fourth ISS DVD, will be released at the end of 2007. It includes an interview with Thomas Reiter and features many of the experiments he performed during his recent mission.
- By the end of 2007, a web lesson about the experiment on stability of rotational motions will be available on the ESA website: www.esa.int

Further details and education materials can be found on the:

European Space Agency Education website: www.esa.int/education and the

European Space Agency Human Spaceflight Education website: www.esa.int/spaceflight/education

REVIEW

This article provides an interesting glimpse into the life of an astronaut. It gives information about some of the experiments and work carried out during a tour of the International Space Station, as well as describing how the astronaut felt during a mission.

The article has a number of uses: as an information source for school projects, an interesting article for a comprehension exercise, or even as a source for careers advice.

Mark Robertson, UK

Sunset seen from the International Space Station

Image courtesy of NASA

Synchrotron light illuminates the orang-utan's obscure origins

Paul Tafforeau from the University of Poitiers and the European Synchrotron Radiation Facility in Grenoble, France, explains what synchrotron X-ray studies of fossil teeth can tell us about the evolution of orang-utans – and our own origins.

Today, the hominoids (apes) are represented by only five genera: gibbons, orang-utans, gorillas, chimpanzees and our own species, *Homo sapiens*. In the Miocene period, between 20 and 6 million years (MY) ago, however, this was a much more diverse group, as demonstrated by the numerous (approximately 20) fossil genera that have been discovered in Africa, Asia and Europe.

The most ancient hominoids lived around 20 million MY ago in Africa. Outside Africa, the first hominoids date from around 16.5 MY ago, but many different forms are known to have lived in Europe and Asia 12-6 MY ago. Subsequently, the group declined in diversity, probably due to climate changes. Several hypotheses have been suggested to explain the phylogenetic (evolutionary) relationships of the fossil and extant (modern) species and to describe their paleobiogeography – that is, their geographic migration and diversification.

The traditional hypothesis is that Africa was the principal area of diversification during the whole Miocene period, with successive migrations to Europe and Asia followed by local evolution on all three continents (map A).

Over the last few years, however, a new hypothesis has emerged. It also proposes that the hominoids originated in Africa, but that primitive forms then migrated towards Asia, and after a progressive extinction in Africa, Africa and Europe were repopulated by successive migrations from Asia (map B). According to this hypothesis, the principal area of hominoid diversification was Asia instead of Africa. The key fossils to test these two scenarios should therefore be found in Asia.

In 2003, research in Thailand led to the discovery of a previously unknown species of fossil hominoid from approximately 12 MY ago (Chaimanee et al., 2003). About 20 isolated teeth (figure 1A), attributed to several male and female individuals, showed that this species was a large hominoid with a strong sexual dimorphism – the male was much larger than the female, with more developed canines. It was named cf. *Lufengpithecus chiangmuanensis*.

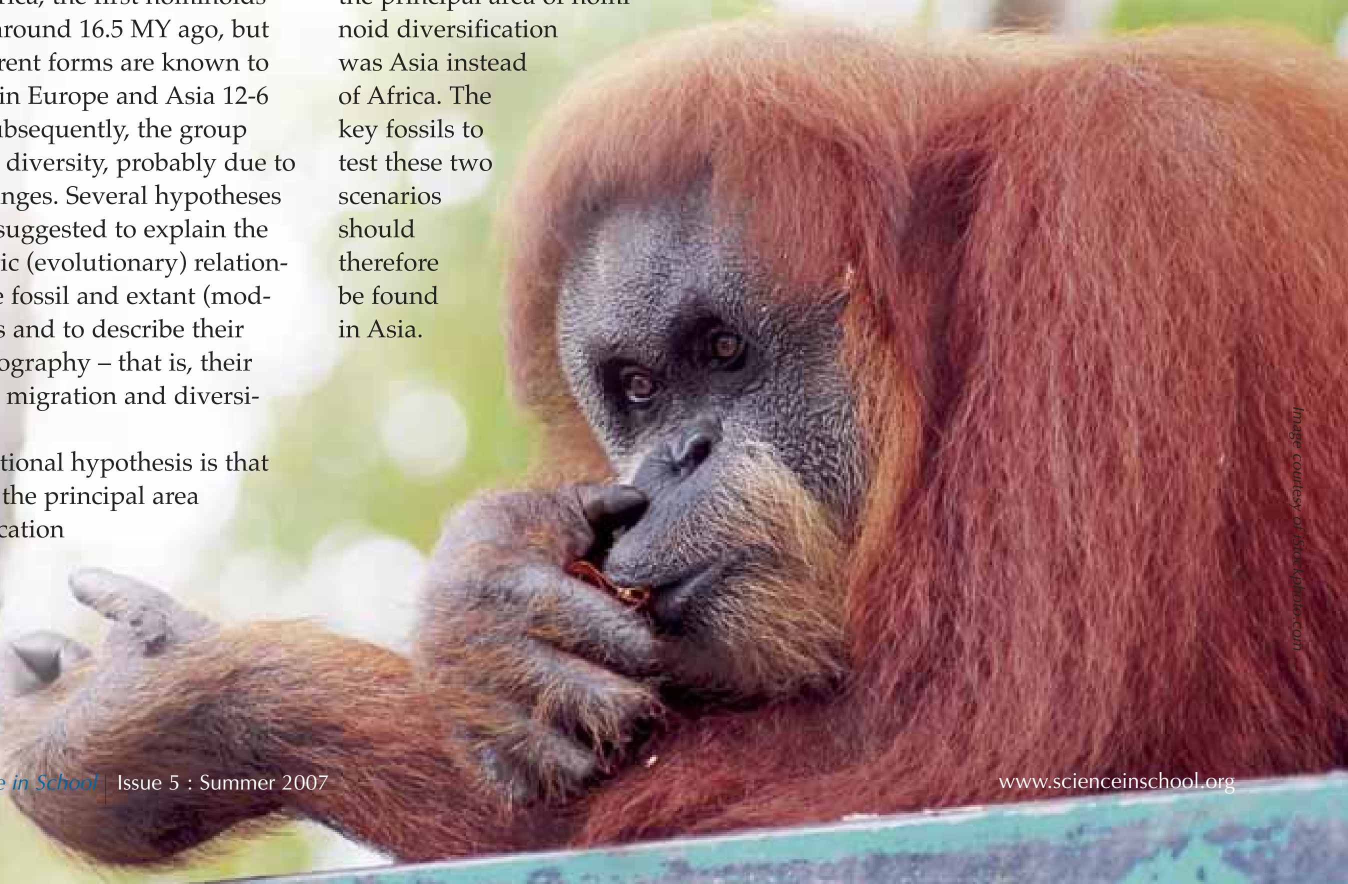


Image courtesy of iStockphoto.com

Dental enamel is the most highly mineralised tissue found in vertebrates; consequently, teeth are very strong and resistant to mechanical or chemical erosion. This, together with the fact that they contain very little organic matter to be decomposed by micro-organisms, means that teeth are often better preserved during the fossilisation process than the rest of the organism, including bones. Indeed, the vast majority of the vertebrate fossil record consists of teeth and most palaeontological (fossil) studies on vertebrate remains (including hominoids) are based on teeth. Fortunately for the palaeontologist, teeth have many anatomical characteristics linked to both phylogeny and function, whether for feeding or as sexual attributes (the males of many primates have particularly well-developed canines, for example).

In addition to a traditional palaeontological study of external dental morphology, the internal structure of the teeth of cf. *L. chiangmuanensis* was studied in a non-destructive way, providing results of previously unattainable quality (Chaimanee et al., 2003; Tafforeau, 2004; Tafforeau et al., 2006). At the European Synchrotron Radiation Facility (ESRF)[w1] in Grenoble, France, the teeth were imaged in three dimensions using X-ray synchrotron microtomography. This made it possible to quantify precisely the thickness and the distribution of enamel (figure 1B) without having to cut the teeth open. The combination of traditional palaeontology and microtomographic analyses revealed that this fossil species is more similar to modern orang-utans than to any other known fossil hominoids in Asia. It was therefore proposed that cf. *L. chiangmuanensis* could be an ancestor of the orang-utans.

In 2004, a further fossil, approximately 7 MY old, was discovered in Thailand. This beautiful mandible (lower jawbone; figure 2A) was assigned to yet another new species: *Khoratpithecus piriyai* (Chaimanee et al., 2004). On the basis of its overall size, the size of the canines and bone morphology, the mandible was thought to have come from a male. A subsequent comparison of this fossil with the cf. *L. chiangmuanensis* teeth showed that these two forms were more similar and therefore more closely related to one another than to any other fossil or extant species. The older species, cf. *L. chiangmuanensis*, was then reattributed the new genus and renamed *Khoratpithecus chiangmuanensis*.

K. piriyai's mandible was also imaged at the ESRF using X-ray synchrotron microtomography, resulting in the first high-quality scan of such a large fossil of a hominoid. Using this exceptional data set, it was possible to analyse the dental structure and the bone architecture (figure 2B), and to virtually extract the teeth from the right side of the mandible to study the size and the shape of tooth roots (figure 2C; Tafforeau, 2004; Tafforeau et al., 2006; Chaimanee et al., 2006). The 3D data of *K. chiangmuanensis*'s teeth were used in a virtual reconstruction of the jaws (figure 3), which allowed further comparisons of the general morphology of the jaws and the relative sizes of teeth in the two species of *Khoratpithecus*. This showed that their similarities were even stronger than initially thought and fully justified their classification in a single genus, which had been made on the basis of traditional palaeontological studies.

Image courtesy of Petra Riedinger, EMBL

A: The classical hypothesis of hominoid diversification and dispersion is that the group originated in Africa about 20 MY ago and then evolved mainly on that continent. Europe and Asia were populated by successive migration events from Africa. In this hypothesis, the main centre of hominoid diversification is Africa

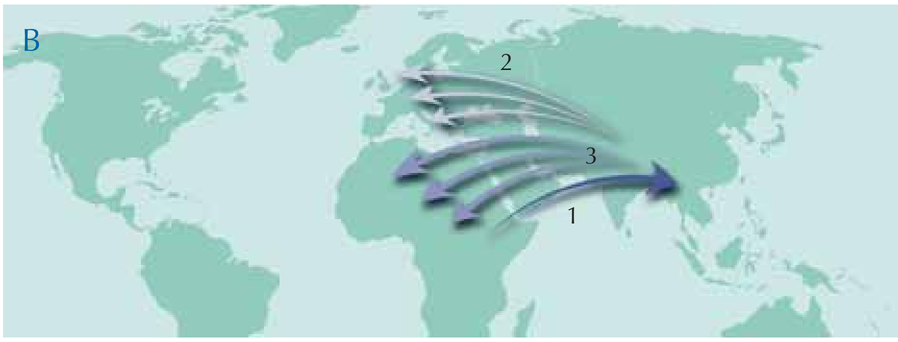


Image courtesy of Petra Riedinger, EMBL

B: In the alternative hypothesis, hominoids originated in Africa and evolved locally for a few million years. They then populated Asia (arrow 1) and became extinct in Africa. The main evolution took place in Asia, after which Europe was populated by Asian groups through several migration events (arrow 2). Africa was repopulated from Asia (arrow 3). In this hypothesis, the main centre of hominoid diversification is Asia

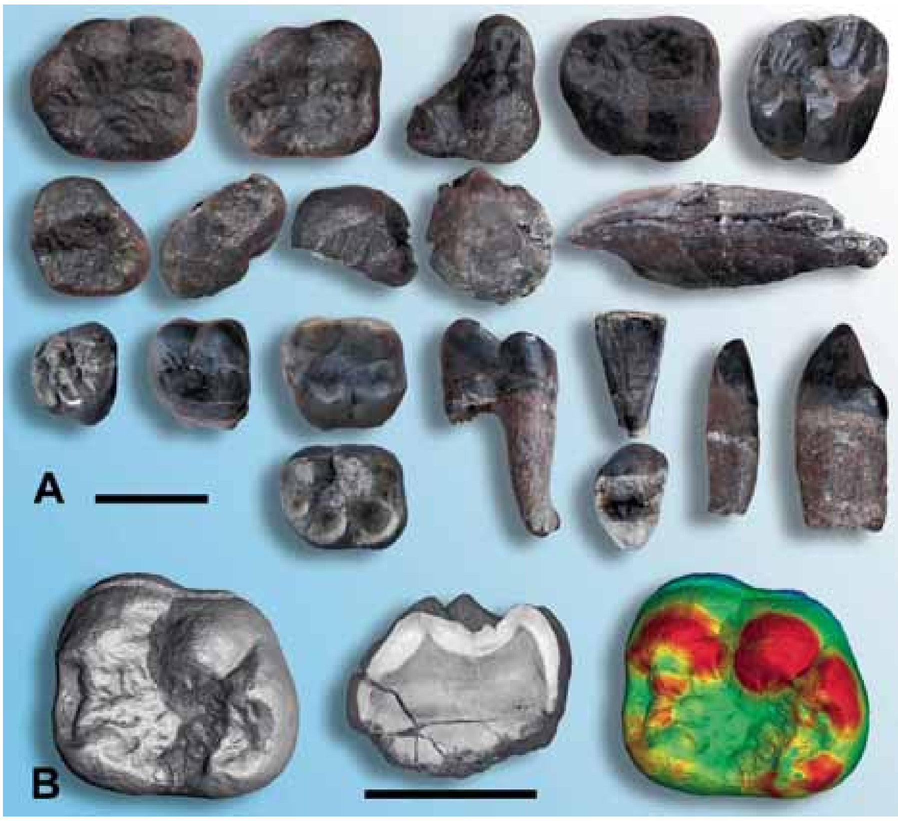


Image courtesy of Paul Tafforeau

Figure 1: *Khoratpithecus chiangmuanensis*. **A**: Isolated teeth discovered on the site of Chiang Muan, Thailand. The top two rows are male teeth, the lower two rows are female teeth. **B**: 3D analysis by X-ray synchrotron microtomography of a second lower molar from a male. From left to right: 3D reconstruction, virtual vertical cut, and quantitative distribution map of enamel. The scale bars represent 1 cm.

Using synchrotron X-ray imaging of these fossils, it was possible to reveal anatomical characteristics that would otherwise have been impossible to study without destroying the fossils. These cutting-edge analyses, combined with a more traditional palaeontological study, revealed that *Khorapithecus* is the known genus most closely related to the orang-utans. Nevertheless, the studies also showed that although *K. piriyai* (the more recent species) had many anatomical features that are typical of the orang-utans, it also displayed specialised features. Among them, *K. piriyai* had a canine morphology very unlike the modern orang-utans, with a dagger-like canine and an extremely enlarged third molar. From what is known from other lineages, it is unlikely that so many specialisations would have evolved and subsequently disappeared.

Therefore, although related, *K. piriyai* is almost certainly not a direct ancestor of the modern orang-utans. *K. chiangmuanensis*, the older species with fewer specialised dental characteristics, is more likely to be a possible ancestor of the orang-utans. Although new fossils are necessary to test the hypothesis, it is possible that the orang-utan's lineage was derived from primitive forms of the *Khoratpithecus* genus and that the two branches evolved in different ways, giving rise both to the orang-utans and to later species of *Khoratpithecus*, such as *K. piriyai*.

We can now return to our two hypotheses of hominoid evolution: African and Asian diversification. The two *Khoratpithecus* species, as well as the numerous other fossil hominoid taxa from Asia, show a higher diversity than African hominoid fossils during the same period. Moreover, both very specialised and primitive species have been found in Asia. Together, the high levels of diversity and the wide geographic distribution in geological strata of Asian hominoids (from 16.5 MY ago to the present) strongly suggest that Asia was an important, perhaps even the principal, centre of diversification for Miocene hominoids. Increasingly, therefore, modern palaeological research is lending weight to the newer hypothesis of hominoid evolution: our hominoid ancestors originated in Africa, after which they diversified in Asia and repopulated Africa and Europe.

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Image courtesy of Paul Tafforeau

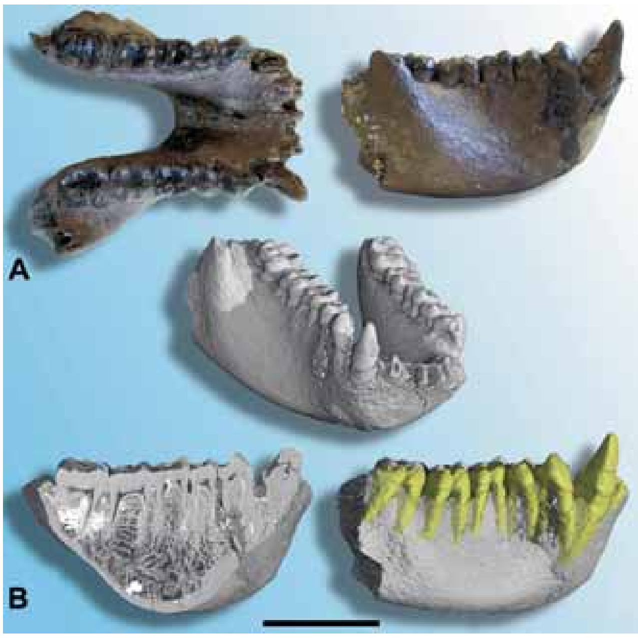


Figure 2: *Khoratpithecus piriyai*. **A**: Photographs of the mandible showing a very good state of preservation. **B**: 3D microtomographic analysis. In the centre, 3D reconstruction. On the left, a virtual vertical cut through the right side of the mandible showing the bone structures and the dental roots. On the right, virtual extraction of the teeth of the right side showing the shape and the size of the dental roots in 3D. The scale bar represents 4 cm

Image courtesy of Paul Tafforeau

Figure 3: Jaw reconstitution of male *Khoratpithecus chiangmuanensis*. Grey: original male teeth. Pink: symmetrical view of these teeth. Blue: female teeth after adjustment of their size to take into account the sexual dimorphism. Green: missing teeth with equivalents extrapolated from existing teeth after calculation of their probable sizes. Yellow: completely unknown teeth replaced by teeth of orang-utans

Web references

w1 - The European Synchrotron Radiation Facility (ESRF) is an international facility that operates, maintains and develops the most powerful synchrotron light source in Europe, with 18 participating countries. More than 5000 researchers come to the ESRF every year to use the light source and its associated instruments: www.esrf.eu

ESRF is a member of EIROforum, a collaboration of seven European inter-governmental research organisations, and the publishers of *Science in School*. See www.eiroforum.org

Resources

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

Tafforeau P et al. (2005) Synchrotron Radiation Microtomography: A Tool for Paleontology. *ESRF Newsletter* **42**: 22-23. www.esrf.eu/files/Newsletter/NL42.pdf

For information about the University of Poitiers, see: www.univ-poitiers.fr

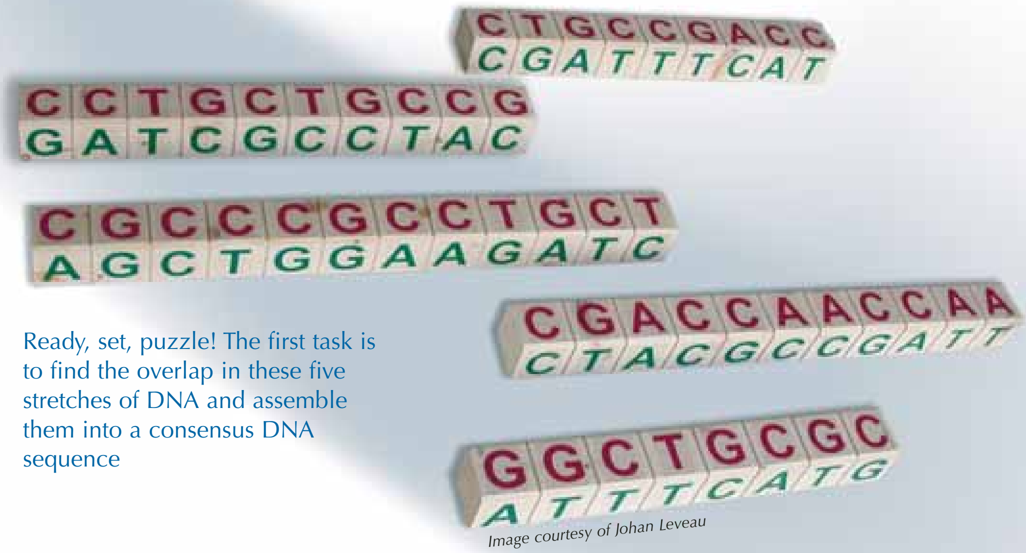
REVIEW

I have always been fascinated by knowledge about the evolution of man. Questions like ‘Where do we come from?’ and ‘Who was our common ancestor?’ are often posed by both pupils and scientists. This article describes a method that helps to strengthen the hypothesis of the hominoid evolution: that our forebears originated in Africa, after which they diversified in Asia, and repopulated Africa and Europe. This article could be used in biology lessons at the highest level, for pupils aged 16-18. It would be very useful when teaching general evolution and human evolution in particular. The article could also be used in physics class to show how advanced use of X-rays can be a valuable tool for biologists.

Sølve Tegnér Stenmark, Norway

Fun with genomes: the Mycomuncher DNA Puzzle

Fed up with explaining genomes, genes and proteins? Why not get your students to figure it out for themselves using **Johan Leveau**'s DNA puzzle?



Ready, set, puzzle! The first task is to find the overlap in these five stretches of DNA and assemble them into a consensus DNA sequence

Looking for a fun, hands-on teaching tool to explain genomes, genes and proteins? The Mycomuncher DNA Puzzle may be just what you're looking for. Like a real scientist, experience the thrill of genome research. Get an appreciation for the work that goes into breaking the DNA code. And learn how DNA carries the information for all kinds of biological functions. Suitable for educating students at the primary- and secondary-school level, the Mycomuncher DNA Puzzle can also be used as supporting material for general-audience science fairs and for university courses in biology and ecology. Ten minutes is all a basic game of DNA puzzling takes.

Meet the mycomuncher

Based on ongoing research at the Netherlands Institute of Ecology (NIOO-KNAW)[w1], the Mycomuncher DNA Puzzle features *Collimonas fungivorans*, a newly discovered soil bacterium that has the unique ability to eat fungi (moulds). Hence its nickname: the mycomuncher, from the Greek word *mycos* meaning fungus. Researchers at the NIOO-KNAW and elsewhere are very excited about this bacterium, because it may hold new clues to treating or preventing fungal diseases in humans, plants, or other organisms. To discover what makes *Collimonas* a mycomuncher, we are currently analysing the total DNA, or genome, of this bacterium. Using the *Collimonas* project as an example, the Mycomuncher DNA Puzzle explains what a genome is, what it is good for, and how genomic DNA can be read and understood in relation to the biology of the organism it belongs to. In other words, how do we go from long sequences of only four different DNA letters (A, C, G, and T) to a property such as 'eating fungus'?

Here's the challenge

The objective of the Mycomuncher DNA Puzzle is to complete several tasks representing the sequential steps in a typical genome project, from DNA assembly to the formulation of hypotheses.

Mission accomplished! The consensus DNA sequence (bottom) perfectly matches the overlapping shorter ones

Image courtesy of Johan Leveau

The first challenge is to assemble five overlapping DNA sequences (represented by five wooden pieces with DNA letters A, C, G and T) into one *consensus DNA sequence* (see above). This exercise shows that a genome cannot be read in one go, but needs to be determined from smaller fragments, which then have to be assembled, much like a puzzle, to obtain a full-length sequence.

The next task is to translate the consensus DNA sequence, representing a typical *Collimonas* gene, into protein. This is achieved by lining up three-letter DNA sequences (*codons*) that are linked to a particular amino acid (see below). Amino acids are the building blocks of proteins. This part of the Mycomuncher DNA Puzzle illustrates the role of DNA as a carrier of information and how this information is translated into proteins.

The third challenge is to find out how *Collimonas* might use this protein to eat fungus. The lesson of this task is that not much can be learned from a protein sequence per se. Instead, players are invited to compare their newly identified protein with a list of proteins from other organisms, the functions of which have already been studied by other researchers.

One of the listed proteins will match the one that the players identified for *Collimonas*. Players are challenged to think about how its function might be involved in mycomunching. An example is the protein chitinase which breaks down chitin, a structural component of the fungal cell wall. One could hypothesise that *Collimonas* uses this protein to degrade the cell wall to access nutrients which are contained within the fungus. To assist in the formulation of hypotheses, the puzzle includes a scale model of the interaction between *Collimonas* and a fungus. Hypotheses from different groups of students can be written on the blackboard, compared and discussed.

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Coming soon…

In response to suggestions from Mai-Britt Meijer and her students, an extended version of the basic puzzle will be available in autumn 2007. Targeted at high-school audiences, the Mycomuncher DNA Puzzle PLUS! includes an additional wooden piece representing messenger RNA (mRNA), the sequence of which is complementary to the DNA and in the true RNA alphabet (A, C, G, U instead of A, C, G, T). In the PLUS! version of the game, anticodons (also in RNA spelling) need to be matched to the mRNA to create the corresponding amino-acid sequence. The addition of a transcription step makes this puzzle more challenging and realistic for high-school students. Visit the *Collimonas* website[w2] for more information.

Decoding the DNA. Wooden blocks representing DNA codons and their associated amino acids are used as a translation key to convert a DNA sequence (top) into its matching amino-acid sequence or protein (bottom). The latter will need to be compared with other proteins to figure out its function

Image courtesy of Johan Leveau

Teaching team work and other scientific principles

Besides educating its players on genes and proteins, the Mycomuncher DNA Puzzle stimulates team effort when played in groups. The four sides of the wooden DNA blocks allow four different DNA assemblies: thus, one game actually represents four puzzles in one, with four different proteins and four opportunities

A teacher's experience of the Mycomuncher DNA Puzzle

Mai-Britt Meijer, a biology teacher from the Netherlands, tested the Mycomuncher DNA Puzzle with her students.

As a teacher, I always welcome new methods and new ways of teaching. The Mycomuncher DNA Puzzle is an original and stimulating teaching tool because it enables students to 'let go' of the textbook and investigate the steps of protein synthesis. Not only are the students physically occupied, but also they are forced to think about the formulation of hypotheses and the scientific method of determining gene functions.

Before playing the puzzle, I discussed the theory of protein synthesis with the class. The knowledge of the students (pre-university education, ages 15-16) was quite high, which is a necessity.

After a short introduction to *Collimonas fungivorans*, the class was divided into groups of three to four students. Those who were not busy with the puzzle worked independently on an assignment related to DNA and proteins.

The class worked together to find the first DNA sequence consensus and to understand how the puzzle worked. Next, one group at a time searched for their own consensus sequence (one of four). As each group found its consensus sequence, it moved onto the next step (identifying the corresponding codons). The groups could work without any guidance since the posters clearly explained each step.

When all groups reached the last step (suggesting the function of the protein encoded by their consensus sequence), we discussed their hypotheses as a group: what did they think were the functions of their encoded proteins? The exercise can raise significant questions such as: How do the students form their hypotheses? Are the hypotheses formulated correctly? What kind of experiments can they think of to test their hypotheses? Especially for the more advanced students, this exercise can prove to be very helpful in training them to give elaborate though precise answers.

The students suggested, and I agree, that the puzzle would be more complete if it included additional steps of transcription from DNA to messenger RNA and translation to amino acids. This extension, which will be available in future, will allow the puzzle to be used as an introduction to DNA transcription and protein translation. It will give the students a physical reminder of all the steps involved in this kind of research and the steps of the puzzle can be referred to when discussing the theory in subsequent lessons.

It was nice to see the students playing around with the wooden blocks. Their initial reaction when seeing the wooden pieces was that they were back in nursery school. When starting with the puzzle, however, they soon realised that it is not as easy as it appears, but that it takes a lot of work to decipher the DNA code and the function of genes.

The Mycomuncher DNA Puzzle in action. This photograph was taken at the 2004 science fair at the Netherlands Institute of Ecology (NIOO-KNAW), showing junior wannabe genome researchers solving the mycomuncher challenge

Even though there are a lot of tools available on the Internet, the Mycomuncher DNA Puzzle has the advantage of enabling students to work with their hands. It is especially useful because they are able to really visualise what they are doing. As a final remark, it's worth noticing that the students have to work together, and discuss issues to be able to complete all the steps of the puzzle. This is, once again, a great advantage.

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to think about how they fit into the mycomunching lifestyle of *Collimonas*.

Typically, it takes no more than 10 minutes to complete one game, although more time can be spent on each of the steps, for example to discuss or provide background information. The puzzle also exposes students to some basic principles of scientific research. These include the formulation of hypotheses and sharing results with fellow scientists (for example, had others not made public their research findings, how would it have been possible for us to assign a possible function to our *Collimonas* protein?).

For advanced students, the basic concepts of the puzzle can be combined with the use of Internet-based programmes on classroom computers to show what it means to assemble and decode not just five short pieces of DNA, but hundreds of thousands, as is the case in a real genome project. The teacher's manual that comes with the puzzle provides several examples. The puzzle can also be used to explain other DNA-related issues, such as the effect of changes (*mutations*) in the DNA on the amino-acid sequence and function of proteins.

Real genes!

The Mycomuncher DNA Puzzle uses real DNA sequence data, derived from the genome of *Collimonas fungivorans*. Each puzzle includes a certificate with a unique link to one of the genes in the *Collimonas* genome. Students can track this gene on the *Collimonas* website[w2] to find its location on the *Collimonas* genome, and learn what protein it codes for, or which laboratories are studying it.

Product information

The Mycomuncher DNA Puzzle is available from the Netherlands Institute of Ecology (NIOO-KNAW): you can either purchase a complete set or request (free) instructions for building the puzzle yourself. For details, please visit the *Collimonas* website[w2], or email c.fungivorans@nioo.knaw.nl

One standard set of the basic game consists of five wooden pieces of DNA sequences for assembly, one wooden piece with four consensus DNA sequences and one with four corresponding protein sequences, 30 wooden pieces representing codons with their matching amino acid, six A3-sized posters with wooden stands, one scale model of the *Collimonas*-fungus interaction, and a teacher's manual.

Web references

w1 - For more information on the Netherlands Institute of Ecology (NIOO-KNAW), visit www.nioo.knaw.nl

w2 - *Collimonas* website: www.nioo.knaw.nl/games/collimonas

Johan Leveau is a researcher at the Netherlands Institute of Ecology (NIOO-KNAW) in Heteren, the Netherlands.

REVIEW

This article describes didactical material aimed at school level and developed within a research institute. This is quite a novelty for teachers, who often see a gap between academic research and science teaching at school.

The idea is simple but ingenious: to transform scientific data about a bacterial genome and its ecology into a game to be played in the classroom and completed on the Internet, thus combining hands-on and e-learning methodologies to address the basic biological topics of DNA, gene expression and metabolism.

I recommend this article to secondary-school teachers interested in innovative didactical tools: they will find structured material ready-to-use and suitable to make pupils think like scientists. The most skilful teachers will even find instructions for building the game by themselves or together with their students.

Giulia Realdon, Italy

Using music in the science classroom

Caroline Molyneux, from Balshaw's Church of England High School, UK, explains how she kick-starts her classes and helps her students remember certain lessons, facts or concepts.

Image courtesy of Pixelquelle/T. Kemnitz

Music is known to affect our feelings and energy levels (Brewer, 1995). It can prompt memories, enhance brain activity and stimulate the mind. In today's consumer-driven society, a piece of classical music can make us think of a certain make of car. A popular song can conjure up thoughts of a famous perfume brand. Why not harness this subliminal messaging method for learning? In a multimedia society, any tool that can be used to engage pupils is invaluable (Beady, 2001).

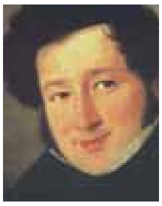
As a pilot project, I experimented with the use of music to inspire my tutorial group at the start of the day. I used any feel-good tune, which I called 'music of the day'. I would write the name and composer of the music on the chalkboard, along with a 'thought for the day'. These were motivating phrases or quotes that were provided by the school, to be read out to all tutorial groups each morning.

Examples of 'thought for the day' include:

- Why is abbreviation such a long word?
- Only the guy who isn't rowing has time to rock the boat
- Anyone who has never made a mistake has never tried anything new
- Imagination is more important than knowledge (Albert Einstein)

I found that simply reading these out loud did not have a great effect on pupils. But when the thought for the day was displayed alongside the music of the day, with the music playing, pupils began to take a lot more notice of both. They wanted to know exactly what the music was and who wrote or sang it, and then what the thought for the day was.

The response was amazing. Each day the pupils would be excited to enter the room to hear what was playing. Pupils would be waiting at the door before I arrived, eager to hear what the day's selection would be. I found that the most successful songs were those that pupils had heard before but did not know by name (or composer), such as Ravel's 'Bolero' and Rossini's 'William Tell



Portrait of Giocchino Rossini by an unknown artist

Public domain image; Image source Wikimedia Commons

Image courtesy of Pixelquelle/Martina Taylor

The Old Opera House in Frankfurt, Germany

Image courtesy of Pixelquelle/Freezman1602

Overture'. I developed the idea of having theme weeks, in which the music would follow a theme such as 'French music' or 'the musicals'.

Pupils began to make requests, and it wasn't popular chart music that they were asking for. All the pupils got involved – both confident and quiet, boys and girls. We took it in turns to pick the music so that everyone got a chance. Pupils would compete to find the most obscure but interesting music. Requests included the classical piece 'Dance of the Knights' from Prokofiev's *Romeo and Juliet* (pupils were studying Shakespeare's play in their drama class) and 'Matchstalk Men' by Brian & Michael – a song about the famous early 20th-century Manchester artist L. S. Lowry.

The music boosted pupils' general knowledge as well as entertaining them. They discovered that the composer John Williams wrote the theme music for the Harry Potter films, and that several famous comedians, including John Cleese of James Bond-film fame (previously one of the Monty Python team) collaborated to produce the well-known novelty song 'Always Look on the Bright Side of Life'. Some pupils even recognised the song from football chants but had no idea where it came from.

Early-morning morale amongst my tutorial group soared and pupils would go off to lessons happy to begin the day. I received visits from other pupils and members of staff who had heard about the music and had come to investigate. The project lasted for a full term (approximately four months), and was so popular that I have continued to use this idea. If I ever forget to put a piece of music on in the morning then I get complaints!

Next, I began to develop a portfolio of music to link to the science curriculum. At the time, I was writing the schemes of work (detailed lesson plans for a whole year group) for the new new GCSE in core science, so I linked music to the topics and included them in the scheme of work.

I would play the music as pupils entered the classroom. Immediately they would begin to search for the link between the music and the lesson title and objectives which I had displayed on the board. Before pupils had even sat down, opened their bags or taken out their pens and pencils, they had begun to think about the les-

Below are some examples of the music I have used.

Song	Science Curriculum Link
'Danger, Danger High Voltage' – Electric Six	Electricity – KS3 and Year 10 Physics (new GCSE)
'The Drugs Don't Work' – The Verve	Drugs – Biology Year 10 (new GCSE)
'Rock DJ' – Robbie Williams	Rocks – Chemistry Year 8
'Me and My Shadow' – Various	Light – Physics Year 8
'Oliver Twist' – Food Glorious Food	Food and Digestion – Years 8 & 10
'Fast Food Rockers' – Fast Food Song	Malnutrition and Obesity – Year 10


Image courtesy of Paranoid; Image source Wikimedia Commons

Statue of Freddie Mercury

son. I began to challenge the higher-ability pupils by making the links more tenuous. One example of this was 'Under Pressure' by Queen, which I used to introduce a lesson entitled 'Salt in the Diet'. Several pupils guessed that too much salt in the diet must cause high blood pressure. Pupils had begun to guess the outcomes of the lesson before I had introduced anything other than the lesson title!

The idea began to develop. My website[w1] displays the lesson titles for the following week; pupils would visit the website, look at the titles and suggest music that could be used to begin the lesson. Pupils were inadvertently preparing themselves for future lessons!

In search of appropriate music, I linked not only the titles but also the lyrics of some songs to the curriculum: 'Big Yellow Taxi' by Joni Mitchell includes the line "They paved paradise and put up a parking lot." This was perfect for use with lessons on how humans affect their environment. Pupils listened attentively, waiting for a link to the lesson.

I developed the idea even further by using other types of music for effect during presentations. 'Carmina Burana' by Carl Orff is an extremely dramatic piece that I linked to a presentation on the huge negative impact of microwave meals on the UK population's diet. Jane Birkin & Serge Gainsbourg's 'Je T'Aime Moi Non Plus' was used during a lesson on hormones to indicate the effect that they have on adolescent boys and girls.

To evaluate the effectiveness of the idea, I would play a piece of music used in a past lesson and give the pupils the duration of the song to summarise the key points of that lesson. I found that the music provoked memories of facts and skills that the pupils had learned. I would simply play the music and pupils would immediately remember facts. During Diana Ross's 'Chain Reaction', which had been linked to a lesson on nerves and reflex reactions, some pupils managed to write down the sequence of events in a reflex arc! This highlighted the success of the project, along with the positive comments made by the pupils: "Miss Molyneux has a song for every occasion" and "Can we have more music throughout the lesson?" Pupils were overheard telling prospective students and their parents about the music and how it made the start of lessons exciting.

In the future I hope to expand the idea across the school, perhaps involving the music teachers, who could suggest pieces to play and link science topics with their curriculum. I already produce a revision CD for pupils, on which I read out useful tips and facts for the new GCSE examinations. Incorporating some of the music that has been used during lessons might give pupils a further boost in their preparation for exams.

Is this a gimmick? Well, yes, it probably is. But we live in a society full of gimmicks that *work*. I believe that any way to get pupils to pay attention, learn and retain information is worth trying.

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Brewer C (1995) *Music and Learning: Seven Ways to Use Music in the Classroom*. Tequesta, FL, USA: LifeSounds

Web references

w1 - Caroline Molyneux's website: www.missmolyneux.co.uk

Resources

For more information or if you would like further examples of music that can be used in the science classroom, visit our website, www.balshawshigh.co.uk, and click on'Science' then 'Science Teacher Area'.

Mike Fleetham's Thinking Classroom website has information on music and learning: www.thinkingclassroom.co.uk/General/music.aspx

Music in the Classroom: http://teacher.scholastic.com/products/instructor/Jan05_music.htm

Songs for Teaching: www.songsforteaching.com

For an excellent article on the science in music, see: Woodhouse J, Galluzzo PM (2004) Why is the violin so hard to play? *Plus Magazine* **31**. http://plus.maths.org/issue31/features/woodhouse/index.html

REVIEW

The article deals with music, which is an important feature of today's world but is rarely incorporated into the classroom. The article makes interesting reading for teachers who are seeking new approaches to teaching and learning, which have already been tested by others and found to be successful. The article engages all kinds of teachers, who teach motivated and non-motivated students, in all educational settings.

The article is clearly written and gives practical examples of songs that the author has used, together with the related syllabus topics as applied in the classroom. The article also cites other literature (in journals and online resources) to support its assertions. Another interesting link that I found discussed Gardner's Multiple Intelligences theory, which includes 'musical intelligence' in the eight intelligences that encompass human potential.

The content of the article is easily transferable from the science arena to other areas of the school curriculum. Some of the links provided also give similar resources to non-science teachers. The article could well be the starting point of a staff development meeting in which teachers explore the possibilities of using music in their classrooms. Music may be used at different stages of the lesson – as an introduction, conclusion or reinforcement, for example. Music may be linked to other multimedia activities in the classroom to make learning spontaneous and within reach for all students.

It would be great if, as a consequence of this article, an educational organisation took the initiative to create a website with music clips, together with suggested areas of the curriculum with which the music can be used. This website could provide all the available freeware music clips in one location, where teachers around the world could access related educational materials. A forum or blog on the website would enable other teachers to relate their experiences when particular music clips were used in their classrooms and even suggest other music clips.

Gaetano Bugeja, Malta

Image courtesy of Pixelquelle/Christina Erbel

Travel wisely: the globe is warming!

Elisabeth Schepers from the Deutsches Museum in Munich, Germany, introduces a school programme linking climate change and the future of traffic technology.

The Earth's climate is warming, mostly as a result of increasing carbon dioxide (CO_2) levels in the atmosphere. Today, traffic is held responsible for one fifth of this increase.

Rising levels of the greenhouse gas CO_2 will lead to further global warming and will restrict life on Earth. Furthermore, fossil fuels – the most important energy source for our civilisation – are limited. Humans will soon have to switch to alternative energy sources – if not today, then in the near future. But mobility is one of our basic needs: to live comfortably involves transporting goods, energy or ourselves.

To live, we need to move, but by moving, we destroy the environment in which we live. How can we solve this dilemma? The Deutsches Museum[w1] addressed this question with students aged 10-16, in a PENCIL project (see box) involving three messages:

1. Climate is a system and we are part of it. Individually, we make a minute contribution to this system, but the effects of our collective contributions can be devastating – such as tropical storms in Europe.
2. The key is creative solutions, such as alternative fuels, regenerative energies and different approaches to mobility. What options do we have? Which one is right for me?
3. As we all produce CO_2, we all share the responsibility. What can we do to address these responsibilities?

Climate and education experts from the Deutsches Museum worked with teachers from 15 secondary schools to develop activities based on current climate research and the future of traffic technology. The project, run in the environment gallery and the traffic museum of the Deutsches Museum, aims to develop students' basic research skills and individual opinion-building capacities, to take an interdisciplinary, cross-curricular approach, and to be socially inclusive.

The first message is addressed in a visit to the environment gallery, which investigates the climate system and the effects that a change in one

Image courtesy of pixelquelle.de/S. Hofschlaeger

sub-system has on all other sub-systems. The second message is discussed in a further visit, to the traffic museum, where students come up with questions and recommendations for stakeholders such as the municipality, local car manufacturers, automobile clubs or transport companies. The third message forms the centre of a role-play that invites students to use the information they have collected in the first two activities and from the dedicated website to develop their own opinions about the topic and to exchange the arguments for and against specific traffic developments.

Typically, special programmes at the Deutsches Museum have been visited mostly by primary schools or elite secondary schools (*Gymnasien*). To reach a wider range of students, we invited less-elite secondary schools to take part in the development of the climate change project. The response from these schools was very positive, and the involvement of teachers from different subjects and types of schools helped us to develop a project with a basic structure but versatile contents.

Visiting the museum

In the course of a 90-minute visit to the museum, the topic of climate change and traffic is used to introduce students to current scientific research and model building as well as to the political and individual options following this research.

For example, in the hurricane activity in the environment gallery, students are introduced to the effects of weather disasters such as hurricanes in Europe. Students particularly wanted to deal with real threats when learning about climate change, not just with models or theoretical information. The abstract 'global warming' caused by increasing CO_2 levels results not only in sunnier summer

BACKGROUND

PENCIL

The Deutsches Museum project is one of the activities in the PENCIL project[w3] (Permanent EuropeaN resource Centre for Informal Learning). PENCIL, co-ordinated by Ecsite[w4] and funded by the European Commission as part of the NUCLEUS cluster[w5], aims to strengthen the operational relations between schools and informal science education in science centres and museums.

Fourteen science centres and museums have developed pilot activities in partnership with teachers and schools; material is already available online. Academic and school partners are now working to identify key ways to transform informal science activities into innovative, high-quality tools for science teaching.

BACKGROUND

Evaluation

How did the project develop? It involved an intense co-operation between teachers, their students and the museum.

Initially, the opinions of 133 students from different schools and school types were surveyed. Most had no basic knowledge of the context of climate change and traffic. They were interested in climate disasters, but not so much in climate politics or the climate system. They were looking for sensations rather than the political or scientific background.

The 16 teachers involved in the project wanted to address renewable energies and changes in personal behaviours in an attempt to combat climate change. Once again, climate politics was not seen as important.

On the basis of this evaluation, the topics were chosen. We used a sensation (the hurricane in Europe) as an introduction and concluded with the personal challenge to deal with climate change. In between, we considered the teachers' wishes for an all-embracing approach and included the climate system. To avoid leaving students with a feeling of helplessness and despair, information on the Intergovernmental Panel on Climate Change (IPCC) was included.

Regardless of age and school, students who took part in the next stage of the evaluation enjoyed learning outside the classroom, working on activities and experiments with friends and experts, and actively drawing information from experts rather than passively listening. Some wanted the activities to be less structured, allowing them to do experiments and interact with elements of the exhibition, or even solve a mystery. They did not want to fill in questionnaires.

Teachers also appreciated the experiments and mystery tasks but were not so keen on 'free work'. They wanted guided tours by experts and questionnaires for students to fill in, if possible in multiple-choice format.

Using this feedback from students and teachers, we combined the approaches in the current programme, mixing a worksheet that involves active participation by the students with a more dialogue-based format of presentations and role-plays.

Since the revised programme was opened to all schools in Febuary 2007, the evaluation findings have been proven many times. Teachers appreciate the mix of structure and free work of the students, students enjoy working in a different setting, using oral rather than writing skills and discussing with an expert. The programme runs about once a week – and the demand is such that it could run more frequently but for the limited staff resources of the Deutsches Museum education department.

days, but also extreme weather such as the aforementioned hurricane. As an example of climate change, we therefore chose Hurricane Vince, which struck the Iberian peninsula in October 2005. Currently, there are no reliable precautions against tropical storms in Europe. The question to the students is: how can we avoid tropical storms in non-tropical regions of the world? To answer this question, students choose from a range of different research tasks.

Working in small groups, students are introduced to their research task by a museum educator and then use a worksheet to collect information from the museum galleries. A great deal of care was put into developing the worksheet, which presents a main research task – one of seven questions leading to a final answer on how to avoid hurricanes in Europe. Topics include the model of the climate system, constituents of the atmosphere and the contribution of traffic to the pollutants, a physical experiment, historical and geographical information, climate politics, personal options and an overview of renewable energies. Students are encouraged not only to answer the questions, but also to discuss the issues and come up with further questions for the museum educator. For that reason, the museum educator is a highly trained expert who holds a PhD in biology.

Image courtesy of the Deutsches Museum

Deutsches Museum in Munich

Image courtesy of pixelquelle.de/Kurt Michel

Next, students take their peers on a tour of the gallery, presenting their research findings, answering further questions, referring to previous presentations, and using the museum's experiments and interactive exhibits to visualise their findings. Museum educators help out with missing information, linking the single presentations to the central topic and, most importantly, encouraging the students to contribute and research further.

Students who visit are amazed that teenagers can have political influence, for example as consumers, participants of traffic or members of environmental groups. They start discussing the pros and cons of some of the topics during the group presentation: will there be floods in Europe? Does my contribution make a difference? If we decrease CO_2 emissions, will the temperature fall immediately? Teachers appreciate the all-embracing approach of the programme, as school curricula are usually more detailed but lack an overall view of a topic.

A corresponding programme is being designed in the traffic museum, covering topics such as pollutants, renewable fuels, alternative engines and mobility as a basic human need. Together, the programmes develop an understanding of the role that traffic plays in climate change and the personal options that people have to influence this. They also reveal the impact not only of climate but also of society and make students aware of their responsibility.

Role play

In the next stage, role-plays are used to introduce students to scenarios that require them to make a decision, for example:

- How should I do the weekly shopping for my family?
- Where should I shop, and how should I get there?
- Should I stop driving and shop via the Internet instead?

The students already have some general information on these topics from their museum visit. To encourage more discussion and opinions, students are given statements from people involved in traffic and climate issues, such as the manager of a car company or the bicycle club, a Green City[w6] representative, or a professor for traffic development. These materials will shortly be available on the website of the Deutsches Museum[w2].

For each of three scenarios, the role-play pack includes statements that present a number of arguments and opinions, enabling the students to exchange views that they share or to provoke debate. The pack also includes advice for the moderator of the role-play, who can be a student or a teacher.

The role-play can take place after one of the museum programmes or back at school. Either way, students recall the information from the museum visit (or the website) and argue from different points of view. As a result, they develop their own opinion on climate change, personal options, renewable energies and so forth, rather than adopting an institutional point of view.

Image courtesy of the Deutsches Museum

A Year-9 student explaining the greenhouse effect to his classmates

Image courtesy of the Deutsches Museum

Climate change – what about renewable energies? This student introduces his peers to different options


Deutsches Museum

4. Luft und Klima

Woraus besteht Luft?

Welche Stoffe sind in der Luft für die Erwärmung verantwortlich?

Informationen: Luftschadstoffe -Tafel

Welcher Schadstoff ist vor allem für den Klimawandel verantwortlich?

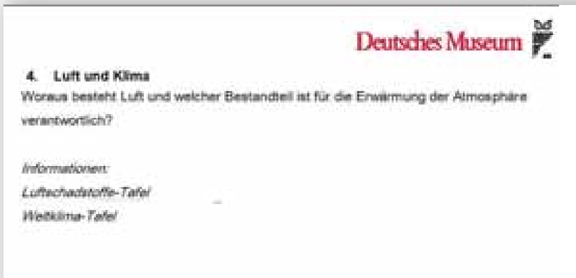
Wie entsteht er?

Informationen: Weltklima /Tafel

Image courtesy of the Deutsches Museum

Worksheet with detailed questions guiding through the work assignment. Hints on where to find the information save the students from too much reading. The lines for taking notes help structure the presentation

Image courtesy of the Deutsches Museum


Deutsches Museum

4. Luft und Klima

Woraus besteht Luft und welcher Bestandteil ist für die Erwärmung der Atmosphäre verantwortlich?

Informationen:

Luftschadstoffe-Tafel

Weltklima-Tafel

Worksheet for advanced students with general instructions and room for personal notes

Website

To help teachers follow up the museum visits in the classroom, the website of the Deutsches Museum provides information on climate change[w2], with a new section on climate change and traffic. The information is provided in both English and German, and addresses seven general climate topics. Another new section is particularly appropriate for the project, covering the greenhouse effect, climate change, climate system, Antarctica, climate history, climate politics, a game, and climate and traffic, including alternative fuels and new motor technologies and ideas about future mobility.

Web references

w1 - The Deutsches Museum is one of the biggest European science museums: www.deutsches-museum.de

w2 - Materials on climate change are available on the Deutsches Museum website: www.deutsches-museum.de/dmznt/climate/index.html

w3 - Information about PENCIL is available on the Xplora website: www.xplora.org

w4 - The website of Ecsite, the European organisation representing science centres and museums: www.ecsite.net

w5 - Information about NUCLEUS is available on the Xplora website: www.xplora.org

w6 - Green City is a non-governmental organisation working to improve Munich's quality of life through ecological urban planning: www.greencity.de

Resources

For more information on formal, non-formal and informal learning, see:

Davies P (2004) Anerkennung und Wertschätzung informellen und formellen Lernens. In John H, Thinesse-Demel J (eds) *Lernort Museum – neu verortet*. Bielefeld, Germany: Transcript Verlag für Kommunikation, Kultur und soziale Praxis

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Weber T (2002) Learning in schools and learning in museums: which methods best promote active learning? In Calcagnini S, Felfoldi Z, Van Den Bosch J, Xanthoudaki M (eds) *A Manual of Good Practice Based on the Collaboration Between Science Museums and Schools*. Milan, Italy: Museo Nazionale della Scienza e della Tecnologia

Bevan B, Semper RJ (2006) Mapping Informal Science Institutions onto the Science Education Landscape. www.exploratorium.edu/cils/research/mapping.html

Science on Stage Deutschland (2006) The importance of interdisciplinary education. In *Teaching Science in Europe*. Berlin, Germany. www.science-on-stage.de

Lewalter D, Geyer C (2005) Die Evaluation der Homepage des ZNT. In Noschka-Roos A, Hauser W, Schepers E (eds) *Mit neuen Medien im Dialog mit den Besucher* pp 32-42. Berlin, Germany: G+H Verlag

CyberMentor: e-mentoring to strengthen interest and participation of girls in STEM

Germany, like many other European countries, has difficulties attracting women into science. **Diana Schimke** from the University of Ulm, is working improve matters by putting schoolgirls directly in contact with women scientists.

Mentees in a lab at the Fraunhofer Institut IZM, Munich, Germany

Image courtesy of Diana Schimke

CyberMentor is a programme for German high-school girls to foster interest and participation in science, technology, engineering, and mathematics (STEM) by pairing them with professional women in STEM who can inform and advise them.

Why is a programme like CyberMentor important?

In Germany, few women study STEM subjects, in particular applied subjects such as electrical engineering, informatics and industrial engineering[w1]. This is a loss not only for society, because there are fewer engineers and well-educated people in STEM, but also for the women themselves, who tend to take less secure and less well-paid positions in other fields.

Two possible reasons why girls choose not to study STEM are a lack of information about STEM career opportunities and the absence of suitable role models. To address both of these problems, we created the

CyberMentor online community to bring together German high-school girls and professional women in STEM.

Description of the programme

CyberMentor is an e-mentoring programme to foster interest and participation of high-school girls in STEM via the Internet. It provides suitable role models via mentoring, which involves a one-to-one relationship between women who work in the field of STEM (such as researchers, professors or engineers) and high-school girls. The girls communicate with their mentors via email.

Each high-school student (mentee) is paired with one female mentor who is working in STEM. They interact via email once a week over a period of 10 months. Topics range from private themes like "Do you have children?" to special scientific questions about the mentor's work ("Can you explain what a Petri net is?"[w2]). Some mentees also ask for advice on homework or presentations that they have to prepare for school, or about study cours-

Image courtesy of Diana Schimke

Each user can fill out a personal page. Mentors describe their jobs and what they are doing. That way, the girls get impressions of STEM jobs and see the variety that exists

es and what it is like to be a student in a male-dominated subject. Others are interested in the different study possibilities (university, college of higher education, corporate education) and which option their mentors chose. Each mentoring pair chooses their own topics and both mentoring partners can introduce themes they are interested in; in some cases, the mentee asks question after question, in other cases the mentor offers interesting themes for discussion. Handbooks with advice and guidelines on how to communicate are made available to both mentors and mentees. Besides emailing, some mentors arrange chat sessions with their mentees inside the CyberMentor community platform or offer to show them (and often other mentees as well) their workplace.

Besides the one-to-one communication between the members of each mentoring pair, participants can post questions to a discussion forum. From other mentees and mentors they get advice on schoolwork, possible jobs, staying abroad, internships and other topics the students are interested in. Having so many other students and mentors as contact persons offers a great possibility for information exchange. In the first year, for example, one girl didn't know if she was able to study technical cybernetics and still be able to have a family some day. Instead of studying her favourite subject, she thought about choosing a typical female study course. Several mentors answered and told the girl that it is possible to be an engineer and have children at the same time. They told her their own stories or stories from women they knew. A few months later the girl posted to the topic again and wrote that she has signed in for technical cybernetics and wanted to thank all the mentors for their advice.

Furthermore, CyberMentor offers personal pages for each member to introduce themselves, and a monthly journal, called *CyberNews*. *CyberNews* reports on interesting STEM articles, quizzes and interviews with female students talking about their study courses in STEM. Mentees and mentors can also submit their own articles. In addition to the virtual exchange, the CyberMentor programme arranges two to three face-to-face meetings, training sessions for mentors and workshops for mentees. The meetings allow mentees and mentors to get to know each other personally. Training sessions teach the mentors what is expected of them and offer advice on how to interact with the mentees. Workshops for mentees give them an insight into STEM topics and enable the girls to work together in teams to address interesting STEM topics. The workshops range from lab work at research institutes (e.g. Fraunhofer, Max Planck Institutes) to computer workshops at the University of Ulm. The workshops are often combined with online discussions in the CyberMentor forum and chat room.

Participation in the CyberMentor programme is free for both mentees and mentors. This includes all the meetings and workshops. Only transport and accommodation has to be covered by the participants. For some mentee workshops, sponsors from industry can be found and mentees do not have to pay for their transport.

BACKGROUND

How can I join?

The programme first started in September 2005 with about 100 mentoring pairs. The second, current, round started in September 2006 with 240 pairs. The next CyberMentor season starts in September 2007 and we plan to invite 300 new mentoring pairs into the programme. Mentors and mentees can apply now.

What do CyberMentor participants think about the programme?

The evaluation of the programme is not yet complete; first results suggest however, that interest in STEM and the willingness to participation in science is strengthened by active participation in CyberMentor. Mentors see the programme as a great chance for girls to learn about possible jobs in the fields of science, technology, engineering and mathematics.

I like the CyberMentor project because it offers female students an uncomplicated possibility to get to know STEM jobs and study courses. It shows the mentees many interesting fields of work and can create new interests or deepen existing ones. As a mentor, I can give an insight into my work, answer questions about studying and hopefully pass on a little enthusiasm. But mentors also benefit from the exchange: you get a different perspective on things.

Cornelia Beck, PhD student, University of Ulm

I think CyberMentor is a fantastic programme because it covers a wide variety of needs. A girl who is finishing school and doesn't know where to study can get professional advice, as can a girl who wants to know if a science career can be combined with a family. Also younger girls learn about STEM topics by exchanging with mentors or older students and by participating at workshops and in teams. This I believe is especially important. Many approaches to get girls interested in STEM careers are introduced too late. Informative meetings about science for female students who are about to graduate reach only very few students – most have already decided "STEM is not for me", but often it would have been had they received more information at an earlier stage. CyberMentor offers the possibility to get to know science early and through a positive approach.

Birgitta König-Ries, Professor of Computer Science, University of Jena

I was convinced by this mentoring programme right away. It is important to show girls that they do not have to choose 'typically female' jobs, but that they can choose different careers too. Especially in STEM, girls often think they are not good enough or if they are, they are still not interested. I think CyberMentor is a great possibility to show girls that STEM subjects and STEM jobs can be awesome too and that there is room for them. Maybe this programme will help to ensure that someday it will be normal that there are as many women as men in leadership positions, in research and in industry.

Marlies Kepp, industrial engineer, Trumpf GmbH + Co. KG, Ditzingen

Image courtesy of Diana Schinke

Teamwork at a CyberMentor workshop

I am totally amazed by CyberMentor! You can exchange messages about all different kinds of topics, you get to know new people and you can ask them anything about STEM or personal themes. Furthermore there are competitions and projects to participate in and you get to go on trips and visit institutes you otherwise would not be able to visit (e.g. Fraunhofer IZM, Munich). You learn about new and interesting topics, get to know new people and have lots of fun!

Tanja (Year 8)

CyberMentor offers the possibility to learn new and interesting things about STEM. I often feel that what is offered in school is not enough for me. I like to get involved in different topics and to exchange ideas with mentors and other students. Furthermore I think it is an interesting and exciting chance to communicate with like-minded people and to learn more through this.

Angela (Year 11)

At the Fraunhofer IZM, where mentor Sabine works, the girls learned about radio-frequency identification and visited, for example, the clean room, where they could practice wafer handling

Image courtesy of Diana Schimke

Mentor and mentee get to know each other personally at a CyberMentor meeting

REVIEW

This project is a good idea, and the article can provide a stimulus for a discussion about the problem of a declining interest in science in younger generations of Europeans.

Isabella Marini, Italy

Mentees

Any girl in Years 6-13 (ages 12-19) at a German school who is interested in STEM can apply to be a mentee. On the online application form, specify which STEM topics you are most interested in and we will try to find a suitable mentor for you. Every girl who applies is assigned a mentor, although late applicants may have to wait until the following academic year.

To join the next CyberMentor season (starting in September 2007), apply soon so that we can guarantee you one of the 300 mentors. For more information, visit the CyberMentor website[w3].

Mentors

We are looking for women working in STEM fields (such as teachers, industrial scientists, engineers, researchers, professors and so forth), within and outside Germany, to be mentors. We expect mentors to offer 10 minutes a week to stay in contact with their mentees. This can be more if you are discussing interesting topics or less in cases of vacation or business trips, of course.

You need to understand German to be able to read our newsletters for mentors but if you prefer, you can communicate with your mentee in English. For more information, visit the CyberMentor website[w3].

Schools

The CyberMentor team are happy to visit German schools to present the project to students of all ages. To request a visit or receive an information pack for schools and students, email cybermentor@uni-ulm.de.

Web references

w1 - More details of the gender difference at university are available in the report *In the Spotlight: Women in Germany 2006* which can be downloaded here: www-ec.destatis.de /csp/shop/sfg/bpm.html.cms. cBroker.cls?cmspath=struktur, vollanzeige.csp&ID=1018406

For a European comparison of women in industrial research, see the EU report Women in Industrial Research – speeding up changes in Europe which can be downloaded here: http://ec.europa.eu/ research/science-society/women/ wir/ index_en.html

w2 - What is a Petri net? See http:// en.wikipedia.org/wiki/Petri_net

w3 - The CyberMentor website www.cybermentor.de

BACKGROUND

Who runs CyberMentor?

CyberMentor is a non-profit programme organised by the University of Ulm, Germany. The administrators are the psychologists Dr Heidrun Stoeger and Professor Albert Ziegler. Diana Schimke is a computer scientist and works full-time for the programme. She is supported by Iris Woersdoerfer, a research assistant who is studying computer science. The programme is financed by the German Ministerium für Ernährung und Ländlichen Raum (Ministry for Nutrition and Rural Areas) and the University of Ulm.

If you would like to know more about the programme or get advice about setting up a similar project in your own country, please contact Diana Schimke (diana.schimke@uni-ulm.de) or visit the CyberMentor website[w3].

Inspirational lessons in the science class

Naheed Alizadeh from Imperial College, London, UK, explains how and why the INSPIRE project is trying to make inspirational science lessons, clubs, and master classes regular features of the state school timetable in the UK.

Image courtesy of Naheed Alizadeh

INSPIRE (INnovative Scheme for Post-docs In Research and Education) arose in response to the well-known concern that fewer students are studying science in schools and universities. This decline has, in turn, led to fewer qualified science teachers, with pupils often being taught by staff who have limited formal qualifications in the subject or who graduated in their subjects many years ago. Thus, an increasing number of science teachers lack the necessary scientific experience and confidence to communicate science and current developments in science.

Imperial College[w1] and its partners, GlaxoSmithKline[w2] and the Specialist Schools and Academies Trust[w3], are working together to reverse this trend. INSPIRE, launched by UK Prime Minister Tony Blair in 2002, employs post-doctoral research assistants ('post-docs', those who have already completed a PhD) from a science, engineering or medical-related discipline on two-year contracts. They spend 50% of their time in partner schools teaching the science curriculum and working towards a qualified teacher status. The remainder of each post-doc's time is spent doing research at Imperial College in their chosen field.

In addition, post-docs use their scientific expertise and experience of university and research to help schools run science-based activities such as master classes, science clubs, university-level training for A-level students (ages 16-18), careers advice, science conferences, and student visits to university research laboratories.

Although the post-docs are placed long-term in secondary schools, they are also sent for one-week placements in primary schools. This helps them to find out how science is taught at the primary level and how it progresses into secondary schools. Some children from local primary schools take part in master classes or science clubs run by INSPIRE post-docs at the secondary school.

"We studied crime scene investigation, which included using ink samples with chromatography paper. The next week, we researched magnets, magnetic breakfast cereals, attracting and repelling and a magnetic challenge in which we had to

Image courtesy of Naheed Alizadeh

move a chocolate bar from one end of a piece of wood to the other. .... I enjoyed the science club."

Student in Year 5 (age 10/11)

The post-docs are able to take university-style teaching into the classroom not only by referring to their research experience but also by taking equipment not normally seen in school. David, an INSPIRE post-doc and expert in laser technology, impressed his school students with a session on 'How to Make a Call Across the Atlantic', exhibiting state-of-the-art fibre optic equipment from Imperial College. Jenny, another INSPIRE post-doc and a specialist in pig nutrition, wowed her students with the dissection of a stillborn piglet. The INSPIRE scheme thus allows David and Jenny to bring aspects of their everyday research – an unknown world to most school students – into the classroom.

These benefits do not end when the post-doc leaves, however, as Imperial College continues to support the INSPIRE schools after the end of their scheme. School students are invited to experience undergraduate life at the College, visiting the electron microscope facilities or the laser lab, and finding out what it is like to study molecular biology or astronomy. The schools can also have demonstration lectures from other post-doctoral scientists.

The INSPIRE scheme is distinctively different from many other schemes designed to increase participation in science in state schools. It places emphasis on practising post-doctoral scientists (rather than first-degree graduates) teaching science at schools for significant periods of time. Furthermore, the scheme aims to make inspirational science lessons, clubs, and master classes regular features of the schools' timetable. Prolonged contact enables the students to see the post-docs as positive role models, embodying advanced academic scientific success.

Who benefits from the scheme?

School students who have experienced the post-docs' enthusiasm and expertise express great appreciation of what INSPIRE has brought to the classroom.

"[In] a biology master-class in molecular biology [we gained] an insight into a university-style event, [...] enjoyed the experience and had the chance to use [modern] lab technology and equipment in a classroom."

Year 12 biology student (age 17)

Schools who have experienced the scheme are keen to have more post-docs and to continue their commitment to INSPIRE. The post-doctoral researcher teachers not only challenged the orthodoxy of how some aspects of science are taught and offered a fresh approach, but also added a dimension of authority with their extra scientific expertise. Post-docs bring a depth of current scientific knowledge that less-experienced scientists lack, and when this is combined with a willingness to share this knowledge with students and teachers, it can enrich the scientific culture of the whole school.

Teachers find that the INSPIRE post-docs bring a wealth of information on cutting-edge research, allowing the teachers to update their knowledge in that area of science and giving them confidence to teach it better. Many teachers ask the post-

BACKGROUND

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How to get involved

How to apply to be an INSPIRE post-doc

Vacancies for new INSPIRE post-docs are advertised, for example, on www.jobs.ac.uk

How to get an INSPIRE post-doc in your school

Schools that are interested in hosting an INSPIRE post-doc can contact Naheed Alizadeh, the Director of the INSPIRE project (s.alizadeh@imperial.ac.uk). With the help of the Specialist Schools and Academies Trust, Imperial College selects those schools most likely to benefit from the scheme.

docs to leave their presentations behind for further use in the classroom.

For the post-docs, the INSPIRE scheme is attractive because it allows them to attain a teaching qualification without dropping their research – and to do this while earning more than a trainee teacher. One post-doc explains:

"INSPIRE allows post-docs to span two disciplines: science and education. The unique fusion enables a post-doc to experience teaching without having to commit immediately to a career change. For a post-doc to move out of science is a massive decision, [so] this scheme is a perfect vehicle to enable post-docs to achieve this transition or to return to science with a much broader understanding of how to teach science within a university setting."

Whether the post-docs decide to stay in research or to move into school teaching at the end of the two years, most of them say they enjoy the opportunity to investigate an alternative career, motivate and work with young people, bring science to life and have a huge – and ongoing – impact on science lessons at school. David describes some further benefits:

"I picked up management skills, how to organise people and motivate them. It also helped me to build up confidence in public speaking and belief in my own abilities. Teaching helped me to refresh my knowledge and broaden it, which can feed back into my work in the lab."

The overall responses of the post-docs' research supervisors have also been very positive – they get a free part-time post-doc as well as money for the research consumables – even though some initially had their doubts about adapting research projects to fit the INSPIRE post-doc's timetable. It all comes down to careful planning of work and choice of project to ensure success.

The future of INSPIRE

The INSPIRE scheme has completed its first four years, and already, the signs are very positive:

- Ten post-docs from the first, second and third cohorts completed their PGCE over these four years. Five of them have changed careers and chosen school teaching.
- Every time two post-doc positions are advertised for the new cohort, 200 applications are submitted.
- The scheme has been positively judged by Roehampton University, the independent evaluation body.
- INSPIRE has been reported positively in the press, including articles in *Nature* (Peplow, 2004) and the *Financial Times* (Kelly, 2005).

Finding funding to continue the scheme, however, is not as straightforward as recruiting enthusiastic scientists and schools. Although GlaxoSmithKline provided a large initial sum of money and the Training and Development Agency for Schools[w4], responsible for funding teacher training in the UK, has been very supportive, the main government departments responsible for research and education have tended to say that it was other department's responsibility. The pilot scheme received welcome initial funding from the Department for Education and Skills[w5] but this was not enough for INSPIRE to be extended to other universities.

Nonetheless, Imperial College is keen to replicate this successful scheme on a national scale: it is launching a new national initiative based on similar principles but in a more time- and cost-effective mode. The new scheme, to be launched in September 2007, offers post-doctoral researchers and PhD graduates at the end of their research a seven-month teacher training course (PGCE – normally one year) attached to two months of INSPIRE activities in schools, including master classes, science clubs, and university visits.

BACKGROUND

Help is at hand

If you would like advice about setting up a similar scheme in your own country, Naheed Alizadeh, the Director of the INSPIRE project, would be happy to help. E-mail: s.alizadeh@imperial.ac.uk

Imperial College is actively seeking new sponsors to enable many more schools, their pupils and post-docs across the country to benefit from this exciting scheme.

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Peplow M (2004) Doing it for the kids. *Nature* **430**: 286-287

Kelly J (2005) The Stewards School: Inspiration in the classroom. *Financial Times*, 26 Feb

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w1 – Imperial College website: www.imperial.ac.uk

w2 - GlaxoSmithKline website: www.gsk.com

w3 - The Specialist Schools and Academies Trust website: www.specialistschools.org.uk

w4 - The Training and Development Agency for Schools website: www.tda.gov.uk

w5 - The Department for Education and Skills website: www.dfes.gov.uk

Resources

For more information on INSPIRE visit: www.imperial.ac.uk/inspire

Science Learning Centres: training for teachers

Image courtesy of the Science Learning Centres

Anna Gawthorp describes the creation of the ambitious Science Learning Centres network to help UK teachers, technicians and classroom assistants to make UK science education world-class.

Why was the network created?

England's national data tells a contrasting story about pupils' achievements in science. Attainment in primary and secondary schools has risen steadily over the past 10 years yet paradoxically, fewer pupils are taking the opportunity to study science after leaving school.

A recent international comparative study[w1] based at the University of Oslo asked school students about their views on science education (see Sjøberg & Schreiner, 2006). On the whole, the English students who were surveyed believe that science is important in their lives and for their future careers, and that everyone should study it. They do not find science excessively difficult, and many find it interesting, but students do not see themselves becoming scientists – and they do not enjoy science as much as other subjects.

The cause of this is not simple, as there seem to be several factors affecting students' perception of science. In England, many teachers feel that the curriculum and assessment are now so demanding that they have little time to develop interesting practical

Image courtesy of the Science Learning Centres

Image courtesy of the Science Learning Centres

work or to keep up with developments in their subject. Furthermore, there is a shortage of subject-specific science teachers, so that, up to the age of 16, students often have teachers qualified in a science subject that is not the one they are teaching. These teachers may not have the skills or knowledge to awaken and sustain interest in the subject.

How does the network of Science Learning Centres address these issues?

The national network of Science Learning Centres has been created to address these issues, offering continuing professional development to inspire science teachers and provide them with the skills and resources to enthuse their pupils. By working with industry leaders, research scientists and scientific organisations, the Science Learning Centres offer practical scientific knowledge and experience. This is matched with educational expertise, ensuring that teachers and technicians gain professional development that is creative, intellectually stimulating and relevant in terms of both contemporary science and the classroom environment.

There are courses tailored to all groups involved in science education, recognising the contribution of many groups of professionals. Thus, courses are available not only to secondary-school science teachers and further education lecturers, but also to primary-school teachers and teaching assistants, as well as those who work outside schools, such as science co-ordinators in local education authorities.

The topics of the courses are just as varied, ranging from traditional science subjects and related subjects such as psychology and citizenship issues, to career development courses. A few examples to illustrate the diversity include ‘Inspiring Learning Through ICT’, ‘Inspiring Post-16 Chemistry’, ‘Skills for New Technicians’ and ‘Support for Laboratory Refurbishment’. In addition to courses, the Centres run lectures, networking sessions, exhibi-

BACKGROUND

The Science Learning Centres network

The Science Learning Centres network is a unique £51 million joint initiative by the UK’s Department for Education and Skills[w2] and the Wellcome Trust[w3], the UK’s largest medical research charity, and is made up of nine regional Science Learning Centres and a national Centre which is based at the University of York. Each of the Centres is run by a regional partnership, awarded the contract following a competitive bid process, involving at least one university partner with additional involvement from industrial and research establishments.

The regional Science Learning Centres will be funded by the Department for Education and Skills until 2008 and aim to become self-sustaining in that time. The National Science Learning Centre will be funded by the Wellcome Trust until 2013, by which time it too should be self-sustaining.

Image courtesy of the Science Learning Centres

The National Science Learning Centre was launched by Tony Blair, the UK Prime Minister

tions, conferences and many other events. All events are listed on the Science Learning Centres website[w4].

To ensure the courses best meet the needs of their attendees, they are developed and delivered by a wide variety of experts. Thus on the 'Controversial and Contemporary Science' course, sessions are given by classroom teachers, educational researchers and academics, as well as world leaders in controversial science topics such as climate change and genomics. On a course to help schools link effectively to industry, there are trainers with various industrial backgrounds, as well as a curriculum expert.

Courses run throughout the year, but mostly during term time. In general, courses at the regional Centres last one or two days, whereas courses at the national Centre may consist of two residential periods of up to three or four days each. The focus of the regional centres is local, with courses run throughout the region, including some tailored to individual schools. By contrast, the National Science Learning Centre offers residential courses, providing access to state-of-the-art facilities for teachers from across England, Scotland, Wales and Northern Ireland.

Although the courses are normally paid for from the school's training budget, there are often bursaries and discount schemes available to help pay for all or part of a course. Some include a contribution towards the cost of a replacement teacher at school for the duration of the course.

Image courtesy of the Science Learning Centres

To enable the teachers – and their students – to continue to benefit from the training after the course has finished, almost all courses have a range of associated resources. Many are provided free of charge to attendees and are usually available online to delegates after the course. To further widen their impact, the Science

Learning Centres are currently developing an online resource bank that will be launched soon[w4]. This library will include everything from helpful tips, games, worksheets, slides and classroom activities created by fellow teachers, to relevant government documents or research papers, or links to the best science education websites.

In their first year of operation, the Science Learning Centres delivered over 10,000 days of training. Although an independent evaluation to investigate the impact in schools is ongoing, initial feedback from teachers has been very positive: "This has renewed my enthusiasm for the job that I do" (science technician); "This course has far exceeded any expectations I had – it may have saved my career" (head of science).

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Sjøberg S, Schreiner C (2006) How do students perceive science and technology? *Science in School* **1**: 66-69. www.scienceinschool.org/2006/issue1/rose/

Web references

w1 - For further information about ROSE, an international comparative study that investigates the diversity of interests, experiences, priorities, hopes and attitudes that children in different countries bring to school or have developed at school, see www.ils.uio.no/english/rose

w2 - The UK government's Department for Education and Skills (DfES): www.dfes.gov.uk

w3 - The Wellcome Trust is the UK's largest medical research charity funding research into human and animal health: www.wellcome.ac.uk

w4 - More information about the Science Learning Centres is available here: www.sciencelearningcentres.org.uk

REVIEW

This interesting and appealing article describes a possible answer to a crisis that is common to all of Europe. The continuation of teachers' skills improvement and professional education is an issue rarely considered by governments and decision-makers, but extremely important and decisive for providing teachers with the ability to communicate their knowledge and to stimulate pupils.

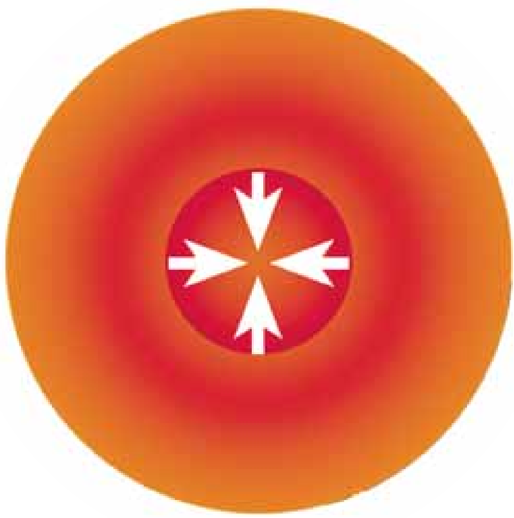
The UK experience can provide a solution, allowing teachers to continue their professional education and re-lighting their fire of motivation. Science Learning Centres represent a good example for decision-makers in other European countries to follow.

Marco Nicolini, Italy

Image courtesy of the Science Learning Centres

Image courtesy of the Science Learning Centres

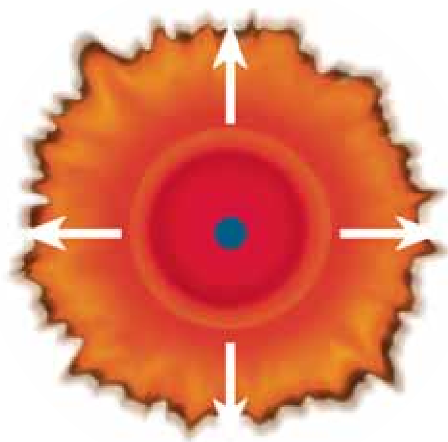
Fusion in the Universe: where your jewellery comes from



Does alchemy sound too good to be true? **Paola Rebusco**, **Henri Boffin** and **Douglas Pierce-Price**, from ESO in Garching, Germany, describe how creating gold – and other heavy metals – is possible, though sadly not in the laboratory.

How are heavy elements formed? The last episode of the 'Fusion in the Universe' saga (Boffin & Pierce-Price, 2007) ended with the production of iron, but the nucleosynthesis adventure – in which atomic nuclei are created – does not stop there. Let us refresh our memory. In the first few minutes after the Big Bang, the temperature of the newborn Universe cooled down (to a few billion degrees!) to form hydrogen and helium. Stars spend most of their life burning hydrogen into helium. Only when temperature and pressure become high enough do they start to fuse helium atoms, forming new elements. Lighter elements are the bricks that successively fuse together to produce heavier elements, up to iron-56.

Iron-56 has the most stable nucleus because it has the maximum nuclear binding energy (see box on page 54 and diagram on page 53). Nature cherishes stable configurations and therefore the fusion process described in our last article, which brings us from hydrogen up to heavier, more stable nuclei, will not continue beyond iron-56. So, where do heavier elements such as lead, silver, gold and uranium come from? There is no magic: the Universe provides other fascinating ways to produce all the heavy elements. In the high temperature and pressure of a star, fusion is as spontaneous as rolling down a hill (a process that releases energy). However, these new mechanisms are more laborious, like climbing a hill (a process that needs energy). Furthermore the next stages of nucleosynthesis are quite hectic, as they involve captures and explosions. Three types of capture are involved, two dealing with the capture of neutrons (the s- and r-processes) and one with the capture of protons (the p-process).



Neutron capture

One route to create elements heavier than iron-56 starts when extra neutrons collide and fuse with an existing nucleus. In this way we get neutron-richer, heavier nuclei, but with the same number of protons, or the same

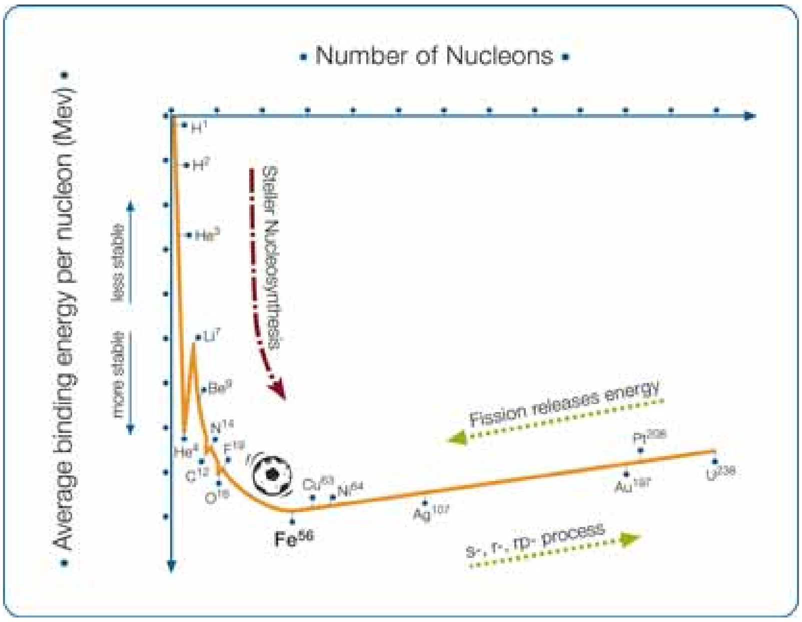


Image courtesy of Mafalda Martins, ESO

Binding energy plot: the graph shows the nuclear binding energy per nucleon (i.e. per proton or neutron), expressed in MeV (1MeV=1.6x10^{-13}J). For increasing atomic number the binding energy increases (downwards in this plot), until it reaches its maximum for iron-56. The nucleosynthesis from hydrogen to iron-56 is energetically favourable and occurs through consecutive fusion reactions. If you want to climb the rest of the periodic table, then new mechanisms, such as the s-process, r-process and p-process, are needed. Note that one can go in the opposite direction (from heavy to light nuclei) through nuclear fission

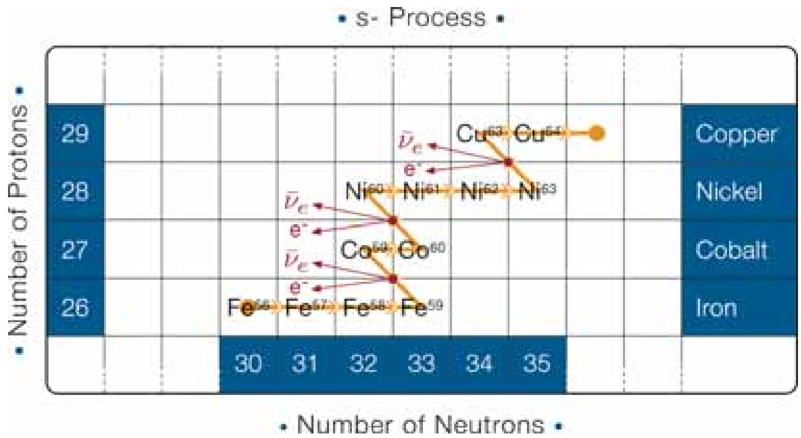


Image courtesy of Mafalda Martins, ESO

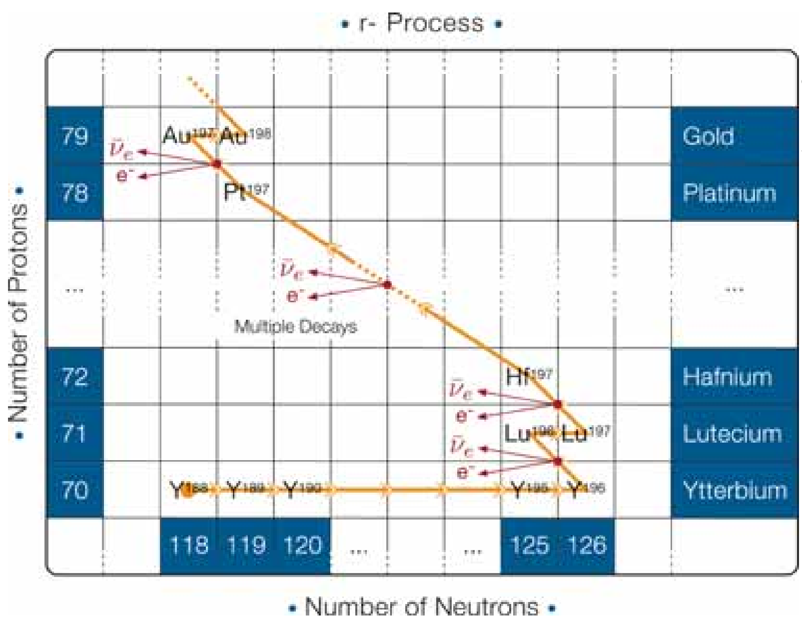


Image courtesy of Mafalda Martins, ESO

Examples of the s-process (top) and r-process (bottom). Each position on the grid represents a different possible nucleus, with the number of neutrons varying horizontally, and number of protons varying vertically. Thus, each horizontal row represents isotopes of a single element. In the paths shown, a step to the right corresponds to a neutron being acquired by the nucleus. A diagonal step up and to the left corresponds to a beta-decay in which a neutron turns into a proton, releasing an electron and an anti-neutrino.

Notice that the horizontal track in the s-process is shorter than in the r-process (in the s-process fewer neutrons are captured); as a consequence the movement in the vertical direction is also shorter (there are fewer neutrons that can be converted into protons) atomic number. These nuclei are just heavier isotopes of the original element, so we have not yet achieved our aim of creating a heavier, different element.

However, the process has not yet finished. These new isotopes may be stable or unstable, depending on their number of protons and neutrons. If the neutron capture produces an unstable isotope, then it can undergo a spontaneous radioactive decay. One such decay is 'beta decay', in which an electron and an anti-neutrino are emitted, so that one of the nucleus' neutrons is converted into a proton. The net result of this conversion is a nucleus with one more proton and one fewer neutrons. Since the number of protons has changed, this has indeed produced a new, different element.

In this process of neutron capture followed by beta decay, it is important whether the initial neutron capture is slow or rapid relative to the beta decay. The two cases, referred to respectively as the s-process and r-process, produce different elements and occur in different circumstances in the Universe.

Slow neutron capture: the s-process

Each neutron capture in the s-process converts a nucleus to an isotope of the same element with one more neutron. Eventually, these single increases in neutron number lead to an unstable isotope. Because the neutron capture is relatively slow in the s-process, the unstable nucleus beta-decays before any more neutrons can be captured. In other words, as soon as the first unstable configuration is reached, a beta decay turns the nucleus into one with one more proton and one fewer neutrons, see diagram on page 53.

Where in the Universe can we find the right conditions for the s-process to occur? It turns out that it can occur during the late stages of the life of Sun-like stars. We already know (see, for example, Boffin & Pierce-Price 2007) that if the initial mass of a star is comparable to that of the Sun, then at the end of the star's life, it runs out of fuel and cools to become a white dwarf. Before it cools down, free neutrons are produced (mainly from the decay of carbon and neon): they are plentiful enough to produce heavy elements via slow neutron capture. In this way, elements such as barium, copper, osmium, strontium and technetium are produced.

Rapid neutron capture: the r-process

If, instead, the neutrons are produced at a very high rate, then the unstable nuclei that are formed have

BACKGROUND

The mystery of the vanished mass

The nuclear binding energy is the amount of energy needed to break a nucleus apart into protons and neutrons. It is also the energy that two particles release when they merge. Let's imagine you have a proton and a neutron and that they have the same mass (a very good approximation). Push them together until they merge and they will form a deuterium nucleus. What is its mass? If the proton has mass 1 and the neutron has mass 1, you would expect 2, wouldn't you? Not so: the mass of a deuterium nucleus is lower than the sum of the two – some mass has vanished! The solution lies in the famous Einstein equation, $E = mc^2$. When two particles merge, they release the nuclear binding energy EB, but since energy and mass are equivalent, this means that the correspondent mass, $m_B = E_B/c^2$, is lost.

Let's consider first helium-4 and then iron-56. In atomic mass units ($u = 1.66 \times 10^{-27}$ kg = 931.5 MeV/c^2) the mass of a proton and a neutron are $m_P = 1.00728$ u and $m_n = 1.00866$ u, respectively. The measured mass of a nucleus of helium-4 is $m_{He} = 4.00150$ u, while the sum of the mass of its components is $2m_P + 2m_n = 4.03188$. The difference gives the mass 4.03188 u – 4.00150 u = 0.03038 u, which corresponds to a total binding energy of approximately 28.3 MeV (the binding energy per nucleon is 28.3/(2 + 2) = 7.07 MeV).

If you repeat the same steps for iron-56 (which consists of 26 protons and 30 neutrons), the total binding energy is much greater: about 492.2 MeV, or 8.79 MeV per nucleon. This extreme stability places iron-56 at the lowest point of the curve in the binding energy plot, and fusion to heavier elements would be an 'uphill' process, requiring the input of energy. This is why, although helium-4 nuclei can be readily fused into heavier elements, more extreme processes (described in this article) are required to obtain elements heavier than iron-56.

enough time to swallow many neutrons that subsequently decay in cascade into protons (see diagram): this is how the elements with the highest atomic number are synthesised in nature.

Let us discover where the r-process takes place in the Universe. As was also discussed in the previous article, when the mass of a star is greater than about eight solar masses, the temperature and pressure at its centre become high enough to trigger the fusion of carbon and oxygen and, ultimately, to form a core of iron. In this final stage, a star's interior is very like an onion (see right): the outermost envelope is composed of hydrogen and helium, with the inner layers consisting of progressively heavier nuclei, due to successive fusion reactions.

Iron is too stable to start to burn, hence it accumulates and the iron core continues to increase. There is, however, a mass limit (called the Chandrasekhar limit) above which the iron core can no longer grow, as its gravity becomes too high for it to support itself. At this point a catastrophic collapse (with the outer layers of the core reaching velocities up to 250 million km/h) shrinks the core, until the infalling matter bounces back and all the energy is transferred to the outer layers, in a titanic explosion (see below). This phenomenon is called a supernova explosion, specifically a Type II supernova (SN II).

It is in the collapsing iron core of SN II that the r-process occurs. During collapse, electrons and protons merge to produce neutrons and neutrinos. The flux (the number per unit time and unit area) of neutrons is so high (of the order of 10^{22} neutrons per cm^2/s) that a nucleus has time to capture many neutrons before it beta-decays. Gold, europium, lanthanum, polonium, thorium and uranium are some of the elements produced through the r-process.

The onion-like structure in the final stage of a massive star: the outermost envelope is composed of hydrogen and helium, and progressively heavier nuclei (up to iron) are layered, due to successive fusion reactions

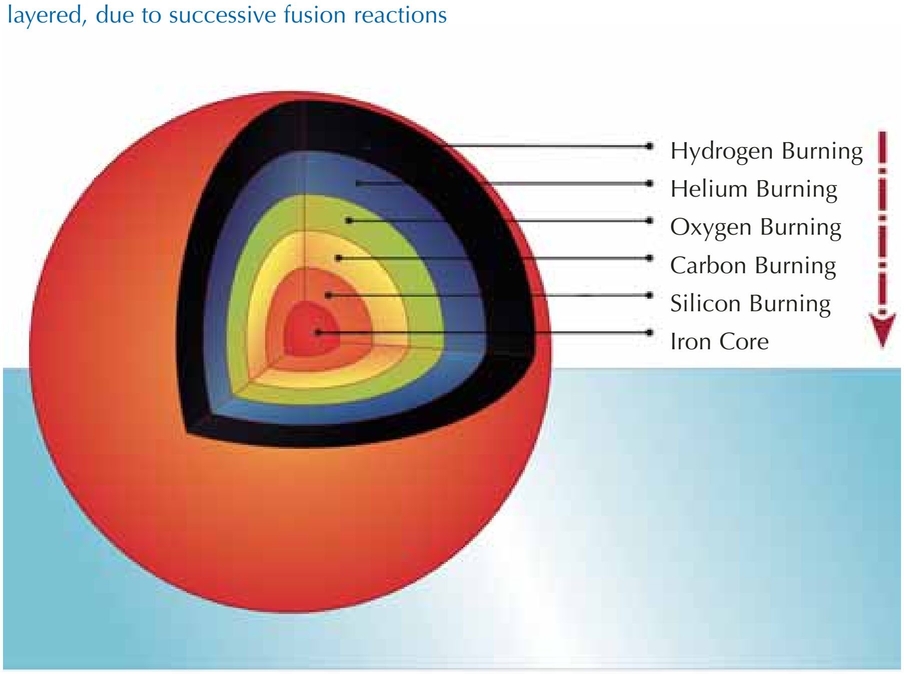


Image courtesy of Mafalda Martins, ESO

Proton capture

Another process by which heavier nuclei are produced is via proton capture (p-process). However, a large nucleus containing many protons has a high positive charge, which repels

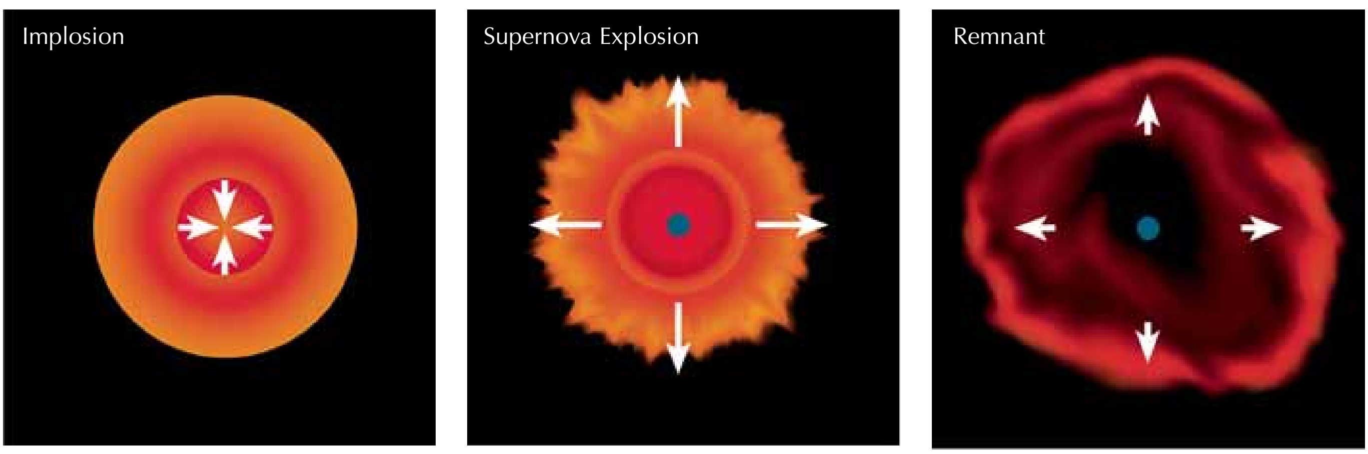


Image courtesy of Mafalda Martins, ESO

The different phases for Type II supernovae: core contraction, explosion, and supernova remnant

BACKGROUND

Margaret Burbidge and the B^2HF team

The mechanisms behind the production of the heavier elements (the s- and r-processes) were first pointed out in a long theoretical paper published in 1957: 'Synthesis of the elements in stars' (Burbidge et al., 1957). This revolutionary and still up-to-date paper is signed B^2HF – not a strange chemical compound but the initials of the surnames of the scientists who wrote it: Margaret Burbidge, Geoffrey Burbidge, William Fowler and Fred Hoyle.

The British astronomer Margaret Burbidge was born in 1919 and is still active in research, as professor emeritus of physics at the University of California, San Diego, USA. When she was a teenager, her grandfather gave her popular books on astronomy: "I saw my fascination with the stars, born at age 4", she writes in her witty autobiography (Burbidge, 1994), "linked with my other delight, large numbers." Her life has been full of scientific discoveries and political fights; it was not always easy to be a female scientist but she never gave up. "If you meet with a blockage, find a way around it," she suggests. The rest of the group is no less notable: Fred Hoyle and Margaret's husband, Geoffrey Burbidge, are most famous for their iconoclastic theories opposing the Big Bang theory, while William Fowler shared the 1983 Nobel Prize in Physics for his theoretical and experimental studies on nucleosynthesis.

additional approaching protons. This repulsion (the Coulomb barrier) is very high, and ensures that proton capture is a much rarer event than neutron capture. To be absorbed by the nucleus, a free proton must be very energetic, so this process only takes place at very high temperatures.

So where can we find high enough temperatures for proton capture? Again, we look to the stars. Although our own Solar System has only one star – the Sun – a large number of stars are actually in systems with at least two stars. When two stars are orbiting each other, they form a 'binary system'. If the stars are close enough, it is possible for one star with a strong gravitational pull to 'steal' gas from its companion star. This can happen, for example, when a massive, compact white dwarf or neutron star pulls hydrogen-rich gas down onto its surface from its partner. This material provides a flow of free protons, hot and energetic enough to overcome the Coulomb barrier and fuse with other nuclei. Lanthanum, ruthenium and samarium are typical elements produced in the p-process.

Conclusion

We have seen how, although nuclear fusion in stars produces elements only up to iron-56, heavier elements are produced by a variety of processes. These nucleosynthesis processes, involving the capture of neutrons or protons, and radioactive decays, happen in exotic situations in the Universe. Slow neutron capture can occur late in the lives of Sun-like stars, before they end their days as white dwarfs. Proton capture is a result of a white dwarf or neutron star cannibalising gas from an unfortunate companion star. And rapid neutron capture takes place during the catastrophic stellar collapse which occurs just before the dramatic explosion of a Type II supernova. By changing one element into another, these fascinating natural processes achieve what mediaeval alchemists could not – the transformation of base metals into (among other elements) gold.

Nevertheless, we cannot blame the alchemists. Their laboratories may have been well equipped, but they lacked a key piece of apparatus: a supernova explosion.

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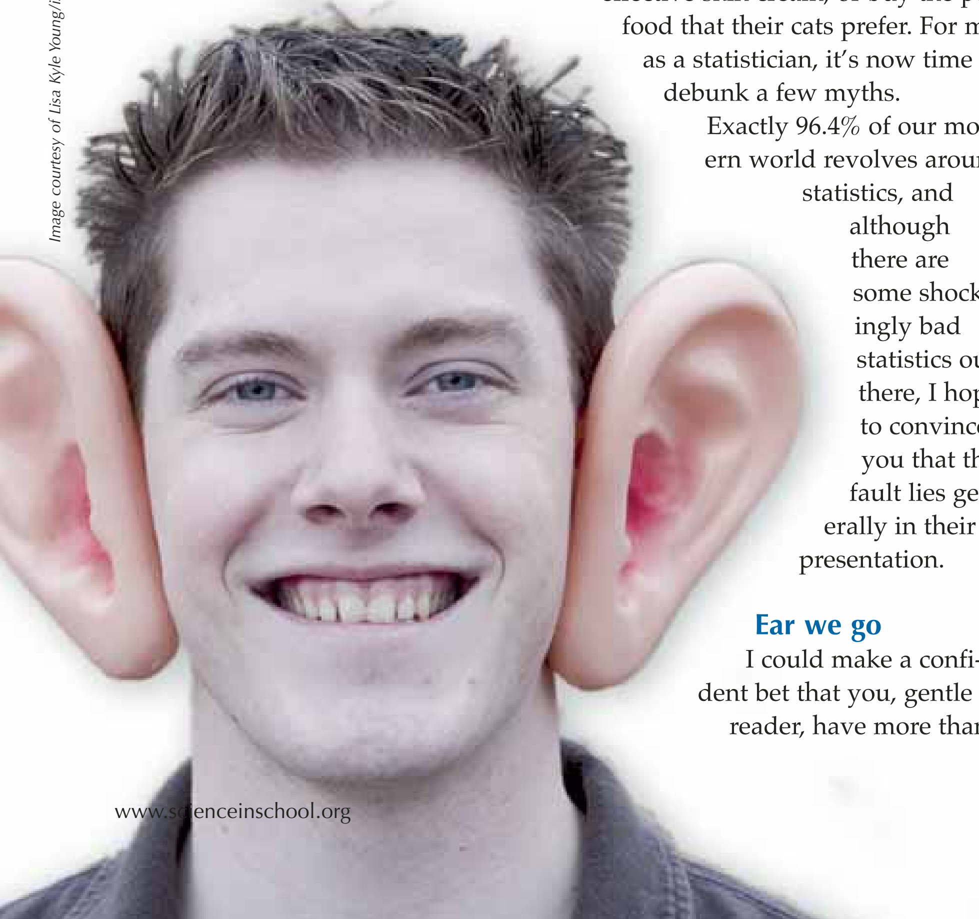
Burbidge EM (1994) Watcher of the skies. *Annual Review of Astronomy and Astrophysics* **32**: 1-36

Resources

To discover when and where the latest supernovae have detonated, see the Supernovae website, where scientists and amateurs hunt and register new supernova explosions: www.supernovae.net

Damn lies

Do you have more than the average number of ears? Is your salary lower than average? When will the next bus arrive? **Ben Parker** attempts to convince us of the value of statistics – when used correctly.



More than the average number of ears?

Image courtesy of Lisa Kyle Young/iStockphoto

Whether it was Mark Twain or Benjamin Disraeli who first coined the idea that there are three types of falsehood – "Lies, damned lies, and statistics" – the sentiment still persists. Statisticians are manipulative, deceitful types, set to pollute our minds with meaningless and mendacious information that will make us vote for their favourite political party, use their demonstrably effective skin cream, or buy the pet food that their cats prefer. For me, as a statistician, it's now time to debunk a few myths.

Exactly 96.4% of our modern world revolves around statistics, and although there are some shockingly bad statistics out there, I hope to convince you that the fault lies generally in their presentation.

Ear we go

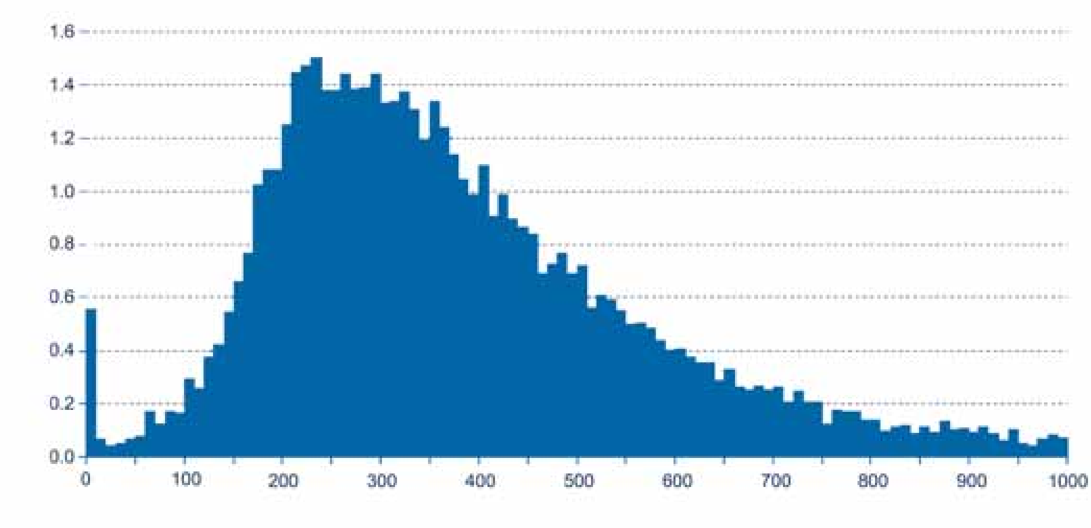
I could make a confident bet that you, gentle reader, have more than the average number of ears. Why? Let's assume that there are six billion people in this crowded world of ours, more than 99% of whom have two ears. There are a few exceptional people who, due to injury or birth, may have one or even no ears. There are, to my knowledge, no three-eared people (Captain Kirk is unfortunately fictional, but he did have three ears: a left ear, a right ear, and a final front ear). When we take an average (add up the total number of ears that humanity possesses, and divide by the number of people), we get the sum

$$\frac{\text{Slightly less than 12 billion}}{\text{6 billion}}$$

which is slightly less than two. This means that, as most people in the world have two ears, they have very slightly more than the average, so most times I would win my bet.

What does this mean?

Now, of course, this is obviously just a statistician being pedantic. However, slightly less silly examples abound. Statistics on how one group of people earn less than a certain percentage of the national average



Distribution of household weekly income 2004/2005: Number of individuals (millions), Great Britain. Source: Households Below Average Income (HBAI) 1994/95-2004/05, Department for Work and Pensions

income are used as political footballs. It is all too common to read commentaries in newspapers about how shocking it is that people earn only a percentage of the national income, and it's all the fault of the Labour government, previous Conservative administration, European Union or sunspots.

The distribution of incomes, according to the UK Department for Work and Pensions (see figure above), is such that there are relatively few people who earn large sums of money (unfortunately statisticians do not fall into this high-income group). This means that the average income, which the Department has calculated to be £427 per week for a couple with no children (DWP, 2006), is much more than what the majority of people earn, in parallel with the above explanation of average ear count. A few extraordinary people, whether they have fewer than two ears or earn large amounts of money, skew the average from the situation for the majority of people.

Now of course, people soon realised that this commonly used average, calculated by adding everything up and dividing by the number of things you added up, more properly referred to as the *mean*, was likely to be misinterpreted. So the concept of the *median* is one that is often used in practice. If we were to put all the people in the UK in a line according to their income, the median salary would be that which the person standing in the middle of the line would have. The median, about £349 per week in this example, in practice often gives a better idea about what is typical.

At least we have reached some common sense – so can we expect everyone to understand this fairly basic problem in conveying ideas with averages? After all, surely the role of a good journalist is to take ideas and present the truth in a way the public can understand?

Unfortunately, factual accuracy and correctly interpreting data sometimes don't sell newspapers, or make the correct political point.

Ironing out the wrinkles

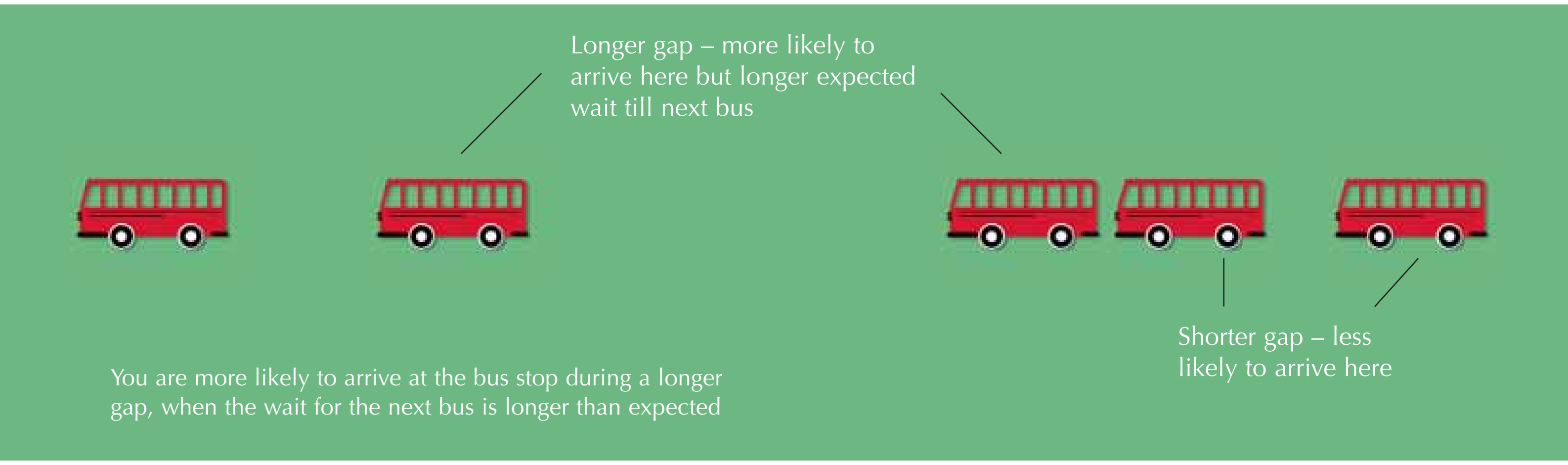
Worse than journalists, but not quite as bad as politicians, are advertisers. A recent television advert for a cosmetics company claims that their latest wrinkle-removing cream satisfies 8 out of 10 customers, based on a survey of 134 people. We can perhaps excuse the small sample size – and even the rounding (134 x 8/10 = 107.2), which means they must have found 0.2 of a customer to try out the cream – but the crucial question is how did they do the survey?

It seems to me that asking 134 customers whether they like the product is dubious – if the people are already customers, and have bought the product voluntarily, perhaps it's not the fairest sample in the world. Why would anyone buy the product who doesn't like it? In most sensible scientific trials, one would hope to compare the performance of the cream

Image courtesy of Al Wekelo/iStockphoto

Only 0.2 of this customer was satisfied

Image courtesy of Ben Parker



objectively against a brand X cream, or a placebo, to see whether people chosen at random have had a positive effect with the cream.

There's no problem with advertising *per se*; philosophers argue that advertising is the most vital thing for a strong democracy. It's fine for advertisers to let people know about their product and promote its benefits. However, what's not acceptable is putting a thin veneer of science around the marketing; although cunningly worded, without explaining the method, the statistic '8 out of 10' is meaningless. It's just as bad as saying "Our car has a top speed of 500 miles an hour" without adding that this speed is only obtainable when measuring how fast the car drops out of an aeroplane: it's true, but it's misleading. Using this kind of fake survey in advertising is paramount to lying.

Three come along at once

Maybe it's unfair to blame the conveyors instead of the statistics themselves. There are some real, difficult, non-intuitive facts that statistics throws up, the truth of which can be very hard to work out. Let's say you're waiting for a bus, and you look at the schedule, which, assuming it hasn't been vandalised, tells you that there are five buses an hour. How long would you expect to wait for a bus?

Sensible logic tells us that if there are 5 buses an hour, then the average (sorry, mean) time between buses is 12 minutes. So, assuming you arrive at the bus stop at a random time within this period, you'd expect to wait 6 minutes for a bus. Good logic, but unfortunately, in general, wrong.

We know that buses don't run to the minute. They may leave the depot on time, but chance factors will alter their progress in different ways, so we have to assume that the incoming pattern at our bus stop varies somewhat. What exact distribution we choose might vary – we may, for example, assume that times between arrivals of buses follow an exponential distribution – but the important fact is that the buses do not come at regular times. So let us now assume that we arrive at the bus stop at some random point in time – how long is our expected wait for a bus now?

When we turn up at the bus stop, we are more likely to pick a period when there is a big gap between buses – a big gap occupies more time than a small gap, so we're more likely to get a big one when picking at random. But given that we've picked a big gap, we know that the length of gap is more than 12 minutes (there are still 5 buses an hour) – so the average time to wait, given that our exact arrival time is equally likely to be somewhere in the big gap, is more than 6 minutes.

This is known as the inspection paradox, and it's tricky to get your head around it. However, it's a real phenomenon that is used by traffic planners and operational researchers, who are responsible for working out the most efficient method of arranging queues in post offices, and then ignoring it totally.

Are the bus companies wrong to advertise, then, that they have a bus approximately every 12 minutes? I think so, although it's difficult to convey all the gory details of the inspection paradox; perhaps in this case we can excuse a little statistical laxity.

Conclusions

In general, statistics is fairly intuitive and cases that are difficult to conceptualise are rare. In general, a questioning reader must:

- Find out who is presenting the data, and what they are trying to achieve.
- If possible, find out the sample methodology – whether the data comes from a suitably representative sample of the population being

Image courtesy of Monika Wisniewska/iStockphoto

REVIEW

The article presents a humorous view of how statistics are misused in everyday life. It would be comprehensible for teachers, students and general readers all over the world. In school, it could be used as an introduction to statistics and probability, to encourage pupils to think about how statistics and probabilities are used and misused.

I particularly like the hilarious headings and humour in the article – sometimes obvious, sometimes less so.

Marco Nicolini, Italy

measured, and whether any testing is applied in a fair manner. Are fair comparisons used, and is the right question being asked?

- Question any averages or percentages and think about how extreme the statistics really are, and what you would expect. In particular, don't assume that mean values are typical of the data.

Statistics is a powerful and useful tool in the right hands, and we need to give people the ability to understand it. We also need to ensure that some basic education in statistics, particularly in relation to interpreting advertising, is something that every pupil receives at school. At the very least, until journalists, the marketing industry, and the people who regulate them learn some statistics and, more importantly, how to present them, the world won't be buying the best skin cream and pet food for their cats, all of whom have an above average number of ears.

This article first appeared in Plus, *a free online magazine opening a window on the world of mathematics: http://plus.maths.org. 'Damn lies' was a runner-up in the general public category of the* Plus *new writers award in 2006.*

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Ben Parker is studying for a PhD at Queen Mary, University of London, and investigating the statistics of data networks. He has an undergraduate mathematics degree from the University of Cambridge, and a master's degree in statistics from Birkbeck, University of London. In his spare time Ben likes to act in pantomimes and drink tea.

Taking the stress out of engineering

Darren Hughes from the Institut Laue-Langevin in Grenoble, France takes a look at stress. How can it be manipulated to make safer rails for trains or more efficient wind turbines – and what can we learn from neutron- and X-ray analysis?

Image courtesy of Darren Hughes

Stress cracks in nature: the natural growth pattern of a tree causes residual stresses in the wood of the trunk. When the trunk is felled and the wood begins to dry, these stresses can overcome the strength of the wood and lead to significant cracks

We all know the feeling: a hard day, overloaded with work, and you feel stressed. Well, did you know that metals used in the construction of aircraft, buildings, cars and trains get stressed as well? In fact almost everything around us is subject to constant stresses, starting from the day they are made. In many situations, it is not too important if the stress causes something to fail because the damaged part can easily be replaced. However these stresses become extremely important in safety-critical components, for example in an aircraft engine or on a railway track. The engineers that design and manufacture these components are now working with scientists in Grenoble, France, to understand how these stresses are caused and to improve the component lifetime and reliability.

Stress in metal components is present right from the time of manufacture and arises during their formation. Stress in engineered components is often described in two ways, as either *residual* or *applied*. The stress that remains locked in a component after manufacturing is called the residual stress. When the component is used, it is subjected to applied stress, for example a train exerts an applied stress on the rail. The total stress on the component is therefore the sum of the applied and residual stresses.

Of course, stress can either be positive or negative depending upon the nature of the force. If a region of a component is stretched, then the stress is generally positive, or tensile; on the other hand, if it is squeezed then the stress is negative, or com-

Public domain image; image source: Wikimedia Commons

Stress plays a major role in modern aircraft. Components are carefully designed to have beneficial stress which extends lifetime and reliability

BACKGROUND

What is stress?

When a force is applied to an object, the object is said to be experiencing stress. Stress is effectively a measure of an object's response to a force. We define stress mathematically as the force applied, divided by the area over which it applies. The SI unit of stress is therefore Newtons per metre squared (Nm^{-2}). It is sometimes easy to confuse stress and pressure as the units of pressure are also Nm^{-2}. The important difference is that pressure is the external force on the object whereas stress is an internal force.

pressive. After manufacturing, the residual stresses in a component change each time the component is used, because of the applied stresses. The degree of change depends on the type of wear, the length of use, and the forces applied. Eventually, mechanical wear combines with the stresses and causes the component to fail.

Are all stresses bad or can some be beneficial? Yes, although a tensile stress is generally considered bad, a compressive stress is usually considered beneficial. Imagine a small crack that has formed in a surface (see below). If the stress around the crack is tensile, the crack is pulled apart by the stress and becomes deeper. On the other hand, if the stress is compressive, then the crack is pushed back together and grows no further. Modern engineers have devised production methods which allow them to put a compressive residual stress into regions of new components where small cracks might develop and thus improve the lifetime and wear resistance of critical components.

Sound simple? One problem is that the whole component has to obey the laws of physics, so that total stress is balanced when it is at rest – this is Newton's first law of motion. Thus, if you have a region of beneficial compression, there will be a balancing region of harmful tension elsewhere. Engineers therefore need to measure the residual stresses in a metal component so that they can locate both the compressive and tensile stresses, measure their magnitude and then further improve the manufacturing techniques. It is generally quite easy to calculate the applied stresses (e.g. from the way the weight of a train is distributed in the rails) but much more difficult to determine the residual stresses.

Understanding residual stress is increasingly important as structures

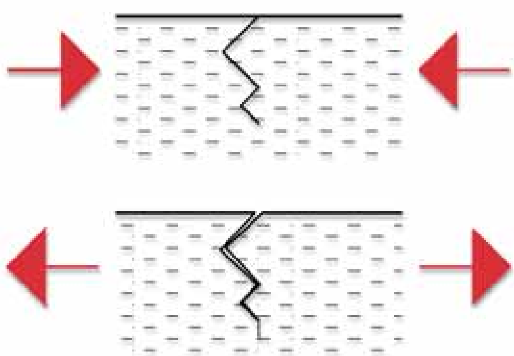


Image courtesy of Darren Hughes

The effect of stress on a crack

are required to be stronger, more economical and less environmentally damaging. In the transport sector, the use of lighter materials can reduce fuel costs dramatically, but it is essential that the component life is not shortened.

In France, engineers are working with scientists, using the world-leading neutron and X-ray science facilities in Grenoble to measure residual stress in components. Neutron and X-ray beams are fired at a metal component and the resulting diffraction pattern (right) provides a map of the residual stress in the component. One of the benefits of this non-destructive method is that neutrons and X-rays can penetrate long distances into metals, so residual stress can be studied without cutting the component into smaller pieces. The choice between neutrons or X-rays depends on the type of metal, the component size and the spatial resolution required.

One particularly important area of study is the significant residual stresses induced when materials are joined, for example by welding. The welding process causes thermal mismatch, driving residual stress formation which in turn affects the strength and fatigue life of the weld (see below).

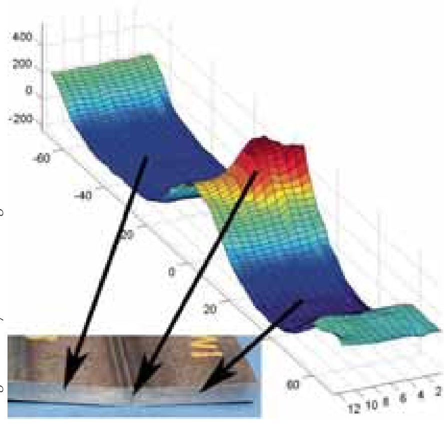


Image courtesy of Darren Hughes

Residual stresses in a steel fusion weld measured using neutrons. The peak tensile stress is located at the weld centre

BACKGROUND

Using neutrons and X-rays to study stress

Neutrons and X-rays are used to probe the crystal lattice of atoms in a metal to gain information on the stress state of the component. A beam of neutrons or X-rays with a fixed wavelength (λ) is fired at the metal and reflects off at a certain angle. There is a relationship between the spacing of the crystal lattice (d) and the angle at which the beam is reflected (θ). This relationship is called the Bragg law.

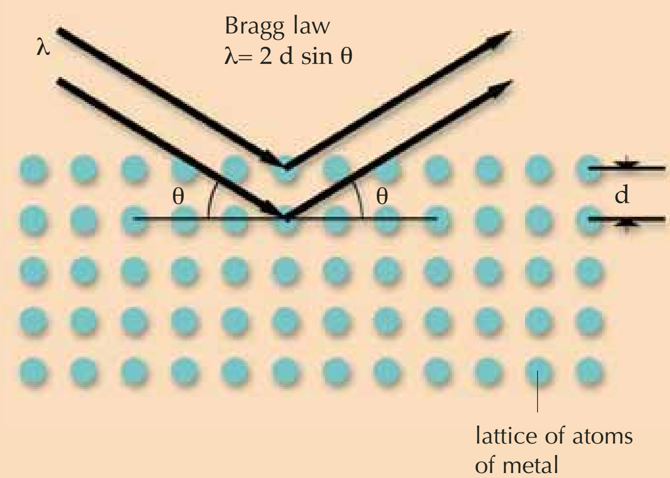


Image courtesy of Darren Hughes

Imagine that you apply a stress – either tension or compression – to the lattice of the metal. When the lattice is stretched, the spacing of the lattice changes. For example, in the case below, d_{tens} is now larger and d_{comp} is smaller. If we look at the Bragg law again, assuming that the wavelength has not changed, then the angle θ must change. By using a detector to measure the angle at which the beam is reflected, we can work out if the metal is in tension or compression and to what magnitude.

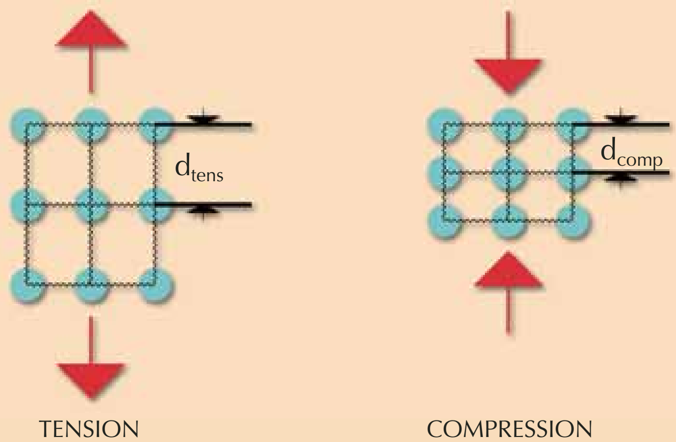
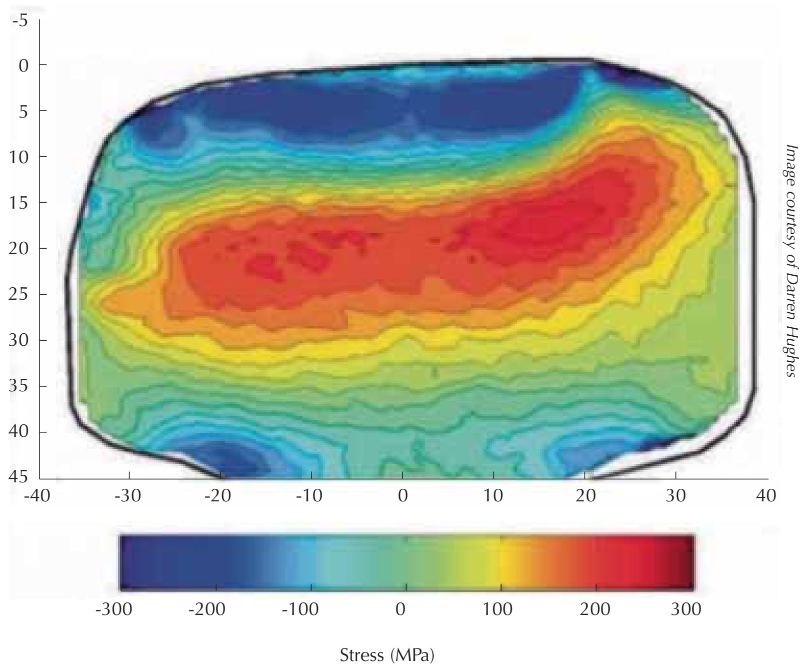


Image courtesy of Darren Hughes

The Hatfield rail crash



Residual stresses in a worn rail head measured using X-ray diffraction

Another important area of investigation is stress in railway rails. The Hatfield train crash in the UK in October 2000 is an example of the extreme consequences that metal failure can have. Four people died and more than 100 were injured when a broken rail derailed a high-speed train. This type of failure in rails is linked to the interaction between small surface cracks and the residual stress in the rail. The image above shows the stress field in the head of a worn rail, measured using X-rays: red zones are tension and blue are compression. The stress pattern is complicated, but regions where the tensile stress approaches the surface of the rail have a greater risk of surface cracks propagating. Understanding how the residual stresses in a rail change with wear allows engineers not only to develop better rail materials but also to improve maintenance procedures and minimise failures.

Failures arising from stress are not always life-threatening but can nonetheless be a serious problem in many industries. For example, with the growing interest in alternative energy sources, the performance of wind-turbine electricity generators is becoming increasingly important. The sheer scale of wind turbines combined with the near-constant running in often remote locations – sometimes offshore – poses some difficult engineering questions. In particular, the central bearing of the drive axis (see right) is a key component; with the bearing in contact with the shaft on one side and the rollers on the other, it is exposed to both internal and surface stresses. Conventional surface treatments to create compressive residual stresses on the surface (to minimise surface cracks) have led to unexpected failures, probably due to balancing tensile stresses in other locations. An ongoing project aims to fully characterise the residual stresses in a complete bearing of 60 cm diameter and 120 kg weight using neutron diffraction. When complete, the project should allow us to modify how the bearing is manufactured and lead to longer service life.

Together, engineers and scientists are working to better understand stress and component failure and ultimately to manufacture long-lasting and safe components. Look on the bright side, not all stress is bad!

Resources

An introduction to the techniques described here can be found in:

Withers PJ, Webster PJ (2001) Neutron and synchrotron X-ray strain scanning. *Strain* **37**: 19-33

Image courtesy of Neutronic; source of image: Wikipedia

Electricity generating wind turbine...

Image courtesy of Darren Hughes

... and the 120kg central roller bearing being measured using neutron diffraction

Information about neutron facilities at the Institut Laue-Langevin in Grenoble, France: www.ill.fr

Information about X-ray facilities at the European Synchrotron Radiation Facility in Grenoble: www.esrf.fr

Both the Institut Laue-Langevin and the European Synchrotron Radiation Facility are members of EIROforum, a collaboration of seven European inter-governmental research organisations, and the publishers of *Science in School*. See: www.eiroforum.org

REVIEW

This article is suitable mainly for pre-university physics students, in particular for the topics of diffraction and properties of matter and materials. It could also be useful for pre-university chemistry students in the context of crystallography. For a more interdisciplinary approach, it could be used to link physics and chemistry with technology and engineering.

The box on neutrons and X-rays could form the basis of a comprehension test. Teachers could ask their students to explain the Bragg law and how a change in tension or in compression affects the diffracted output.

Potential discussion topics include the difference between science and applied science, wave properties (including particle beams as waves), and who bears responsibility for transport accidents. The article also includes some pictures that could be used in lessons.

Eric Deeson, UK

Plastics, naturally

We sit on them, wear them and cook with them: plastics are everywhere. Yet this very versatility and abundance makes it all the more difficult to produce and dispose of plastics in environmentally friendly ways. **David Bradley** explains how researchers at the University of Manchester, UK, are among those working on a solution.

Image courtesy of The University of Manchester

Professor Colin Webb

The cheap plastic toy in your morning cereal box is a well-worn breakfast cliché. However, the disposal of millions of tonnes of scrapped plastics each year is a growing problem requiring more serious discussion than a chat over the cornflakes. Work by team leader Colin Webb and his colleagues Ruohang Wang and Apostolis Koutinas, in the Satake Centre for Grain Process Engineering at the University of Manchester, will yield a fantastic plastic solution that not only promises to solve the problem of disposal but also opens up a new sustainable future across manufacturing.

With the support of the Engineering and Physical Sciences Research Council (EPSRC)[w1], the researchers are combining process engineering and biotechnology with cereal chemistry to develop a novel and highly efficient way of converting cereal grains into biodegradable bioplastics. They are also extending processing techniques for removing grain bran – so-called 'pearling' – that will work as a general tool for extracting useful compounds from a wide range of cereals and allow them to be used as precursors for new materials.

These might include short-chain sugars for other fermentations, arabinoxylans for medical applications, the antioxidant ferulic acid (a precursor to aromatic compounds such as vanillin), as well as functional foods.

Avoiding landfill

Plastics have revolutionised modern life, giving us everything from nylon stockings to PVC teething rings and hypoallergenic synthetic rubber condoms. Plastics are petrochemical products, however, and with annual production at half a billion tonnes we rely on fossilised hydrocarbons for their manufacture. Moreover, the throwaway nature of many plastics means that they are a serious environmental problem because petrochemical products do not degrade naturally. Waste plastics can be disposed of by incineration, but that produces pollutants.

They can be recycled, but that brings its own problems of cleaning, sorting, and finding applications for lower-grade materials. Unfortunately, landfill is currently the safest and least expensive method of disposal. But, with 40% of plastics produced being dumped in landfills, they are quickly filling up. "Environmental issues, the growing demand for energy, political concerns and the medium-term depletion of petroleum has created the need for development of sustainable technologies based on renewable raw materials," says Colin. Along with his colleagues, he hopes to address this concern through the development of an alternative feedstock for the plastics industry based on renewable cereal crops, rather than our limited supplies of crude oil. "Selection of the appropriate raw material to supply sustainable processes is dependent on infrastructural, economical and technological factors such as availability, skilled workforce, pre-treatment technology and costs, and transportation," explains Apostolis. "Cereals belong to those few renewable raw materials that currently meet most of these

At the moment biodegradable polymers such as PHB (polyhydroxybutyrate – whose structure is shown here) are expensive to produce and not suitable for many applications. EPSRC researchers hope to find an inexpensive route to versatile 'green' plastics

Image courtesy of David Bradley

prerequisites." Cereal grains are nutritious enough to sustain a host of microorganisms, such as the fungus *Aspergillus awamori*, and this can be exploited by developing a generic method for refining grain into a feedstock using microbial fermentation that can then be converted chemically or through further fermentation into biofuels, chemicals and bioplastics (plastics derived from plant sources, rather than petroleum).

The idea has many advantages, not least of which are that crops are a renewable resource and using them is essentially carbon neutral. Additionally, the products of cereal chemistry, including bioplastics, will be biodegradable, ultimately rotting to nothing more than water and carbon dioxide in the soil: a sharp contrast to the 10 000-year lifespan of polythene and PVC products. There are also many socioeconomic advantages to developing cereals as an industry feedstock, including a reduced reliance on dwindling crude-oil supplies and benefits to farmers from the increased cultivation of cereal grains.

Currently, there are three ways to make bioplastics. The first involves intracellular production by the fermentation of a feedstock derived from a cereal or other crop. This approach requires extraction and purification steps. The second method involves engineering a crop to 'grow' the plastic within the plant itself, which then requires harvesting and purification. Finally, cereals could be made to produce various precursors, again through fermentation, which could then be processed into bioplastics. If natural microorganisms cannot produce the desired bioplastic, then they too could be genetically engineered for the job.

Clever microbes

Plastic-producing microbes use simple sugars, such as glucose, as their carbon source and organic nitrogen compounds, such as amino acids and short peptides, for their nitrogen. All these nutrients are present in cereal grains. Moreover, the grain also contains the vitamins and minerals essential to microbial growth. Some grains have great potential for producing functional chemical sources. Wheat, for example, shreds the opposition because it contains useful agglutinin and lipids, arabinoxylan, phytic acid and vitamins, and short-chain sugars. 'Pearling' grain to strip off the outer layers of the seeds and then milling into flour produces a starting material packed with nutrients and enzymes that the appropriate microorganisms can feed on to produce bioplastics. "This biorefining strategy provides a complete feedstock for subsequent microbial fermentations for the production of bioplastics and other chemicals," says Colin.

It will not be possible to develop processing methods to produce bioplastics for all applications, but researchers are hoping to cover most bases. "Microbial bioplastics will find many applications as disposable plastics, such as food packaging, that cannot be recycled. It is also possible to blend bioplastics with other materials to make bioplastics resistant to biodegradation. Additionally, recycling could be developed as a generic methodology for the reproduction of longer-lasting items," adds Colin. Conventional grain processing for the

Image courtesy of David Bradley

Researchers at the University of Manchester believe that, with the use of plastic-producing microbes, fields of wheat could replace fossilised hydrocarbons as the source for many plastics

Image courtesy of The University of Manchester

By using a technique known as 'pearling' grain the researchers aim to strip off the outer layers of the seeds that can then be ground into flour – producing a starting material packed with nutrients and enzymes that the appropriate micro-organisms can feed on to produce bioplastics

manufacture of corn syrup and other food and animal feed products produces a lot of waste and waste water, is expensive, and does not fully utilise the rich chemistry of these natural products – including invaluable nutrients and enzymes. In their new process, the Manchester team has attempted to exploit the full potential of whole cereal grains in order to create viable biorefineries for the production of bioplastics as well as other value-added products. Their approach investigates new market applications.

"Gluten, for instance, could be used as a bioplastic with many potential applications," says Apostolis, "while arabinoxylans could be used in medical applications so that none of the cereal grain by-products are wasted." Colin adds: "The current industry producing plastics will have to gradually switch from using petrochemical processing into renewable biomass-based feedstocks. The imminent depletion of petroleum resources will force this change," he says, "making cereals the most important candidates as the raw materials for bioplastic production." According to Colin, the success of this endeavour will depend on collaborations with industrial or other academic partners who can provide expertise in market needs, industrial scale processing, chemistry, cultivation of cereal grains and life-cycle analysis. Colin comments: "The way that this project has been approached targets the improvement of economics for the production of bioplastics via microbial fermentation, which is one of the most important impediments in this process." If they are successful, then the plastic toy in your cereal box may one day be as sustainable as the cereal itself.

REVIEW

Plastic manufacturing is not generally included in science lessons, but this article explores one of those fringe-science fields that is relevant to the central problems of human societies' development.

These days, sustainability of natural resources and human-powered global warming are the main limiting factors for any model of social development. While some groups argue for the convenience of nuclear power or develop alternative sources of energy, Bradley demonstrates that advances in efficient management of renewable resources could have a positive effect.

The article is about efficiency, sustainability, reduction of our carbon footprint, natural resources and social structure. In addition, it shows how scientific specialisation (so often criticised) makes possible advances in very small areas of knowledge that can be useful in a very wide sense.

Within the classroom, the article has an interdisciplinary application. Environmental science and environmental education teachers, at secondary school or early college levels, can use it to illustrate and work with several basic concepts such as sustainability, carbon cycle processes and human influence, social structure changes or the importance of agriculture and soil conservation.

Some possible activities related to the article are:

1. Students can work out a simple sustainability index for different resources (conventional plastics, bioplastics, agricultural soil, nitrate-based fertilisers, wood and forestry, oil, biofuels, and so forth) and use it to discuss its environmental consequences.

$$S = \frac{NGa \times (1 + RCr + RUr)}{HUa + Da}$$

Where: NGa = Natural genesis amount (mass/time)

RCr = Recycling rate (dimensionless, 0 to 1)

RUr = Re-use rate (dimensionless, 0 to 1)

HUa = Human use amount (mass/time)

Da = Degradation amount (mass/time)

2. Students can work out simple carbon-cycle models introducing the effects of bioplastics or biofuels.
3. The article mentions the influence of bioplastics on the relationship between agricultural and industrial structures. Teachers can connect the concepts of biodiversity and social diversity with their influence on ecosystems' and societies' stability or survival.
4. Bioplastics (and biofuels) need agriculture and soil. Teachers can explore the importance of soil conservation, erosion or contamination.
5. Students can evaluate the rate or amount of plastic disposal in their classroom and the group's carbon footprint. Then, students can estimate the effect on their carbon footprint of shifting from conventional plastic to bioplastic.
6. Teachers can help their students to draw parallel flow diagrams for the processes involved in the production and disposal of several products: bioplastic or petroplastic bottles, wood or metal tables, diesel or biofuels.
7. Teachers can also use several indirect questions to work out how bioplastics can influence our lives. The following are just some examples: How can bioplastics help to save Antarctic glaciers? How can bioplastics help to avoid sea-level changes? How can bioplastics save birds that live in your town rubbish dump?

Juan de Dios Centeno Carrillo, Spain

This article was first published in Issue 37 of Newsline, a quarterly magazine highlighting the best research supported by the EPSRC: www.epsrc.ac.uk

Web references

w1 - The EPSRC funds research and post-graduate training in engineering and the physical sciences at universities and other organisations throughout the UK: www.epsrc.ac.uk

David Bradley is a professional science writer. www.sciencebase.com

Developing a teaching resource on peer review

Ellen Raphael from the charity Sense About Science explains why peer review is so important in science, and describes how an existing guide is being adapted to meet the needs of science teachers.

Changes in the English national science curriculum will allow more time than ever before for exploring the inner workings of the scientific method (see Burden, 2007). How scientific ideas are presented, evaluated and disseminated is now a core requirement for key stage 4 students (ages 14-16). At Sense About Science, a charity to promote good science and evidence in public debates, we welcome this emphasis. Students need to discover early in their education what science is, if they are to handle data and evidence maturely and with discrimination, and gain their first insights into mastering a subject rather than being mastered by it.

This is important not just for understanding the scientific method but also for helping students to negotiate the world outside school. We need students to understand that the scientific knowledge we now regard as established fact – such as the Earth revolving around the Sun – is actually the result of many years of academic argument and gathering of evidence. In this way, students can be encouraged to consider new research critically, to consider its evidence base, and not simply to believe new theories because they appear to make sense. At the moment, there are few resources available for teachers to work out how scientific information is evaluated and added to the ongoing body of knowledge.

Image courtesy of Sense about Science

In 2005, Sense About Science published *I don't know what to believe...*, a short guide to peer review[w1]. It has been hugely popular with over 60,000 copies disseminated worldwide. The guide aims to help people understand the journey that scientific ideas undertake before they tentatively join the body of scientific knowledge and other researchers can begin to repeat them. The guide also highlights the difference between published and unpublished research, helping people to determine whether the research

Image courtesy of Sense about Science

claims they read in newspapers or on the Internet come from scientific journals or from scientists who have chosen not to subject their work to the critical scrutiny of their peers.

The guide was developed through workshops with a range of groups, including secondary-school teachers and their students. It was very helpful to hear the teachers’ and students’ perspectives on the guide from the beginning, to find out what information they found useful and what they regarded as superfluous. It also confirmed our belief that very few students know what peer review is, how it relates to science, and how it can help them to evaluate new scientific ideas and research claims. The first time that most students learn about the system is when they study a science subject at university, which means that those who do not continue with science will probably never know the role that peer review plays in the advancement of science.

Following the guide’s release, we received many requests for its use in the classroom. These requests came from primary- and secondary-school teachers, and others involved in science education. We have always been keen to develop a resource specifically for schools on peer review and the acceptance of new scientific ideas. It was decided, therefore, that rather than providing schools only with *I don’t know what to believe...*, we would begin to build a full education resource, with a web resource centre, where teachers and students alike could access further information

BACKGROUND

How to get involved

Sense About Science is recruiting science teachers to trial the resource. We want to ensure that it hits the mark in the same way as *I don’t know what to believe...* has. If you would like to be involved, we will email you the resource with questions to raise with your students. Although the resource is based on the English national curriculum, teachers across Europe are invited to get involved in the trial – peer review is, after all, an international process!

The resource will be freely available online when finished. If you are interested in being part of the review team, or in finding out more, contact Ellen Raphael: eraphael@senseaboutscience.org about peer review, scientific knowledge and evidence. The resource is now under development with a planned completion date in summer 2007.

In addition to the web resource, we will also produce free printed materials for teachers. The printed resource will include the nuts and bolts of the peer-review process and 'day in the life' stories from journal editors and scientists. There will be case studies

of media controversies over scientific research, such as the measles-mum ps-rubella (MMR) vaccine and genetically modified foods, to look at how scientific evidence is interpreted by different stakeholders. Finally, there will be practical exercises where students will be asked to critically evaluate one another's work. The resource, like the short guide, will not shy away from difficult questions, such as how to deal with fraudulent results or maverick scientists who head straight to the media with their results. Confronting difficult questions will, we hope, lead to stimulating classroom discussions.

There have been many arguments lately that the new science curriculum dumbs down science and can be more appropriately termed the 'sociology of science'. There are also concerns that the curriculum does not require consideration of how science is regulated both internally and externally. We hope that our resource will go some way towards illuminating the regulation of science by scientists through peer review. However, it is worth highlighting what the new curriculum does well. For the first time students are being encouraged to consider what scientific evidence is, where scientific ideas come from, and the impact that they might have on society. The curriculum allows us to look deeper into what makes science science.

Although we must fight to retain the practical aspects of science education and the teaching of a broad scientific knowledge base, discussion about the applications of science and the ethical and societal implications should not be seen as detrimental or as the 'easy' option. Providing future scientists and consumers with a true understanding of the scientific method, its theory and practice, and how ideas and evidence are generated, should produce individuals who are well able to hold their own and stand up for science, particularly in controversial areas where it is not easy to see the path ahead.

BACKGROUND

What is peer review?

- Science has a system for assessing the quality of research before it is published. This system is called peer review.
- Peer review means that other scientific experts in the field (the authors' peers) check research papers for validity, significance and originality – and for clarity.
- Editors of scientific journals draw on a large pool of suitable experts to scrutinise papers before deciding whether to publish them.
- Many of the research claims you read in newspapers and magazines, find on the Internet, or hear on television and the radio are not published in a peer-reviewed journal.
- Some of this research may turn out to be good but much of it is flawed or incomplete. Many reported findings, such as claims about 'wonder cures' and 'new dangers', never amount to anything.

Peer review ensures that a research paper has been checked by other qualified scientists for mistakes and omissions, as well as to clarify what the findings show. It also means that the results are available to the wider scientific community, so that others in the field can try to replicate the findings, or use them, in conjunction with other work or results, to reach further conclusions.

Scientific research that has not been subjected to this form of review is of no help to anyone. Scientists cannot repeat or use it and society cannot base decisions about public safety – or individual health, for example – on work that has a high chance of being flawed. The need to clarify the status of scientific evidence is growing. In the UK, the government increasingly uses public consultations, inquiries and commissions to gather evidence for regulatory purposes and everyone involved needs to be clear about the measures of scientific plausibility.

So, no matter how exciting or compelling new scientific or medical research is, you must always ask, "Is it peer-reviewed? If not, why not?"

If it is peer-reviewed, you can look for more information on what other scientists say about it, the size and approach of the study, and whether it is part of a body of evidence pointing towards the same conclusions.

Edited extract from *I don't know what to believe...*[w1]

BACKGROUND

Case study: mobile phones

One of the first claims that mobile-phone emissions are unsafe was made by Roger Coghill, a self-employed researcher who had previously argued that mobile phones cause headaches and memory loss. In 1998, Coghill said that the waves produced by mobile phones could damage the activity of lymphocytes in the body's immune system. Coghill published these claims himself and released them to the media, rather than submitting them for peer review. Many other studies failed to show damage to the body's immune system as a result of mobile-phone usage. Despite the lack of corroboration, Coghill's claims were widely reported, and fuelled discussion about mobile-phone safety. Between 1998 and 2003, he was cited in 119 printed news publications in the UK, most of which made no reference to the lack of peer review of his research or to the fact that other, peer-reviewed research did not corroborate his hypothesis.

More recent large-scale peer-reviewed studies have also found no evidence that mobile phones cause harm, and Coghill's hypothesis still remains unsubstantiated. Claims like Coghill's, which have not been scrutinised by scientific experts through the system of peer review, cannot be validated, and therefore, no matter how widely they are reported, such claims remain, essentially, just an opinion.

References

Burden J (2007) Twenty First Century Science: developing a new science curriculum. *Science in School* **5**: 74-77. www.scienceinschool.org/2007/issue5/c21science

Web references

w1 - *I don't know what to believe...* is freely available from the Sense About Science website: www.senseaboutscience.org.uk. Hard copies can also can also be requested from this page. There is a small charge for sending print copies outside the UK, to cover postal costs.

Resources

For other useful education materials about peer review, see:

Gift N, Krasny M (2003) The great fossil fiasco: teaching about peer review. *The American Biology Teacher* **65**: 270-278. DOI: 10.1662/0002-7685(2003)065[0270:TGFFTA]2.0.CO;2

REVIEW

Even if the topic is not as exciting as the most recent discoveries in cutting-edge research, this article is relevant for secondary-school teachers and students in science education. In fact, the focus on peer review, in addition to the usual sequence of 'observation, hypothesis, experiment, theory', is necessary for a correct epistemological approach to what makes science science.

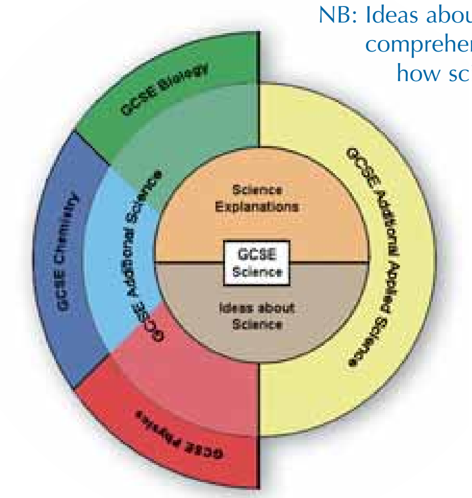
For these reasons, Ellen Raphael's clear and concise article is suitable for teachers interested in updating their knowledge and for students motivated to deepen their study of the scientific method. Moreover, the invitation from Sense About Science to test the didactical materials (printed guide and related website) is also a good opportunity for teachers interested in the societal impact and perception of science. The full article could be used for classroom activities or read by students interested in the topic.

Giulia Realdon, Italy

Image courtesy of Sense about Science

Twenty First Century Science: developing a new science curriculum

In September 2006, after a pilot phase, a new national curriculum for science was introduced for students aged 14-16 in England and Wales. **Jenifer Burden** explains how the new curriculum seeks to address both the scientific needs of all citizens, and the additional needs of future scientists.



NB: Ideas about science provides a comprehensive coverage of how science works

Students in England and Wales follow a compulsory national curriculum to the age of 16. This curriculum includes the study of science, incorporating key ideas from biology, chemistry, and physics. From September 2006, the science curriculum for students aged 14-16 has changed significantly. All students now follow a core course, regardless of their future progression in science, with an emphasis on developing scientific literacy. This is in contrast to the previous national curriculum for this age group, which was determined by the perceived needs of students who would progress to further academic study. In the new scheme, most students also follow an additional science course, discussed further below.

Both the well-documented decline in student uptake of science following compulsory education, and the negative trend in students' attitude to the science curriculum[w1], contributed to a drive to revise the national curriculum. The influential report, *Beyond 2000* (Millar & Osborne, 1998), led to the development of a pilot model for a new approach to the curriculum. Known as *Twenty First Century Science*, this model was commissioned by the Qualifications and Curriculum Authority (QCA)[w2], the government body responsible for regulating the school curriculum in England and Wales. A small team based at the University of York Science Education Group and the Nuffield Curriculum Centre developed the pilot curriculum and supporting teaching resources, which were trialled in more than 75 schools from September 2003. Following a review of the pilot, QCA developed a new national curriculum for England and Wales based on the *Twenty First Century Science* model. It is important to note, however, that not all students follow *Twenty First Century Science* – this is one of several interpretations of the national curriculum which teachers may select.

How did *Beyond 2000* influence the new curriculum?

A key recommendation from *Beyond 2000* is that compulsory science education should focus on scientific literacy. This is science education which can be justified as relevant for any student, regardless of their future aspirations. This recommendation prompted several questions during the early development of *Twenty First Century Science*, such as:

BACKGROUND

Science explanations

- Chemicals
- Chemical change
- Materials and their properties
- The interdependence of living things
- The chemical cycles of life
- Cells as the basic units of living things
- Maintenance of life
- The gene theory of inheritance
- The theory of evolution by natural selection
- The germ theory of disease
- Energy sources and use
- Radiation
- Radioactivity
- The Earth
- The Solar System
- The Universe

- What does 'scientific literacy' mean?
- What might constitute a school science course for scientific literacy?
- How can we, at the same time, educate our future scientists?

We might describe a scientifically literate person as someone who:

- Appreciates what science has to tell us about ourselves, the Earth and Universe;
- Recognises the impact of science and technology on everyday life;
- Takes informed personal decisions about things that involve science, such as health, air quality and use of energy resources;
- Understands the essential points of media reports on science-based issues, and reflects critically on the information in, or crucially omitted from, such reports;
- Takes part confidently in discussions with others about issues involving science.

At the heart of *Twenty First Century Science* is a core course followed by all students, known as GCSE Science, which develops knowledge and skills relevant to the above aims.

What makes up GCSE Science?

Clearly it is impossible to engage with science at all without understanding some science content. The GCSE Science course therefore includes key 'science explanations' – the major stories of scientific knowledge (see left box). A course to develop scientific literacy should emphasise these big explanations, rather than a lot of disconnected detail, which is unnecessary at this level and indeed may discourage many students from pursuing further scientific study.

The second, equally important, element of scientific literacy is an understanding of the nature of science and its social context, referred to in the GCSE Science course as 'ideas about science' (see right box). These are the ideas necessary to engage with science in everyday life, but they are also key ideas needed by any future scientist. For example, an understanding of the distinction between correlation and cause is as useful to a citizen reading a newspaper article about the findings of an epidemiological study as it is to the scientist who designed the study. Both will also need an understanding of the limitations of data to judge its reliability. A new scientific claim may involve controversy, so all of us need some understanding of how scientists develop explanations, and the ability to identify evidence and construct argument, together with a working knowledge of the scientific community and peer-review system. Both a citizen making a personal decision, and a scientist putting forward recommendations for social policy will draw on an understanding of risk and the frameworks within which decisions based on science and technology are made.

BACKGROUND

Ideas about science

- Data and its limitations
- Correlation and cause
- Developing explanations
- The scientific community
- Risk
- Making decisions about science and technology

BACKGROUND

Teacher feedback

"The philosophy is sound, and works in practice. The support materials are excellent, and assessment varied and stimulating, definitely not a set of arbitrary hoops to be jumped through. [...] No student has asked me since we started why they need to do science, or to know something we've covered. Our GCSE grades have improved, and we have detected no problems with transition to science A-levels (ages 16-18(. *Twenty First Century Science* has been the best thing to happen to my science teaching since I started in 1989. We've embraced the change, and haven't regretted it for a moment."

"The parents tell us that their kids are coming home and talking enthusiastically about what they've been doing in science."

"The courses give young people the opportunity to think for themselves and attain informed views and opinions."

Clearly, practising scientists will engage with ideas about science more deeply than the scientifically literate layperson, but at the level of GCSE Science, students gain an understanding of these ideas that will be relevant to them regardless of their future ambitions.

GCSE Science is taught through a series of modules which provide engaging contexts for students. Although the contexts are useful, it is above all the ideas about science and science explanations – key concepts of science and how it works – that the GCSE Science course aims to instil in students. This understanding is essential for all citizens, not only those who go on to be scientists.

What about future scientists?

The great majority of students following the *Twenty First Century Science* curriculum also study one or more additional courses, to satisfy their innate curiosity about the material world, and in some cases because they are interested in a science-based career. Since the key skills of scientific literacy are developed in GCSE Science, a variety of additional courses have been developed, allowing students to select those which best meet their particular needs.

GCSE Additional Science is designed for students who wish to follow a more academic route in science. Students explore a number of science explanations in more detail, encountering more abstract concepts and scientific models than in GCSE Science. Some students may choose to devote an even greater proportion of their time to sciences, and study for separate qualifications in GCSE Biology, GCSE Chemistry, and/or GCSE Physics.

Alternatively, in GCSE Additional Applied Science, students extend their understanding of particular science explanations, but in work-related contexts, which emphasise the role of technical practitioners in fields such as health care, agriculture, and communications.

Course assessment

Clearly a revised curriculum cannot make any real impact on practice unless an appropriate assessment system is devised, consistent with the aims of each course. In *Twenty First Century Science* the most innovative development of assessment is found in the GCSE Science course. Designing tools to assess students' scientific literacy is a challenge, and work is ongoing. Nonetheless, significant progress was made during the pilot. Further information regarding assessment can be found on the project website[w3].

How effective is the new curriculum?

Such a major change in the curriculum requires significant investment, not least by teachers who must implement new courses in their schools. Strong motivation is required to undertake such a change.

As the new national curriculum was introduced into schools across England and Wales only in September 2006, it is much too early to assess the large-scale effects. Nonetheless, feedback from the teachers involved in the *Twenty First Century Science* pilot study since 2003 has been very positive (see box). An independent evaluation of the pilot has been conducted, and further information will be added to the project website as it becomes available.

References

Millar R, Osborne J (1998) *Beyond 2000: Science Education for the Future.* London, UK: King's College

The report can be downloaded from the King's College London website: www.kcl.ac.uk

Web references

w1 - For information about the ROSE study of students' attitudes to science, see:

Sjøberg S, Schreiner C (2006) How do students perceive science and technology? *Science in School* **1**: 66-69. www.scienceinschool.org/2006/issue1/rose and the ROSE study website: www.ils.uio.no/english/rose

w2 - Qualifications and Curriculum Authority (QCA): www.qca.org.uk

w3 - *Twenty First Century Science* website: www.21stcenturyscience.org

Jenifer Burden is Co-director of Twenty First Century Science, based at the University of York Science Education Group. Email: jb56@york.ac.uk

Students at Settle College, North Yorkshire, studying the key science explanation of chemical change

Image courtesy of Twenty First Century Science

Note from the editor

We would be interested to hear about experimental new curricula elsewhere in Europe. Has a radically different curriculum been introduced in your country? How well did it work? What did the teachers and students think about it? What difficulties were faced in the introductory phase, and how were these overcome? We would be particularly interested in teachers' views of the new curricula.

REVIEW

This article makes interesting reading for science policy-makers and teachers furthering their studies at university. The article is relevant outside the UK, for those who seek to enrich their knowledge of the current debate in foreign countries. Although its main interest is for policy-makers, it is useful for school science teachers who want to keep abreast of innovation and the justifications for change.

The article summarises the main features of the new curriculum and gives justification for its introduction in England and Wales. Some of the salient points mentioned, such as the definition of a scientific literate person and what might constitute an appropriate syllabus for such a person, may create a discussion amongst science teachers about what should and should not be taught in the science class.

The introduction of a new science curriculum is never an easy task. However, as Jenifer Burden mentions, the decline in the student uptake of science and the negative trend in students' attitude to the science curriculum compel those responsible to do something. The dilemma of how to offer a science curriculum which caters adequately for both future scientists and other citizens has been debated for the last few years in my country. In a recent meeting of the association of science teachers in Malta, it was stated that such a reform in secondary-school curricula needs to be complemented with a similar reform in primary-school and post-secondary-school science. This point was not mentioned in Burden's article, but she gives details of a rethinking of the assessment policy to accompany the reform, which seems to be supported by teachers in the UK. The reform seems to have the right ingredients to be conducted successfully.

Gaetano Bugeja, Malta

Making dark matter a little brighter

Jenny List, a young particle physicist working at DESY in Germany, leads her own research group to find out how the Universe works. She talks to **Barbara Warmbein**.

Image courtesy of DESY

Jenny List

"I've always wanted to understand how everything works – from the extremely small to the amazingly big." As a physicist with a PhD and the leader of a small group of undergraduate and graduate students, Jenny List is well on the way to doing just that. Her special topic is dark matter, "a bit of a fashionable subject these days", she smiles, but no wonder: scientists believe that finding and studying dark matter will confirm answers to many questions in physics that were previously only suggested by theory. After all, dark matter makes up 22% of the Universe. Dark energy, a concept even less well understood than dark matter, is believed to amount to as much as 74%, and all the stars and matter in the Universe make up a mere 4%.

Jenny is 32 years old and works at the German particle physics research laboratory DESY (for Deutsches Elektronen-Synchrotron)[w1]. DESY has its own 6 km particle-smasher, but Jenny is a researcher for a machine of the future, the planned 30 km electron-positron accelerator International Linear Collider (ILC). "We hope that the ILC will not only find the particles that we think make up dark matter, but also let us examine them closely. This is crucially important for our understanding of the Universe," she says. The ILC will work hand in hand with the Large Hadron Collider (LHC) that is scheduled to start running at CERN[w2] in Geneva this year. Thousands of accelerator and particle physicists around the world – including a very active group at the German laboratory – are busy designing the new linear machine and its detectors to make sure that it will reach all the superlatives required in energy, data production and precision measurement.

The German school system lets students choose two main subjects for their final two years of school. Jenny, who was born in Hamburg, originally wanted to study mathematics as one of these, but wasn't happy about the designated teacher. So she chose physics instead. "I have never regretted this decision. My teacher was great, and physics is such a varied subject!" She went on to study it at Hamburg University and had a hard time deciding which of the many different fields she wanted to concentrate on: cosmology? Theory? Astrophysics? In the end, she opted for particle physics, where scientists use enormous and incredibly precise machines to study the elementary particles and the forces that work

The planned ILC will use these accelerating cavities to bring particles to extremely high energies and let them collide in massive underground detectors

Image courtesy of DESY

between them. Jenny worked on the OPAL[w3] experiment at CERN and finished her PhD there in 2000. As this was the same year that CERN's big accelerator shut down and no experiments were producing data, she returned to Hamburg for a post-doc position at DESY.

"This was the first time I had to work with polarisation, one of the main subjects of my study group today," she recalls. When scientists bring two particle beams to collision, they need to know exactly what these beams look like so they can determine exactly what they recorded in the detector. One aspect of those beams is polarisation, a characteristic that shows how many of the particles spin in the same direction. The ILC will use beams of electrons and their anti-particles, positrons. These normally shoot through 15 km of accelerating cavities and radio-frequency fields until they reach the collision point, but at certain points along their track, observation teams like Jenny's shoot at the beams with a laser.

This isn't 'Gotcha!' for particle physicists but an important exercise to study the properties and behaviour of the particle beams. After the shoot-out, the resulting particles are sent through little gas-filled tubes with mirrors on the inside. Flying through the tubes, they emit a blue light – Cherenkov radiation – which is directed to the end of the tube by the internal mirrored surface. A photo-detector measures the amount of light that comes through and the time it takes to get there. "This way we know our electrons very precisely," summarises Jenny. "The problem is: our polarimeter needs to have double the precision of anything that exists today. We're basing our design on the best one that exists (at the Stanford Linear Accelerator Center[w4] in California) and trying to find ways to improve it and make it more precise."

Image courtesy of DESY

Jenny and two members of her study group check the set-up of their tools

After two positions at different universities in Germany, Jenny returned once again to DESY. She had successfully applied for a scholarship from the Emmy Noether Programme co-ordinated by the German Research Foundation (DFG)[w5]. It fosters young

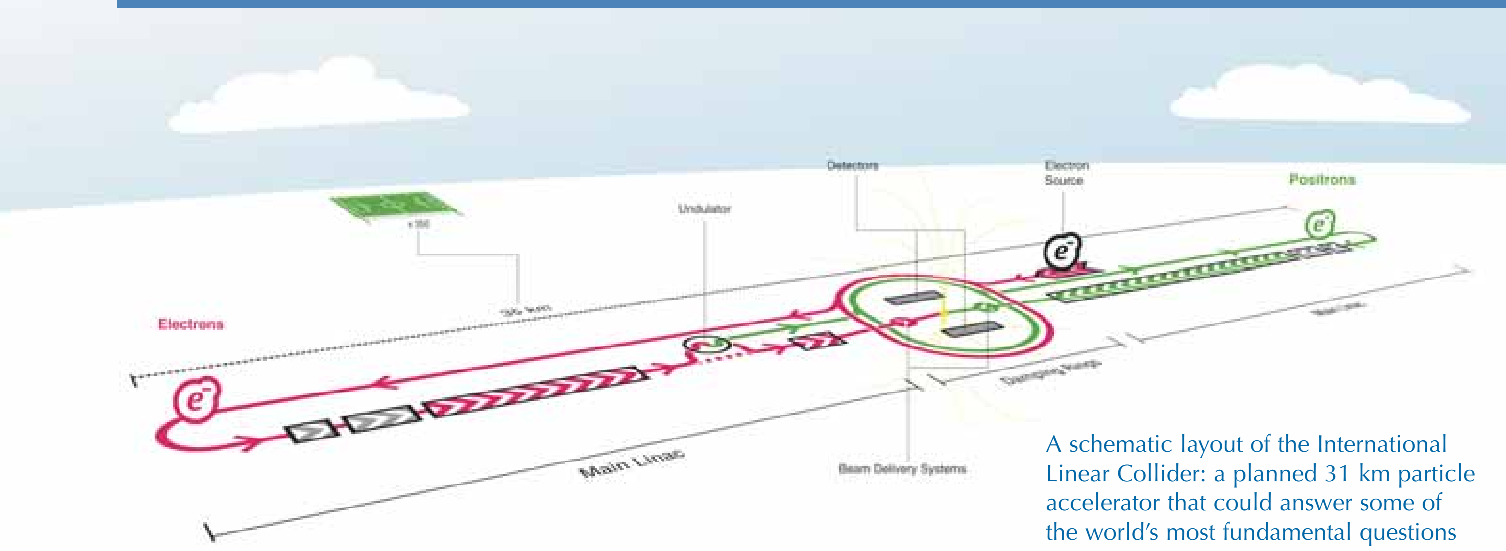


Image courtesy of DESY

A schematic layout of the International Linear Collider: a planned 31 km particle accelerator that could answer some of the world's most fundamental questions

Image courtesy of DESY

The research centre DESY in Hamburg, Germany

researchers, giving them independence and managerial experience at an early stage of their scientific career by setting up independent junior research groups. The scholarships run for five years, and by recruiting them back from abroad, the DFG hopes to encourage outstanding young scientists to stay in the country to continue their university careers. Jenny's group consists of one post-doc, one PhD and two graduate students. Together they are setting up a device to test their polarimetry tool and writing computer programmes to simulate dark-matter events in ILC detectors.

Apart from running her group, doing research and teaching at university, Jenny also has a busy social life. She loves to ski, sings in a choir, plays the piano and the guitar, and collects anything to do with elephants. "I just like them," she says. Her husband is also a physicist working at DESY. Jenny explains: "We used to commute between Geneva, Hamburg, Wuppertal and Zurich for years, which was quite exhausting. But being married to a fellow scientist has a lot of advantages: we know each other's workload, we can go to conferences together and we have a lot of freedom and flexibility in planning our time." They will surely be taking advantage of this flexibility this year: they have just had their first child.

Web references

w1 - DESY is the German particle physics research laboratory: www.desy.de

w2 - CERN is the world's largest particle physics laboratory: www.cern.ch

w3 - The OPAL experiment, which involved studying particles and their interactions by collecting and analysing electron-positron collision events, was one of the major particle physics experiments at CERN: http://opal.web.cern.ch/Opal/

w4 - Stanford Linear Accelerator Center: www.slac.stanford.edu

w5 - The German Research Foundation, DFG: www.dfg.de

Resources

More about dark matter is available from Wikipedia: http://en.wikipedia.org/wiki/Dark_matter

To find out more about the International Linear Collider and its research goals, see: www.linearcollider.org

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Barbara Warmbein works as a communicator at DESY, the German particle physics research laboratory. She is also a member of the editorial board of *Science in School*.

REVIEW

What can you do if you study physics at school? Jenny's story shows that it is possible to reach exciting levels – such as working at CERN or running your own research group while relatively young – and still have time for family and other interests.

This story of career progression can only inspire potential physicists, perhaps girls in particular. It would make a good hand-out for students who are considering physics as a final subject at school or as a print-out displayed on a careers notice board or science lab – perhaps along with information on other role models in the sciences.

Sue Howarth, UK

Launching ideas

Isabel Plantier teaches biology and geology to 15-year-old students in Portugal. She has been teaching for 25 years and tells **Sai Pathmanathan** that time really does fly when you're having fun.

Back in 1982, Isabel graduated in biology and biology education. She has been teaching biology, ecology, geology and health ever since, and has never looked back. However, she didn't plan things this way.

"I always wanted to be a doctor or a researcher," says Isabel. "But at 17, after a disappointing exam result, I found myself studying biology at university and at the end of my third year, I really needed to start earning money. In Portugal, teaching was a secure career with a fixed salary; research, by contrast, was not very well paid so I decided to train as a teacher. I know now that this was the right decision: I like teaching, and I learn something new from my students every day." Isabel believes that a day is successful when her lessons work well and she sees a glint of pleasure in her students' eyes.

Image courtesy of Isabel Plantier

So how does Isabel achieve that enthusiastic glint? "One day in October 2004, after the class had analysed some seeds we'd left to germinate, I asked the students: 'Are we just going to throw these out? With all the space we have outside the school, we could sow them and watch the development of the leaves and flowers – who knows, maybe even some fruit!' As a result, we now have an outdoor space where we carry out excellent fieldwork, revise for tests, and investigate how the plants develop under different conditions. We have attempted to simulate Mendel's first experiments, and we have planted 15 fruit trees, with a group of students responsible for each tree. Even previously unmotivated students are now doing well in biology."

Isabel also believes that visits to scientific research institutes can encourage students – and, of course, contact between teachers and scientists is important too. At a course at the European Learning Laboratory for the Life Sciences[w1], Isabel found the close contact with the research institute very beneficial. "It allowed me to update my knowledge. It also showed that, together with teachers, scientific research institutions can create model experiments that can be used in the classroom. By testing the models and giving feedback, teachers can then help to improve them further."

Isabel has also been lucky enough to travel much further afield in search of teaching ideas. In 2002, she was selected for the International Space Camp (ISC)[w2], an annual event held at the US Space & Rocket Center in Huntsville, Alabama, USA. Its motto is 'Dreaming to teach – teaching to dream', and its main goal is to unite

Images courtesy of Isabel Plantier

Image courtesy of Isabel Plantier

teachers and students from around the globe, to share experiences and create bonds, enabling them to work together to strengthen and nurture educational systems long after the camp's week of activities is over.

"In April 2002, I was contacted by Living Science (an agency linked to the Portuguese Ministry of Science, which develops and supports science projects for and by schools) and asked if I'd be interested in taking part in the ISC, with two of my students. Living Science needed an answer more or less immediately, so – it was a bank holiday – I picked up the phone, rang all the students, and decided to go for it, not really knowing what I was letting us in for!"

All activities revolve around space exploration, ranging from simulated space-shuttle missions using astronaut-training devices to lectures and talks by international astronauts and cosmonauts. Every year, it is attended free of charge by the US Teachers of the Year (the best teacher in each US state), plus one teacher and two students from each of the invited countries (23 countries in 2002); some students also pay to attend. Throughout the whole week, teamwork is a key factor in every activity. Students' and teachers' teams have slightly different programmes, as teachers' activities also involve modules on how to use space exploration in the classroom.

Image courtesy of Isabel Plantier

One fun and useful student activity was 'fizzy tablet rockets', in which students built rockets out of film canisters filled with water and effervescent antacid tablets. They varied the amount of 'fuel' in the rockets, and predicted and investigated the effect on launch time. In the process, they discussed statistics and probability, different types of measurement, and used both fractions and decimals.

Image courtesy of Isabel Plantier

At the closing ceremony, Isabel was awarded the 'Right Stuff' medal, which meant she could send another student to the ISC in 2003, free of charge. "So that the student would not have to go alone, we managed to raise sponsorship funds to pay for the enrolment of a second student. In 2005, five of my students paid their own enrolment in the ISC."

When Isabel and her two students, Bruno Pereira and Teresa Ribeiro, returned from the ISC in 2002, they took every opportunity to share their experiences with the rest of the school. As part of the ISC, all teachers had to design a project to apply space science in school. Isabel responded enthusiastically and designed her ideal project – but she still dreams of turning the plan into ambitious reality. She would like to involve all 14- to 19-year-old science, arts and humanities students at the school (about 400 in total) in activities to stimulate creativity and an interest in space exploration.

Isabel, Bruno and Teresa would make information panels of the activities at the ISC and suggest activities that could be developed at school. Students would select which activities to be involved in and the activities would be shared among teachers of different disciplines, for example:

- The chemistry, physics and mathematics teachers could organise activities for students interested in fizzy tablet rockets, rocket-show quadratics or vector navigation.
- Together with the art and language teachers, students could design mission patches.
- The biology and geology teachers would lead investigations of the

physiological changes experienced by astronauts in space, and 'hydroponics in the classroom' (growing plants without soil).

Each group of teachers would organise the activities to fit into their syllabus and to meet the interests of the students. The emphasis would be on allowing and encouraging students to do their own research and work co-operatively – and each work group would seek sponsorship to cover the costs of their activities. At the end of the year, all the research, artwork, experiments and results would be presented – and the rockets and balloons would be launched!

Image courtesy of Isabel Plantier

The project is based very much on the activities that Isabel and the others did at the ISC. She was particularly impressed in Huntsville by the mission patch activity, in which teams not only designed their picture, but also described the team and its mission. "This team-building idea had a strong impact on me, and I think it would be a very good way to start off each group's work. In fact, I would make this the one activity that all groups do – the others would vary according to students' interest, motivation, or subjects studied."

In terms of practicalities, Isabel is fairly flexible. Involvement in the project could be obligatory or not, carried out within lessons or as an extra activity – either would work.

Image courtesy of Isabel Plantier

"Thinking up activities would probably not be too hard... The main problem is that I can't carry out a project like this on my own. It would have to be a joint effort by several teachers, and so far not enough of my colleagues have been willing to embark on such a project." But Isabel is not deterred: "Although I've not yet tried out the full-scale project, I take every opportunity to use all I learnt at the ISC every chance I get, both in my own classes and in special events such as open days at the school."

Isabel's dream project not only brings an element of fun into science, but also demonstrates that space exploration unites many disciplines. "I would love to extend this project to schools throughout Portugal – or even beyond – as the basis of an international student-exchange programme!" Does this sound interesting? Would you like to know more? Isabel would be happy to hear from you.

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.
Education materials designed together with teachers are available in the ELLS TeachingBASE. See www.embl.org/ells/ for further details.

w2 - For more information about the International Space Camp, run by the US Space & Rocket Center, see: www.spacecamp.com

Isabel Plantier teaches at the Escola Secundária do Professor Reynaldo dos Santos in Vila Franca de Xira, Portugal. Her email address is isabel.plantier@clix.pt

Image courtesy of Isabel Plantier

The Selfish Gene⁺ and *Richard Dawkins: How a Scientist Changed the Way We Think**

⁺By Richard Dawkins

***Edited by Alan Grafen and Mark Ridley**

Reviewed by Bernhard Haubold, Fachhochschule Weihenstephan, Germany

If you are not interested in how evolution came about, and cannot conceive how anyone could be seriously concerned about anything other than human affairs, then do not read it: it will only make you needlessly angry," wrote John Maynard Smith about *The Selfish Gene*. Richard Dawkin's classic exposition of modern evolutionary biology was published in 1976 and has recently been reissued as a 30th anniversary edition with a new introduction by the author. Why should anyone get angry about a book on evolutionary biology? Maynard Smith's cautionary comment is interesting, if only because he is one of the four biologists cited in the introduction to the first edition of *The Selfish Gene* as providing its intellectual basis (along with R.A. Fisher, G. C. Williams, and W. D. Hamilton). But Maynard Smith's warning to the non-biologist is strangely at odds with Dawkins' express intention "to examine the biology of selfishness and altruism" – what could be closer to human affairs? In his preface to this edition, Harvard biologist Robert Trivers supports Dawkins' claim of universal relevance when he writes that "natural selection has built us, and it is natural selection we must understand if we are to comprehend our own identities."

This quote gives us a taste of the kind of hyperbole that has accompanied public debates of evolution since the mid-19th century. To imply that people who do not understand natural selection have no comprehension of their own identities is so pompous that anger might well be the reaction of a reader unaware of the rules of popular science writing.

But I do not want to suggest for an instant that Dawkins' book is in any way cheap. In fact, it is a lucid statement of what turned out to be a paradigm shift in evolutionary biology. Before the publication of *The Selfish Gene*, many biologists were happy to accept the idea that natural selection acted to maximise the success of a species or a group. For example, Nobel laureate Konrad Lorenz advocated this view in his once immensely popular book *On Aggression*, published in 1963. According to Dawkins, Lorenz "got it totally and utterly wrong" because he "misunderstood how evolution works".

Hamilton was the first to argue that instead of maximising the good of the species, evolution works by maximising what he referred to as an individual's "inclusive fitness". Starting from the simple idea that, genetically speaking, my own survival is equivalent to that of two of my siblings, this suggests that fitness calculations should include not only direct offspring but also relatives, because they too carry copies of an individual's genes. This gene-centred – rather than group-centred – perspective leads to neat explanations for a wide range of animal behaviour, including the altruism of worker bees, which under the new theory turns out to be a strategy for maximising their genetic progeny.

Inclusive fitness also implies that animals should be capable of quantifying the degree of relatedness between themselves and others. In a paper published in *Nature* on 15 February 2007, Debra Lieberman and colleagues show for the first time that humans do indeed possess a kin detection system that influences their disposition towards others. The relevance of inclusive fitness to human affairs has become a lot clearer since Hamilton postulated it in 1964 in the context of social insect societies and

The Selfish Gene was the place where a new generation of biologists first learned about it.

Thirty years ago, Dawkins advocated a set of ideas that were mature enough to coalesce into a coherent view of evolution but still new enough to be confined to a select group of mainly English and American biologists. The whiff of revolution, combined with deep insights into the mechanics of altruism, is what makes the book exciting to read even today.

The context is very different for the authors contributing to the volume of essays published simultaneously with the anniversary edition of *The Selfish Gene*. *Richard Dawkins: How a Scientist Changed the Way We Think – Reflections by Scientists, Writers, and Philosophers*, edited by Alan Grafen and Mark Ridley, is a rather mixed collection of short pieces. Too many are of the 'Dawkins is brilliant' school of writing, which is true in some respects but ultimately boring. There are exceptions, though, and I particularly recommend David Haig's musings on 'The Gene Meme'. This takes up the idea of a meme as a unit of cultural evolution, proposed by Dawkins in the last chapter of *The Selfish Gene*. The concept of the gene might be such a meme and Haig traces its evolution to conclude that a gene-centred view of biology is more fruitful than a meme-centred perspective on culture. If this leaves you intrigued, go and (re)read Dawkins' original – but don't get angry.

Details

The Selfish Gene

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ISBN: 0199291152

Richard Dawkins: How a Scientist Changed the Way We Think

Publisher: Oxford University Press

Publication year: 2006

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ChemMatters CD-ROM

Reviewed by Tim Harrison, University of Bristol, UK

ChemMatters is an award-winning magazine published quarterly by the American Chemical Society for secondary-school students. Each issue is full of readable articles about the chemistry used in everyday life, and is of interest to budding chemists and their teachers alike. The ChemMatters CD-ROM (version 3.0) contains two decades of the magazine from February 1983 (volume 1, number 1) to December 2003 (volume 21, number 4).

This archive of more than 300 articles is a useful resource for students, whether they are working on specific projects or undertaking general research. All the material is suitable for school students studying pre-university chemistry and much of it would be accessible to bright 15-year-olds.

For teachers, it is a great source of background information for enlivening lessons with snippets of information that hook students. Whether your students want to know the chemistry involved in measuring ground-level ozone (September 2001 issue) or what the atmospheres on other planets in our Solar System are like (October 2003 issue), then this is the right resource for you.

Users can search the whole CD-ROM for keywords in articles, or browse the magazine issues one page at a time. The articles are in Adobe PDF format and can be printed easily.

The American Chemical Society website[w1] includes a free archive of samples from more recent magazine issues (February 2003 to December 2006), plus a full archive of the teachers' guides. These magazine supplements contain additional information, comprehension questions, laboratory activities related to articles, and other activities such as instructions for building a methane ice model out of card (October 1995 issue).

Web references

w1 - For the free archive of articles, see: www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education\curriculum\chemmatters\issue_arch.html

Ordering

The ChemMatters CD-ROM costs US$25 for a single user or US$99 for a single school site licence, which allows all the information to be shared across a school or library network. It can be purchased online from http://chemistry.org/chemmatters/cd3.html

A Clone of Your Own?

By Arlene Judith Klotzko

Reviewed by Michalis Hadjimarcou, Cyprus

To clone or not to clone? That is the question that the book *A Clone of Your Own?* sets out to investigate. In the process, the reader is taken along a majestic journey through the science and ethics of cloning. The result is a thorough and accurate account of what cloning is all about, and why a natural method of asexual reproduction – practiced by millions of species since the beginning of life on Earth – has recently caught the attention of scientists, law-makers and lay public worldwide.

Removing a twig from a rose bush and planting it to produce a new bush is cloning. So is the cell-division process by which bacteria and other microbes replicate. Embryo splitting, the rare but naturally occurring event that produces identical twins, is another form of cloning. None of these phenomena has ever caused much concern. However, when Dolly the sheep was cloned in 1997, the announcement made headlines around the world. The reason is simple: a mammal was cloned by transferring the nucleus from a fully differentiated mammary cell from an adult sheep to an enucleated egg cell from another adult sheep. The resulting cell was able to develop into a fertile new organism, Dolly, who in turn was able to reproduce naturally. In the years that followed, scientists have successfully cloned cows, pigs, goats, mice, rabbits, horses, rats, cats and mules. These developments have led to a lively debate about whether humans should be included on the list of mammalian species to be cloned. The pros and cons of this possibility is the main subject of *A Clone of Your Own?*.

The initial chapters of the book introduce the reader to an interesting account of how people's attitudes, beliefs and fears about the power of science change with time and in response to landmark developments, such as the birth of test-tube babies. Additionally, the book includes a fascinating description of the negative effect that certain science-fiction books and movies have on the way people view science. This effect is derived mostly from science's ability to give humans the most distinctive power of God: the ability to create life. Two of the most prominent examples of such books and movies are Mary Shelley's *Frankenstein* and Aldous Huxley's *Brave New World*.

In the remaining chapters of the book, Arlene Judith Klotzko sheds light on the history of the efforts to clone mammals, as well as on future prospects. Special attention is paid to the various applications of cloning, such as its use for therapeutic purposes. Scientific information is given on how cloning can be combined with other biotechnology techniques, such as xenotransplantation and the production of transgenic animals, to help cure many of humanity's worst diseases. Also, the book provides important details of the cloning process and its possible adverse implications for the cloned organisms. Finally, a detailed presentation of the legal and moral issues that would arise from the various cloning applications in humans completes the discussion of whether human cloning should be allowed.

Considering the massive attention given to cloning since the birth of Dolly the sheep, this book is likely to appeal to anyone with enough curiosity to find out what the excitement was all about. Despite its complex vocabulary, the book is easy to follow and both the content and style maintain a high level of interest.

A Clone of Your Own? could be valuable to advanced high-school biology teachers. Firstly, the information on the science of cloning and other related biotechnology applications is simple enough to be used directly as teaching material. Secondly, the book includes a number of the important questions that scientists had to answer as they attempted to unravel the mysteries of how complete organisms develop from single cells. The experiments designed and executed to answer these questions could be the subject of productive and insightful discussions in the classroom.

Apart from the scientific information provided, the book's most important contribution is perhaps the fact that it helps to dispel many irrational fears about cloning and its resulting products, which have terrorised people's imaginations for decades.

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Contact us

Dr Eleanor Hayes
Editor of *Science in School*
Office of Information and Public Affairs
European Molecular Biology Laboratory
Meyerhofstrasse 1
69117 Heidelberg
Germany
editor@scienceinschool.org

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