

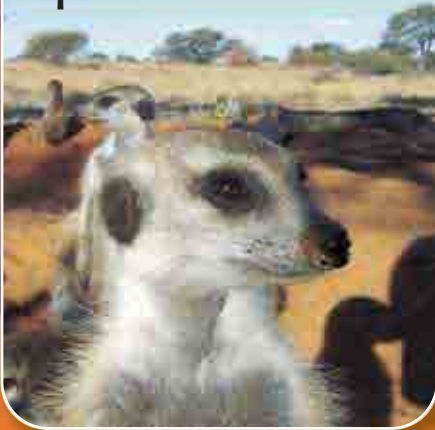
SCIENCE in SCHOOL

In this issue:

The LHC: a step closer to the Big Bang

Also:

Sentinels: meerkat superheroes



Highlighting the best in science teaching and research

About *Science in School*

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

Science in School addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge research. It covers not only biology, physics and chemistry, but also maths, earth sciences, engineering and medicine, focusing on interdisciplinary work.

The contents include teaching materials; cutting-edge science; education projects; interviews with young scientists and inspiring teachers; European education news; reviews of books and other resources; and European events for teachers.

Science in School is published quarterly and is available free online; free print copies are distributed across Europe. Online articles are published in many European languages; the print version is in English.

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

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

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Science in School is published by EIROforum (a collaboration between seven European inter-governmental scientific research organisations: www.eiroforum.org) and is based at the European Molecular Biology Laboratory (EMBL: www.embl.org) in Heidelberg, Germany.

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Submissions

We welcome articles submitted by scientists, teachers and others interested in European science education. Please see the author guidelines on our website for details.

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If you would like to review books or other resources for *Science in School*, please read the guidelines for reviewing books on our website.

Translators

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Advertising in *Science in School*

Science in School is the **only** European journal aimed at secondary-school science teachers across Europe, and across the full spectrum of sciences. It is freely available on the web and over 30 000 full-colour printed copies are distributed each quarter.

The target readership of *Science in School* includes everyone involved in European science teaching, including:

- Secondary-school science teachers
- Scientists
- Science museums
- Curriculum authorities

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Welcome to the tenth issue of *Science in School*



“Intelligence is of secondary importance in research.” So says our featured scientist, cosmologist Tamara Davis. For

her, interest and inspiration are far more important for success in science. Tamara herself certainly lacks neither interest nor inspiration (nor, I suspect, intelligence). She tells Henri Boffin about her work on dark energy, supernovae, the speed of light, and life elsewhere in the Universe – and how she combines this with playing world-class sport.

Shamim Hartevelt-Velani, Carl Walker and Benny Elmann-Larsen also have their eyes to the heavens, if not quite so distantly. In their second article about the International Space Station, they describe the daily life of an astronaut on board and the physiological effects of space.

Still closer to home is Mico Tatalovic’s research: his group has spent 15 years following the daily life not of humans but of meerkats. Why do some of these small African carnivores spend so much time watching for predators? Are these sentinels risking their safety for the sake of the



group, or do they have something to gain as individuals? And why are scientists so interested?

Recently, the interest not only of scientists but also of the general public has been drawn to the topic of particle physics. When the Large Hadron Collider (LHC) at CERN was switched on – and almost immediately switched off again – it made headline news across Europe and beyond. Rolf Landua and Marlene Rau investigate why this colossal experiment is necessary, how it works and what it will be able to tell us about the origins of the Universe.

If that all sounds a bit remote from the classroom, you might prefer the latest in our series of articles about climate change: Dudley Shallcross and Tim Harrison’s practical chemistry demonstrations. For younger students concerned about our climate, Sue Johnson offers experiments and a role play about carbon dioxide, oxygen and plant conservation.

While climate change is certainly a hot topic, nanotechnology is also frequently in the news. But what is it? With the help of Matthias Mallmann’s practical activities, you can introduce



nanotechnology into your classroom – what is the science behind pregnancy tests, and how can you visualise a magnetic field in a liquid?

Climate change, the LHC, nanotechnology – if we hear about a scientific topic in the media, we assume it must be important. But is it? And who decides what we hear about? TV journalist Nadia Salem takes Marlene Rau behind the scenes, discussing her daily work, her love of science and what it takes to become a science journalist.

If you find these articles useful and inspiring, why not help us to share them with teachers across Europe by translating them into your native language? Or if that doesn't appeal, perhaps you could join our reviewer panel, and help us decide which articles to publish. And of course, we welcome articles written by our readers. For more information, please visit our website.

On the *Science in School* website, you can also join our discussion forum (www.scienceinschool.org/forum) to contact teachers across Europe, pose scientific questions and offer your

own tips and advice. We look forward to your contributions.

Eleanor Hayes

Editor-in-Chief of *Science in School*
editor@scienceinschool.org
www.scienceinschool.org



The Hauptschule Munderfing (Upper Austria) presents their energy-saving project 'Save & Win'

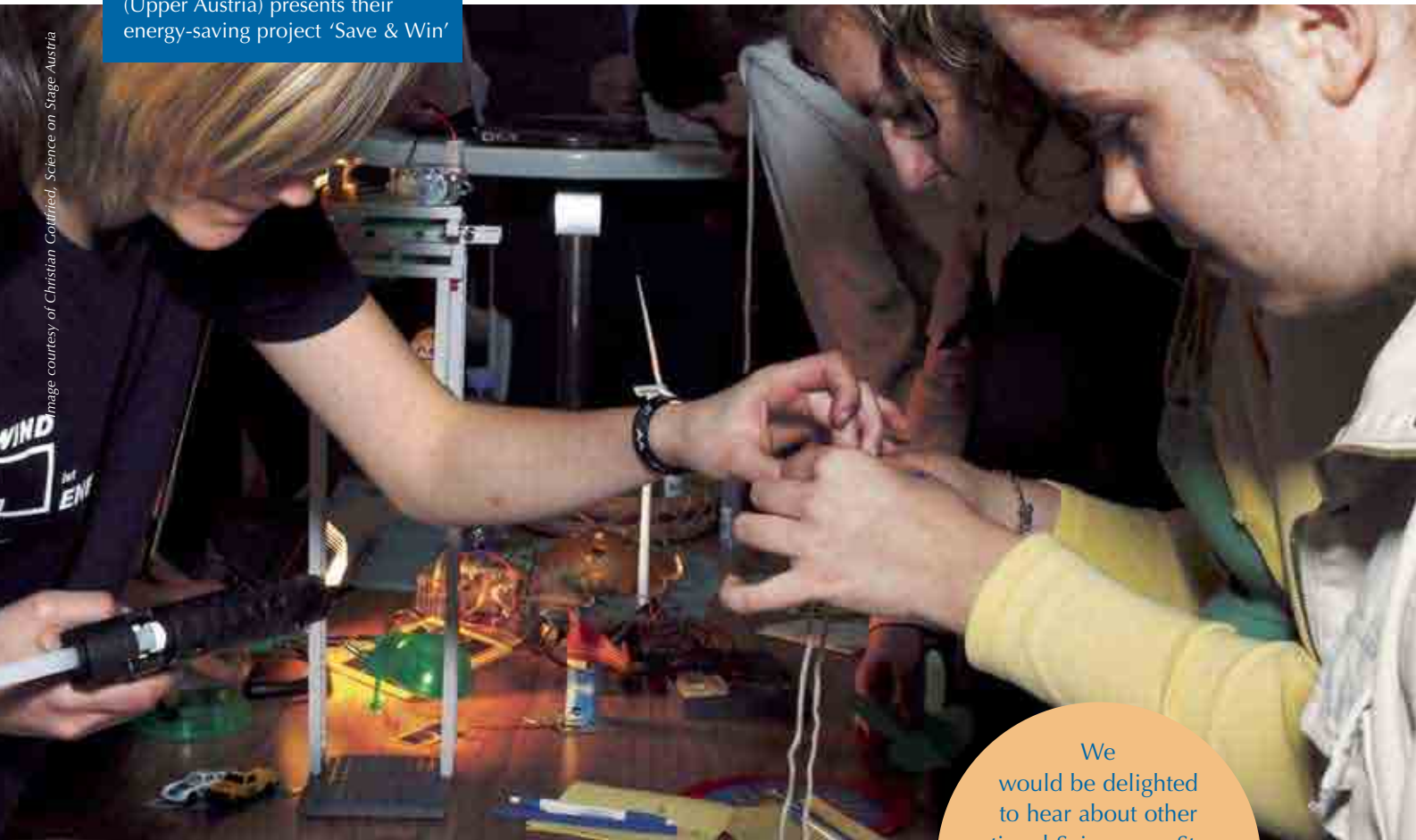


Image courtesy of Christian Cottried, Science on Stage Austria

We would be delighted to hear about other national Science on Stage events and collaborations. Please send details to

editor@scienceinschool.org

Science on Stage: recent activities



Many of the national Science on Stage organisations are becoming increasingly well established: running inspirational national events, inviting participants from across Europe to join them, and setting up projects with teachers in other countries. This commitment to European science education requires a great deal of effort from all involved: organisers, presenters and participants. **Eleanor Hayes** reports on some of the recent activities.

Margit Fischer, wife of the Austrian Federal President and head of the Science Center Netzwerk^{w6} tries her hand at the 'Save & Win' project

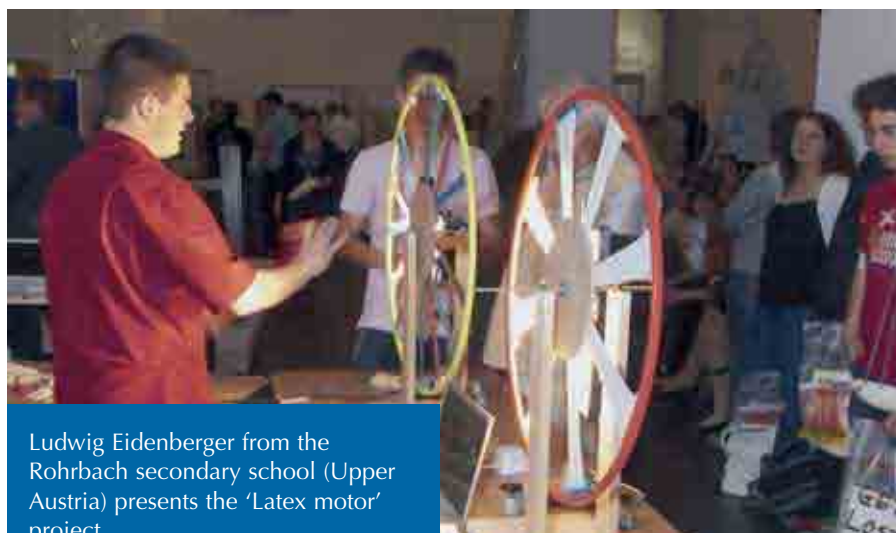


Image courtesy of Christian Gottfried, Science on Stage Austria

Image courtesy of Christian Gottfried, Science on Stage Austria



Prof. Martijn van Griensven asks: "Can we create a new man from stem cells?"



Ludwig Eidenberger from the Rohrbach secondary school (Upper Austria) presents the 'Latex motor' project

Image courtesy of Christian Gottfried, Science on Stage Austria

Science on Stage Austria

On 28 April 2008, 25 scientists and teachers competed for the attention of their public: 50 science teachers and 370 school students at the Austrian Science on Stage^{w1} event in Vienna. The event aimed to interest students in scientific topics – so the students themselves helped to select the four winning contributions.

The competition was tough. Should the prizes be awarded for a play about quantum physics, a talk on the importance of stem-cell research, a school-built machine to measure the nicotine concentration in smokers'

blood, a school project to measure cosmic radiation, or something entirely different? Together, the jury and the audience selected their favourites: Ludwig Eidenberger's 'Latex motor', Franz-Josef Natschläger's 'Ultrasound in fluids', Gerhard Horacek's 'Mini wind tunnel' and Josef Greiner's 'Particles and energy'. As a result, all four were invited to attend the German Science on Stage festival in Berlin on 23-26 October 2008^{w2}.

Details of all the contributions are available on the Austrian Science on Stage website^{w1}.

Playful Science 2: Belgium

Multilingual workshops, inspiring presentations, a fair of teachers' favourite experiments, a competition, explosions, prizes, music and a bagful of experiments to take home. No wonder the Belgian Science on Stage^{w3} event – Playful Science 2 – was filled to capacity on 16 January 2008.

Several of the short presentations linked not only different subjects, but also different senses. Johan Vanbeselaere presented his singing gravity detector, which he and his students used to hear gravity changes aboard an aeroplane, and Marc

Bernadette Anbergen performing an optics experiment at Science on Stage Belgium

Image courtesy of Xavier Van Kesteren



Image courtesy of Christian Gottfried, Science on Stage



Ida Regl wins a European Science Teaching Award for her project, 'Sunny side up', at Science on Stage 2 in Grenoble, France

Debusschere introduced his project to link biology and physics by visualising birdsong.

At the end of the afternoon, each teacher received a bag of €10 worth of experiments and software, as well as tombola prizes of experimental equipment. Most importantly, though, they went home with new ideas, inspiration and contacts.

The next Belgian Science on Stage event will take place on 28 January 2009 in Jemeppe-sur-Sambre, Belgium. See the Belgian Science on Stage website^{w3} for details.



Maltese students joined the international chemistry school in Dublin in July 2008

Image courtesy of Tim Harrison

A three-way collaboration: Ireland, the UK and Malta

The international Science on Stage 2 teaching festival^{w4} in Grenoble, France (in April 2007) not only gave 500 science teachers from 28 countries the opportunity to swap inspiring teaching ideas, meet scientists and visit world-class scientific facilities (Capellas, 2007; Hayes, 2007), but also paved the way for international collaborations – for example, when Tim Harrison and Professor Dudley Shallcross from Bristol ChemLabS^{w5} at the University of Bristol, UK, met Maltese science teachers Chris Schembri, Simon Cassar and Doreen Mizzi.

The Maltese teachers were so impressed with Tim and Dudley's lecture demonstration of atmospheric chemistry ('A pollutant's tale') at Science on Stage that they invited them to Malta. In October 2007, the Bristol chemists repeated their performance – complete with liquid nitrogen, fresh eggs, fruit and exploding rubber gloves – and gave lectures on climate chemistry to 1100 14-

18-year old students (half the country's chemistry students of that age!) and 100 teachers from 19 of the 22 Maltese church secondary schools. Thirty science and geography teachers also attended an evening session on climate change.

In July 2008, the visit was returned when 20 Maltese school students joined the well-established international chemistry summer school run by Trinity College Dublin, Ireland, and the University of Bristol, UK. A total of 61 students (aged 16-17) from the three countries carried out practical activities related to pharmaceutical research. They made aspirin, synthesised an anaesthetic, decaffeinated tea, analysed bleaches, and used electron microscopy as well as ultra-violet visible and infra-red spectroscopy. University scientists gave talks on many topics, including toothpaste (Pathmanathan, 2007), perfume chemistry (Harrison & Shallcross, 2006), extremophile chemistry (Leigh, 2008) and the extraction of drug precursors from sea sponges.

Xylophone experiment
at Science on Stage
Belgium



Image courtesy of Xavier Van Kesteren

w6 – For more information about the Science Center Netzwerk, see: www.science-center-net.at

Resources

For reports on the first Science on Stage international teaching festival at CERN in Geneva, Switzerland, see:

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

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

To learn about some of the Bristol ChemLabS activities for primary schools, see:

Griffin A, Harrison T, Shallcross D (2007) Primary circuses of experiments. *Science in School* 7: 28-32. www.scienceinschool.org/2007/issue7/primarycircus

For Tim and Dudley's suggestions on teaching climate change, see:

Harrison T, Shallcross D (2008) Climate change modelling in the classroom. *Science in School* 9: 28-33. www.scienceinschool.org/2008/issue9/climate

and:

Harrison T, Shallcross D (2008) Practical demonstrations to augment climate change lessons. *Science in School* 10: 46-50. www.scienceinschool.org/2008/issue10/climate



The relationship between Bristol ChemLabS and Science on Stage Malta looks set to continue. Already, Tim and Dudley are planning to return for the first Maltese School Science Week in November 2009, to give lectures for Maltese state schools, for schools on the sister island of Gozo and for trainee teachers.

Tim Harrison and Dudley Shallcross would be happy to hear from other European organisations or groups who are planning summer schools and would like the Bristol scientists either to take part or to offer advice.

Students of Luc Van Meertvelt, professor at the University of Leuven, presenting a chemistry show at Science on Stage Belgium



Image courtesy of Xavier Van Kesteren



Image courtesy of Xavier Van Kesteren

Patrick Walravens and a colleague present a science quiz at Science on Stage Belgium

w2 – For more information about Science on Stage Deutschland eV and the 2008 festival, see: www.science-on-stage.de

w3 – For information (in French, Dutch and English) about past and future Science on Stage Belgium events, see: www.scienceonstage.be

w4 – For information about the five international Science on Stage festivals, links to national Science on Stage activities and many inspiring teaching ideas, see: www.science-on-stage.net

w5 – Bristol ChemLabS is based at the School of Chemistry, University of Bristol, UK. See: www.chemlabs.bris.ac.uk

References

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

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

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

Forthcoming events

By 31 March 2009

Worldwide

Competition: The *Plus* magazine new writers award

Plus magazine is once again looking for the science writers of the future, who can make mathematics lively and interesting for a general audience. There are three categories in this writing competition: school students, university students and the general public. In the first category, secondary-school and sixth-form students are invited to write a piece of up to 900 words about the life and/or work of any mathematician, living or dead. The winning entries will be read by an international audience of over 100 000 in the June 2009 issue of *Plus*. There are also prizes for the best submissions, including signed copies of popular science books and an Apple iPod.

The closing date is 31 March 2009.

More information:

<http://plus.maths.org/competition>

13 November 2008 – May 2009

Competition: The chemical detective (Mit Chemie auf Spurensuche)

The ninth DECHEMAX school competition will start in November 2008. In the first round, teams of three to five students from Years 7-11 answer weekly questions on the Internet about biology, biotechnology and chemistry. Teams that pass the first round can take part in the second – experimental – round. There are certificates for all successful teams, and attractive prizes for the winners.

The competition is run in German. Registration open online on 1 October:

www.dechemax.de/anmeldung

More information: www.dechemax.de

Contact: dechemax@dechema.de, +49 (0)69 7564 164/172

12-14 December 2008

**Engineering Department,
University of Cambridge, UK**

Training course: Cambridge Update

All practising teachers of physics are invited to take part in a course run by the UK's Institute of Physics. Through a series of talks and workshops, participants will learn about recent developments in physics and the applications of physics, try new practical techniques and find out about developments in physics education.

The course costs £130 (residential) or £70 (non-residential). There is a discount for members of the Institute of Physics.

Flyers and application forms will be sent to UK schools early in September. Schools outside the UK who would like to be informed about the course are invited to contact the organisers.

Contact: Leila Solomon
(leila.solomon@iop.org)

Until 15 January 2009

Germany

Competition: Siemens school competition

This year's Siemens school competition in science, engineering and mathematics is all about water. How can we reduce our water consumption? How can we avoid water pollution? What technologies are available for acquiring drinking water and treating sewage? Students in Years 11-13 are invited to compete.

The deadline for registration is 31 October 2008. The submission deadline is 15 January 2009. The competition language is German.

More information:
www.siemens.de/generation21/schuelerwettbewerb

28 January 2009

Jemeppe-sur-Sambre, Belgium

Conference: Playful Sciences 3

Science on Stage Belgium invites secondary-school teachers and trainee teachers to join them in a day of playful sciences: presentations, experiments, games, a competition and a bag of experimental material to take home!

The introduction is in English, with the rest of the events in either French or Dutch (with translations available, if necessary). There are places for 200 participants and the event is free. To register, email info@scienceonstage.be by 1 November 2008.

More information: www.scienceonstage.be

15-17 February 2008

London, UK

Training course: Physics in Perspective

This study course for sixth-form and college students (aged 16-19) offers insights into the many aspects of modern physics, including cutting-edge physics topics, technological applications, as well as some 'fun' physics. The programme of six lectures is designed to counteract the misconception that physics is a dry, narrow subject concerned only with certainties and remote concepts, and to demonstrate how physics is used to

help us understand our environment, our planet and our Universe.

Organised by the UK's Institute of Physics, the course costs £20.

Contact: Leila Solomon
(leila.solomon@iop.org)

Until 30 April 2009

Europe-wide

Competition: Check out the Property

To help teachers make science lessons more fun and interesting, Xperimania has launched a new science competition, Check out the Property, for 10- to 20-year-old students.

Via fun and easy experiments detailed on the Xperimania website, students are encouraged to learn about chemical and physical properties of everyday objects, the materials that display those properties, and their uses in everyday life. Students are also invited to devise their own hypotheses and experiments and upload their laboratory reports, along with photographs, films or other multimedia sources.

There are prizes for the best entries: personal media players for the winning students and a prize fund for the winning schools to spend on scientific classroom resources.

More information:
www.xperimania.net/ww/en/pub/xperimania/competition2008.htm

Contact: xperimania@eun.org

26 September 2009

Lisbon, Oporto and Matosinhos, Portugal

Science festival: Researchers' Night 2008 'Scientists across Portugal'

As part of the European Researchers' Night initiative by the European Commission, the Instituto Gulbenkian de Ciência, University of Oporto and Inova+ invite you to join the largest science communication event in Portugal.

In Lisbon, events and activities at the Cultural Centre of Belém include:

- A 'walk for science'
- Speed-dating with scientists
- Science-art exhibits
- Hands-on experiments
- A scientists' bands stage
- Interactive science in the Champimovel.

In Oporto, at the ocean-front of Matosinhos and the Planetarium of the University of Oporto, the activities include:

- Exhibitions and workshops
- Starlab – the portable planetarium
- Speed-dating with scientists
- Hands-on experiments
- Cafes scientifiques
- Performances by university music groups
- Interactive science in the Oceanário Shuttle (Oceanário de Lisboa).

More information:
www.igc.gulbenkian.pt/investigadores2008

All year

CERN, Geneva, Switzerland

Training course: CERN high-school teacher programme

CERN, the world's largest particle physics laboratory, organises one-week courses for secondary-school 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 aged 13-16.

The courses cover (at an introductory level) particle physics, cosmology, detectors, accelerators and applications. Teachers have the opportunity to visit CERN's experimental installations. Each course is aimed at teachers from a particular European country and is run in the national language.

The courses are free of charge, but the participants are expected to pay for their travel expenses and accommodation.

More information:

<http://education.web.cern.ch/education>

Contact: Mick Storr (mick.storr@cern.ch)

All year

Schullabor Novartis, Basel, Switzerland

Workshop: 'Gentechnik Erleben' (Experience Genetic Engineering)

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

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

More information:

www.schullabor.ch

Contact: Gesche Standke (gesche.standke@novartis.com)

All year

Schools and other venues in the UK
Roadshow: Cool Seas

Run by the Marine Conservation Society, the Cool Seas Roadshow visits primary and junior schools throughout the UK. It entertains and educates school children about the importance of conserving the UK's spectacular marine wildlife, using life-size inflatable models of whales, dolphins, sharks, turtles and seals in dynamic presentations given by a marine wildlife education specialist. The roadshow involves a full day of presentations to different classes, and costs either £175 or £350, depending on how much the school can contribute.

Each school that is visited receives printed materials and web-based resources, including an activity booklet for each student, and a poster for every classroom. The curriculum-linked, web-based resources can be viewed here:

www.mcsuk.org/coolseas

The roadshow is also suitable for public events outside school, so if you are planning an environmental event or have a large and suitable audience in mind, please get in touch.

More information: www.mcsuk.org

Contact: info@mcsuk.org

All year

10 locations around the UK

Training courses: science continuing professional development

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

More information:

www.sciencelearningcentres.org.uk

Contact: enquiries@national.slcs.ac.uk

All year

Glasgow Science Centre, Glasgow, UK

Free teacher visits

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

More information:

www.glasgowsciencecentre.org

Contact: +44 (0)871 540 1003

All year

Many Scottish venues, UK

Roadshow: Science Circus

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

More information:

www.glasgowsciencecentre.org

Contact: +44 (0)871 540 1004

All year

Pembrokeshire, Wales, UK

Field trip: Rockpools

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

More information:

www.darwincentre.com

Contact: Marten Lewis

(M.B.Lewis@pembrokeshire.ac.uk)

All year

Pembrokeshire, Wales, UK

Workshops: Primary school

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

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

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

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

More information:

www.darwincentre.com

Contact: Marten Lewis

(M.B.Lewis@pembrokeshire.ac.uk)

All year

Paris-Montagne, Paris, France

Science Academy

Throughout the year, Paris-Montagne runs an outreach programme in all Parisian suburbs and in the Lyon area. The science academy is for high-school students who are interested in science but not confident enough to enrol for 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 labs, from three hospitals and a dozen universities and research institutes, participated in April 2008). The most dedicated participants in the programme are offered the chance to take part in a summer camp during the Paris-Montagne science festival in July, and also to attend other scientific summer camps in Europe (including Petnica, Kut Diak and Visnjan).

Since its creation in 2006, nearly 300 high-school students have participated in the science academy, and each year around 1500 participants visit the Paris-Montagne science festival.

More information:

www.scienceacademie.org

All year

Portugal

School visits: MIT professors go to Portuguese secondary schools

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

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

More information:

www.cienciaviva.pt/divulgacao/mit

Contact: mit@cienciaviva.pt

All year

INTECH Winchester, UK

Free teacher visits

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

More information:

www.intech-uk.com

Contact: Angela Ryde-Weller

(AngelaRydeWeller@intech-uk.com)

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



Practical courses in molecular biology for teachers

ELLS LearningLABs

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“Intelligence is of secondary importance in research”

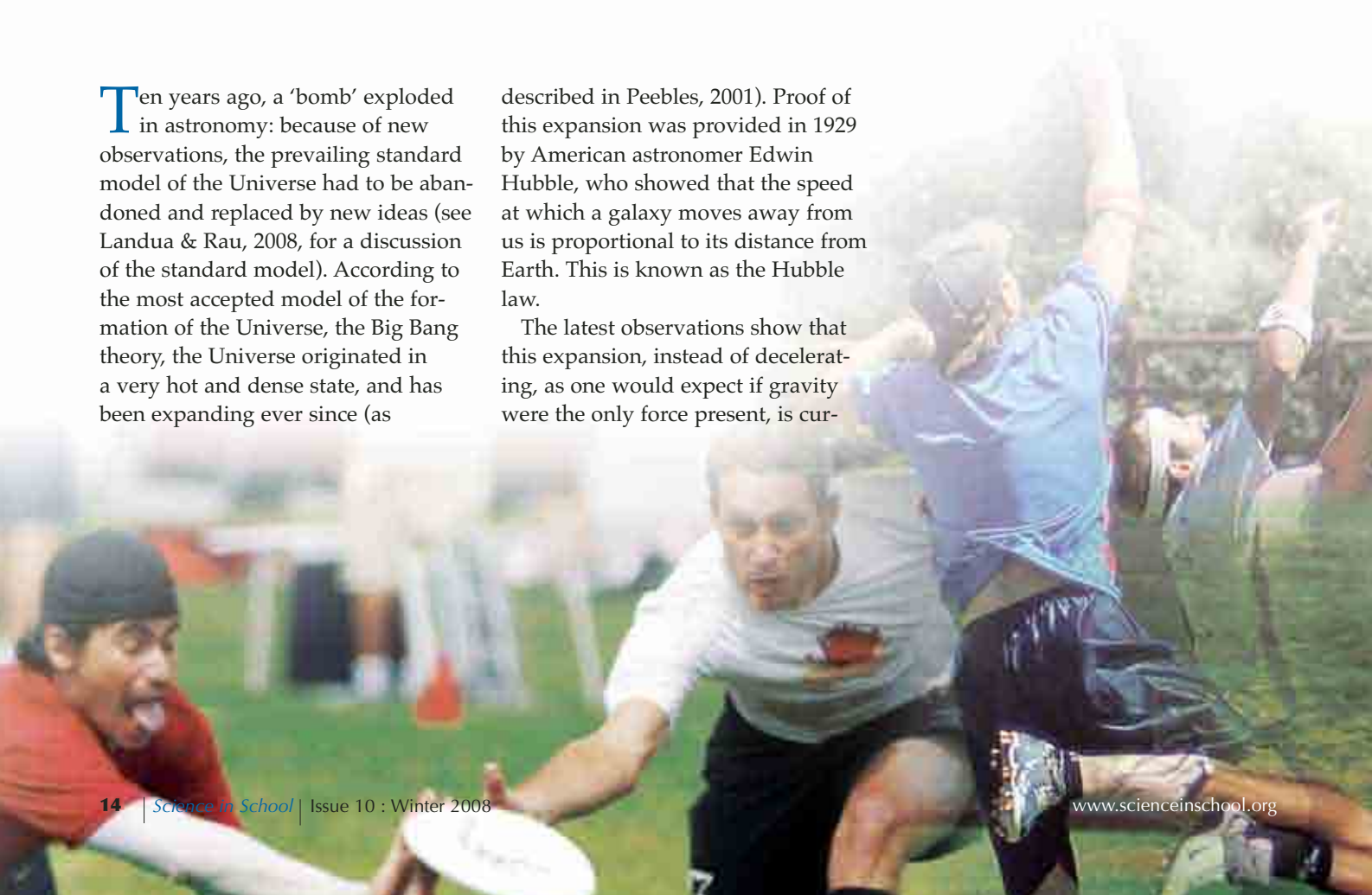
Image courtesy of H. Boffin / ESO

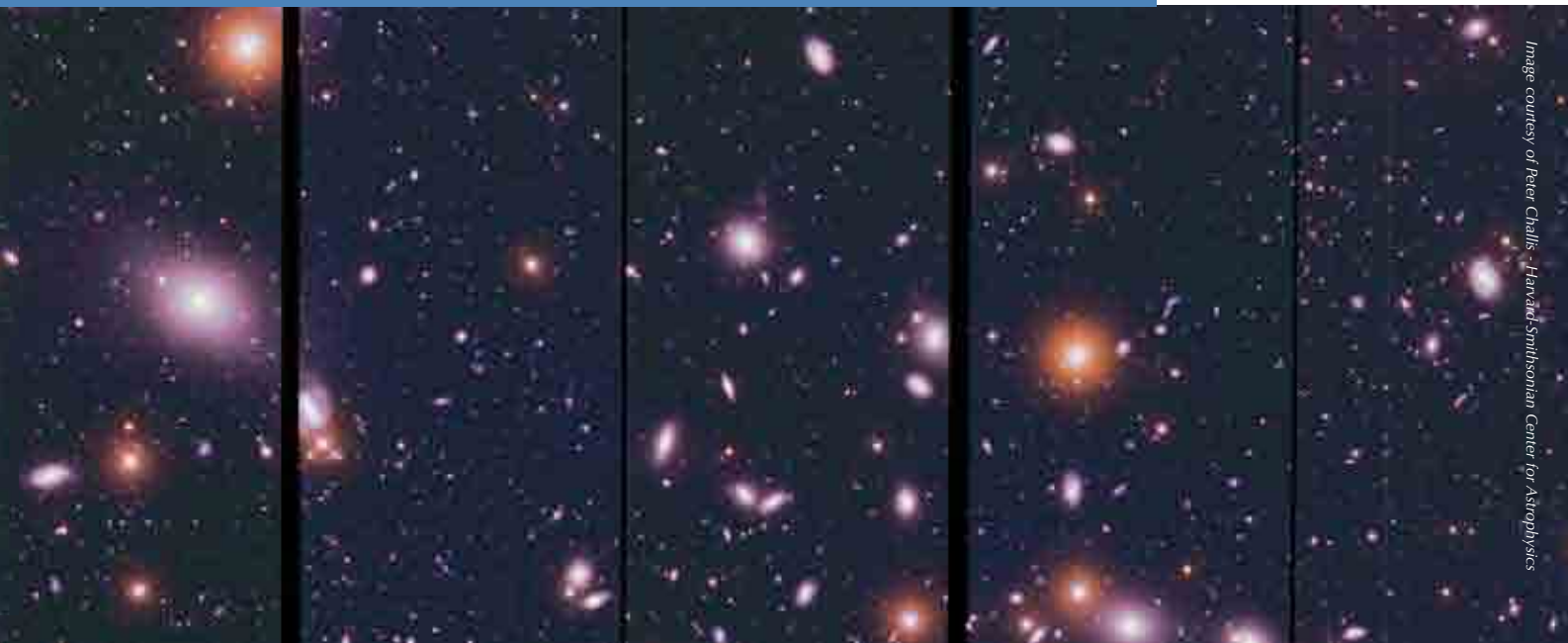
Can you play world-class sport and also be part of a team that tries to understand the nature of our Universe? Yes – just ask Tamara Davis. **Henri Boffin** from ESO talked to her in Copenhagen, Denmark.

Ten years ago, a ‘bomb’ exploded in astronomy: because of new observations, the prevailing standard model of the Universe had to be abandoned and replaced by new ideas (see Landua & Rau, 2008, for a discussion of the standard model). According to the most accepted model of the formation of the Universe, the Big Bang theory, the Universe originated in a very hot and dense state, and has been expanding ever since (as

described in Peebles, 2001). Proof of this expansion was provided in 1929 by American astronomer Edwin Hubble, who showed that the speed at which a galaxy moves away from us is proportional to its distance from Earth. This is known as the Hubble law.

The latest observations show that this expansion, instead of decelerating, as one would expect if gravity were the only force present, is cur-





Images of clusters of galaxies like this one from the CTIO Blanco 4-m telescope are used to discover distant supernovae by Tamara Davis' team

rently accelerating. Galaxies are moving away from each other at an ever-increasing rate (see, for example, Leibundgut & Sollerman, 2001).

"Astronomers thus came up with the idea of dark energy, which is the name we give to the mysterious source of the acceleration of the Universe," says astronomer Tamara Davis. "We do not yet know what it is. It could be a kind of material that has anti-gravity properties, in which case this bizarre stuff would make up over 70% of the energy in our Universe. Or it could be that our theory of gravity might not yet be complete, in the same way as Newton's theory needed to be extended by Einstein's theory of general relativity."

Now that astronomers also have evidence that 25% of the Universe is made of an unknown form of matter

(as described in Warmbein, 2007) – dark matter – we only really know about approximately 5% of our Universe. This certainly calls for a degree of modesty!

Tamara works at the Dark Cosmology Centre in Copenhagen, Denmark, and teams up with people from around the world in large collaborations, not unlike those that are now tackling crucial questions in particle physics. Tamara is part of the ESSENCE^{w1} collaboration, which studies supernovae in order to understand dark energy. She started working on this amazing topic when she moved to the Australian National University and Mount Stromlo Observatory in 2003, after completing her PhD at the University of New South Wales, Australia. "I was extremely lucky to work with a really inspirational scientist, Brian Schmidt, who is one of the

researchers who discovered that the expansion of the Universe is accelerating."

One way to determine the properties of dark energy is to measure distances and velocities of distant light sources so as to calculate how much the Universe expands over time. For this purpose, astronomers observe primarily Type Ia supernovae (as described in Székely & Benedekfi, 2007) – that is, exploding stars. The most distant observed supernovae are so far away that they actually exploded before Earth even formed. Their light has been travelling through space towards us since before our Sun started shining – and remember that, because light moves at a finite speed, looking far away means looking back in time. Because they are so far away, very little light reaches us, so such observations can only be made with

Image source: Wikimedia Commons





The supernova discovery telescope (CTIO Blanco 4-m) magnificently framed by the two Magellanic clouds (some of our nearest galactic neighbours) on the left and our own Milky way galaxy on the right

Image courtesy of Roger Smith / NOAO / AURA / NSF

the most powerful of telescopes, such as ESO's^{w2} Very Large Telescope (see Pierce-Price, 2006, for a description of working with this telescope), or the Keck^{w3} and Gemini^{w4} telescopes – all of which are in remote areas with climatic conditions well suited to telescope observation (almost no clouds, almost no water vapour, and a thin atmosphere). By observing a great number of supernovae spanning a wide range of distances, and measuring their distances and velocities, it is possible to measure how the expansion of the Universe changes with time.

The ESSENCE collaboration is a group of about 30 researchers from around the world, who come together to discover distant supernovae so they can be used to understand the acceleration of the Universe and dark energy. Tamara has the daunting task of trying to work out what the measurements of supernovae actually tell us. After she has done her share of the observations, she lets others in the collaboration turn the raw images of supernovae into information about their distance and velocity. Meanwhile, she studies different theories of

dark energy and what they predict for the behaviour of the supernovae.

When the observations are ready, it is her job to compare the data with the theories and figure out which work best.

“Far and away my favourite part of astronomy is observing at the big telescopes, particularly the ones down in Chile. Using space telescopes [which eliminate the blurring and absorbing effects of Earth's atmosphere] is also extremely cool, but you don't get to control the telescope yourself. Actually going up to the telescopes in the Chilean Andes, such as the Very Large Telescope, is amazing. The whole experience of travelling through South America, getting the bus up into some wild, remote part of the desert and then seeing a huge telescope appear on the horizon is like something out of a science fiction film. Then when you are actually there you have a building-size piece of precision machinery obeying your commands. It's fantastic.”

Tamara not only got hands-on with telescopes in the Chilean Andes – back home in Australia, she used many telescopes, and had some entertaining moments. Once, she was

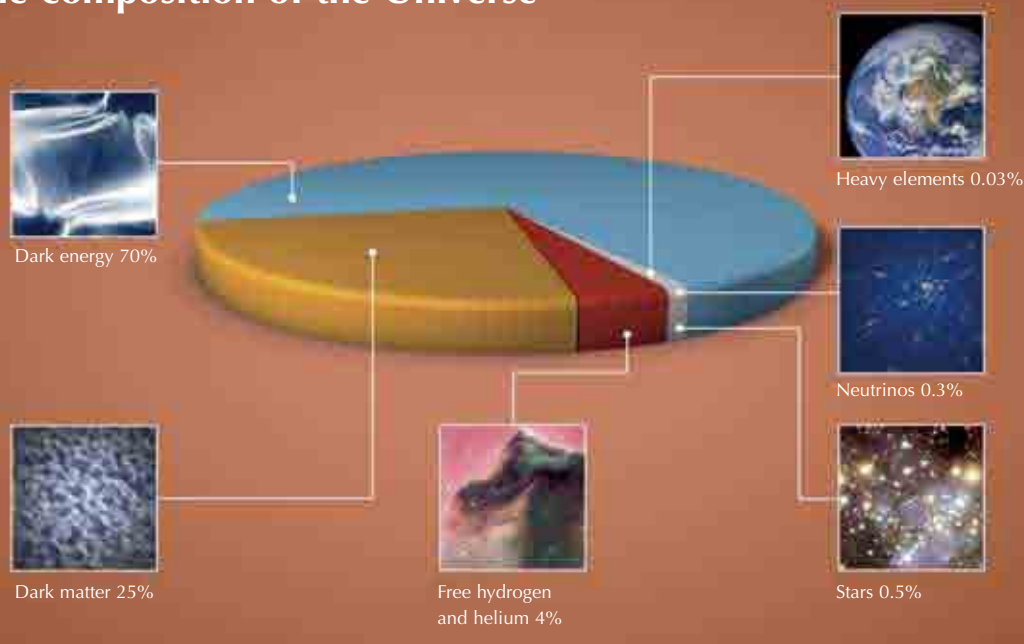
trapped outside the telescope enclosure because a pack of kangaroos was grazing at the gate.

But Tamara also has her eyes on space. In Copenhagen, she is part of a group that is proposing to build a space observatory called SNAP, the SuperNova Acceleration Probe^{w5}. SNAP is designed to measure the expansion of the Universe and to determine the nature of the mysterious dark energy that is accelerating this expansion. “I love telling people that part of my job is building a spaceship,” she jokes.

But what is it really all about? “We are trying to understand the fundamental building blocks of our Universe and how the laws of physics work. The kind of advancements in knowledge and in technology that are possible from this work will be truly staggering, although turning this fundamental research into practical applications will take a long time. Current theories don't explain what this dark energy is, but they are flexible enough to allow it.

“Most exciting to me is that explaining the acceleration of the expansion of the Universe may, according to the

The composition of the Universe



We only really know about five percent of the composition of the cosmos – dark matter and dark energy are still subject to intense research

Image courtesy of L. Calçada / ESO

Ever since the Big Bang, the Universe has been expanding – and with accelerating speed

The expanding Universe

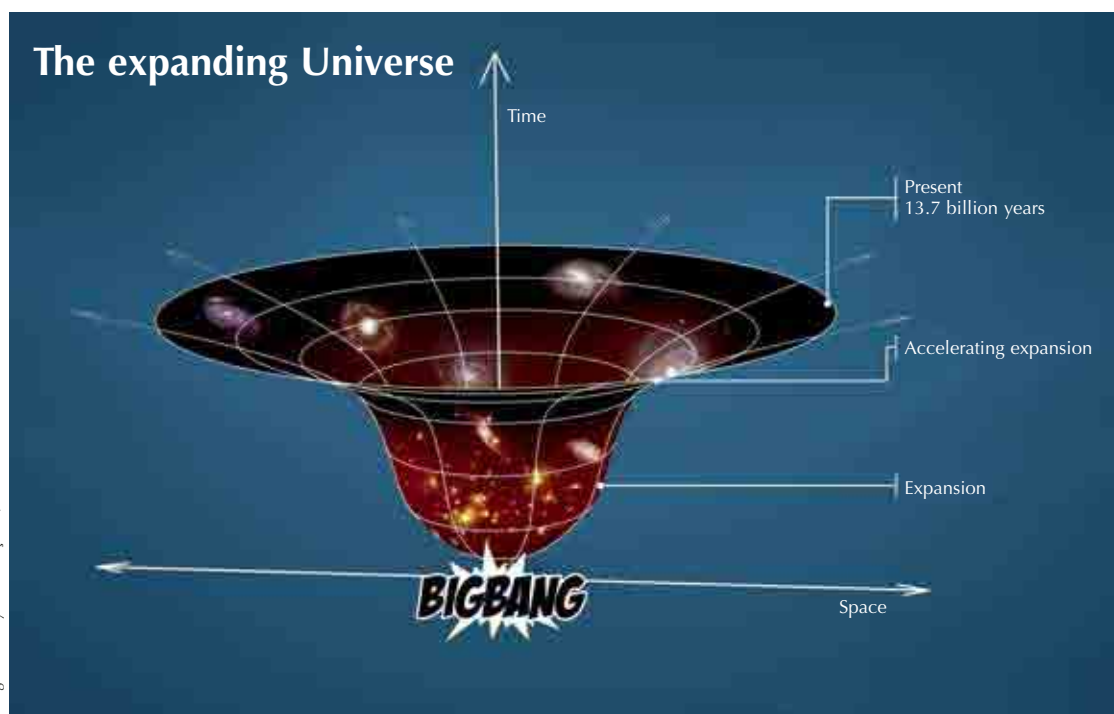


Image courtesy of L. Calçada / ESO

most prevalent theories, require a merging of gravity and quantum theory – the physics of the very large with that of the very small. I love the interconnectedness of nature when you realise that the physics of the tiniest particles that make up humans

can affect the physics of the entire Universe on the largest scales. Isn't it mind-blowing?"

According to Tamara and many of her colleagues, the evidence for dark energy is now fairly incontrovertible. "If it was only supernovae that point-

ed towards such an outlandish idea, it would be easy to suggest that there was just something we had missed in the observations – that somewhere we'd made a mistake. But since the initial discovery, more and more evidence has been piling up from com-

pletely different observational tests, and they all require dark energy.”

The cosmic microwave background radiation⁶ (the afterglow left over from the Big Bang), observations of galaxy clusters, measurements of baryon acoustic oscillations (the pattern of galaxies in the sky), weak and strong gravitational lensing (for a brief description of gravitational lensing, see Jørgensen, 2006) – these widely varying measurements, which probe very different physics, all agree that the expansion of the Universe cannot be explained without dark energy (see Peebles, 2001).

One would think that following this quest would not leave much time for anything but science. But Tamara’s achievements reach beyond physics. As a PhD student, she served for two years as an elected member of the university sports association executive committee, organising sport for more than 30 000 students. She has competed at national level in no fewer than six sports. She is a ski instructor, gymnastics coach and surf lifesaver. At the world championships for ultimate frisbee in Germany in 2000, Tamara represented her country for the first time and has since remained an active member of the Australian team, vice-captaining the team to fifth place at the 2004 world championships in Finland. Ultimate frisbee is a team sport played with a frisbee on a rugby field (without the posts). Ultimate frisbee is self-referenced: the players make their own foul calls, so fair play and trust in your opposition is vital. Because of this, the players hold a vote at every tournament as to which team played the fairest. Despite being very competitive, Tamara’s team won the ‘spirit of the game’ award at both world cham-

pionships, a remarkable achievement.

With such a love of and devotion to physics and sport, it is perhaps no surprise that Tamara imagined becoming an astronaut. Unfortunately, if you are not American, this is no easy task, but as Tamara also has Canadian citizenship, she intends to apply if the Canadian Space Agency advertises an opening. In the meantime, as becoming an astronaut seems unlikely, astronomy is the next best thing for her. This decision was influenced by a particularly inspirational high-school physics teacher. “He was an amateur astronomer and bought a small telescope for the school which we could use at night. He also took a couple of us along to an astronomy weekend which was memorable because it was my first exposure to relativity. I was hooked.”

Tamara believes that it does not take much to be good in science – only a natural wonder for the world around oneself and for figuring out how it works. “I’ve learned that intelligence is of secondary importance in research. Interest and inspiration are far more telling signs of whether someone will be successful in a scientific career,” she comments.

Tamara’s interests are not limited to dark energy. Part of her research investigated some fairly daring topics, showing (amongst other things) that the Universe can expand faster than the speed of light, that the speed of light might not be constant, and that the rapid appearance of life on Earth suggests that life in the Universe is common.

She also teaches at university, something she thoroughly enjoys. “I guess it is because I am so excited by what I study that it is completely rewarding

to pass on that enthusiasm to others. I love seeing that moment of realisation when someone catches on to a complex concept, or that ‘wow’ moment when they learn something they never knew before.”

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Two topics tend to inspire teenagers to study physics: the fundamental questions relating to how the Universe got its spots (such as Levin, 2003), and astronomy. Neither topic is found in standard secondary-school curricula, but this article contains a bit of both. Students are likely to find it very interesting that the study of supernovae using telescopes can help prove (or disprove) the standard model of cosmology.

In addition, many non-scientists – secondary-school students included – still imagine physicists to be skinny male nerds on the autistic side of normal, or bearded and bespectacled nutters (or, in the unlikely event that they're female, distinctly weird spinsters with no life outside the lab) who work in isolation, never seeing the light of day. A description of a real physicist, whom students might wish to meet, work with, or even emulate, is welcome. Moreover, the job that Tamara does, which requires international collaboration, travel to exotic locations and playing with mega toys, might well persuade students that a career in physics could be seriously interesting, maybe even exciting or fun.

Teachers could use this article to stimulate a discussion of:

- How science advances through experiment, and how ideas change and theories have to be modified (Copernicus, Newton, Einstein...)

- The role of central facilities and international collaborations
- The use of space telescopes to eliminate atmospheric interference in astronomy
- Things we still don't know or understand properly
- The value (or otherwise) of doing this kind of fundamental work
- Stereotypes, caricatures and preconceived ideas.

It could also be used for enrichment when studying light scattering in the atmosphere, or as a basis for student research into how physicists determine the distance to stars or how stars move with respect to Earth.

Collaboration with the art department might lead to some interesting representations of supernovae, and imaginations could be stretched even further by thinking about what the Universe may have looked like when a very distant supernova exploded.

Finally, children might calculate how far the light from a distant supernova was from Earth at the time that Earth was formed, or when dinosaurs roamed Earth, giving their answers (for example) in multiples of the distance to Alpha Centauri.

Halina Stanley, France

Web references

w1 – For more information about the ESSENCE (Equation of State: SupErNovae trace Cosmic Expansion) collaboration to find supernovae distributed evenly over the redshift range, see: www.ctio.noao.edu/wproject/

w2 – For more information about ESO (the European Southern Observatory) and its educational projects, visit: www.eso.org/outreach/eduoff/

w3 – The website of the Keck Observatory in Hawaii, USA: www.keckobservatory.org

w4 – The website of the Gemini Observatory: www.gemini.edu

w5 – The SNAP website: <http://snap.lbl.gov/>

w6 – The Wilkinson Microwave Anisotropy Probe (WMAP) is a NASA Explorer mission producing a wealth of precise and accurate cosmological information. WMAP produced the first full-sky map of the microwave sky. WMAP

measures cosmic microwave background radiation – the light left over from the Big Bang, shifted to microwave wavelengths due to the expansion of the Universe. For more information about WMAP, see: <http://map.gsfc.nasa.gov/>

Resources

For more information about Tamara and her work, see her webpage: www.dark-cosmology.dk/~tamarad/index.html



Sentinels: meerkat superheroes

Mico Tatalovic from the University of Cambridge, UK, investigates the private lives of meerkats. Why do these small carnivores live in groups? Why do they feed each other's pups, dig together and guard each other? And what makes a really good sentinel?

Flower is an internationally acclaimed television star. The Discovery Channel's series *Meerkat Manor*, the first 'animal Big Brother' show, made her cute little face popular around the globe. Now a feature-length biography has also been released with an accompanying book, *Meerkat Manor: The Story of Flower of the Kalahari*.

Flower's story only reached the world because of the research efforts of scientists based at the University of Cambridge, UK, who set up the Kalahari Meerkat Project^{w1} 15 years ago and have studied the lives of several meerkat groups daily ever since. Such long-term field projects have become popular in the field of behavioural biology because they permit the accumulation of an enormous amount of data on every aspect of animals' lives, allowing scientists to ask and answer ever-more detailed questions about their evolution.

When not on camera, Flower, like other meerkats (*Suricata suricatta*), has to worry about two main things in life: finding food, and avoiding being eaten herself. When the right time (and the right male) comes, a third

Meerkats sunning themselves. Especially in winter months, meerkats sun themselves to warm up in the morning before foraging, and in the evening before going to sleep



Image courtesy of Mico Tatalovic

worry comes into her head: reproducing. Such is the nature of natural selection: only those who survive long enough to reproduce will spread their genes to the next generation. Flower is a descendent of a long line of survivors. This means she has adaptations that allow her to survive despite the many predatory species out to get her.

Birds of prey, wild cats, jackals, snakes.... If it's bigger than a meerkat and it eats meat, it's probably a threat. Living in a group is an advantage; many eyes see better. But meerkats have evolved an even more sophisticated strategy to avoid predation: posting sentinels^{w2}, usually one but sometimes several at the time. Like soldiers on guard, meerkat sentinels scan the horizon from an elevated post and announce their duty with a special sentinel call, the 'watchman's song'. They have excellent depth perception that allows them to see predators at a great distance. Having a sentinel on guard reduces the possibility of surprise attacks and allows the rest of the group to be less vigilant.

Sentinel behaviour may seem altruistic since the sentinels help others at



Meerkat research

The Kalahari Meerkat Project was set up some 15 years ago by Professor Clutton-Brock from the University of Cambridge, UK. Since then, the Cambridge scientists have collaborated with colleagues in other countries, especially at the University of Zurich in Switzerland and Pretoria University in South Africa.

All meerkats involved in the project are wild but habituated to people and are easily identifiable by small dye marks that the researchers and volunteers have painted on them. These dye marks make for easy identification, as 'head and shoulders' is different from 'right rib, right thigh'. Familiar with people since birth, the animals ignore us so we can observe them from as little as 0.5 m away and walk among the group without disturbing their normal behaviour. Since most meerkats are studied from birth, each individual's parentage and life history is recorded.

The project manager makes a weekly schedule of group visits to allow researchers (master's students, PhD students and postdoctoral researchers) to visit the meerkat groups they need for their experiments and to make sure all groups are visited at least a couple of times a week by volunteers to keep track of where the animals go and what they do. In every group, one animal has a radio collar that allows it to be tracked; most of their sleeping burrows are also labelled with GPS points so it is easy to locate them.

All pups are caught and an identity microchip is inserted under their skin in case the dye marks on their fur wear out. Blood samples are also taken at regular intervals throughout their lives, to obtain both their DNA and hormonal profiles. This helps researchers to determine relationships within and between the groups and to correlate behaviours with hormone levels. The animals are captured for only a few minutes, to avoid stressing them too much.

For the scientists, a typical day of meerkat research involves waking up before sunrise to arrive at the sleeping burrow before meerkats get up. Various records have to be kept, such as where the animals slept, when they got up, how heavy they are (we use small crumbs of hard-boiled egg to lure them onto scales, saying "yum, yum, yum!"). We also count and identify all the animals to check the group's composition and then follow them for three hours while they forage for food and avoid predators. When following them, we also take regular GPS readings to calculate the routes that the meerkats take on their foraging trips. At midday, when the meerkats have a siesta to avoid the heat of the desert sun, we leave to have lunch and return in the afternoon for more data collection. Afternoon experiments might include playing the meerkats' own vocalisations back to them or presenting them with predator cues or faeces to observe their responses.

BACKGROUND

Image courtesy of Mico Tatalovic

Meerkats resting. In the summer months, meerkats rest at midday to avoid the heat



Meerkat society

Meerkats (*Suricata suricatta*) are small, carnivorous mammals weighing on average less than one kilogram. They inhabit the arid areas of southern Africa and live in social groups of 2-50 individuals, consisting of one dominant pair and a variable number of subordinate helpers who may or may not be related to the dominant pair. These members of the mongoose family (Herpestidae) eat mainly arthropods (insects, spiders and their relatives), as well as the occasional small mammal, reptile or plant bulb.

They have territories with several sleeping burrows, from which they make daily foraging trips of up to a few kilometres. Depending on food availability and predation pressure at specific spots, they will either return to the same sleeping burrow for several nights, or change burrows quite frequently.

On average, litters consist of three to four pups that stay within the burrow until they are approximately three weeks old. During that time, while the pups are being fed on milk, the group returns to the same burrow. At four weeks of age, the pups begin travelling with the group and for their first three months of life, are fed on invertebrates and small vertebrates by helpers.

Meerkats reach adulthood at around one year of age. At around 18-30 months of age, males voluntarily leave the group, either to join an existing group or to form a new group with unrelated females. Adult females, particularly pregnant ones, may be evicted from their home group by the pregnant dominant female; this is thought to reduce the chance of the dominant female's pups being eaten by the other females. Most females return to the group once the dominant female has given birth, but some may permanently disperse to form new groups with unrelated males.

Dominant meerkats live for 6-10 years on average, with the oldest individual in the Kalahari Meerkat Project being almost 13 years. The age of subordinate meerkats is more difficult to record, as many disperse or are evicted by the age of around three years, and are subsequently lost to the project records. The most important known causes of death are predation, fights with other meerkats (including infanticide), diseases and human-caused factors such as car fatalities – but for two-thirds of the Kalahari Meerkat Project meerkats, the cause of death is unknown, since the individuals just disappeared.

BACKGROUND



Image courtesy of Mico Tatalovic

Meerkats at a sleeping burrow. Sleeping burrows may have several exits and rooms inside. Meerkats maintain them but don't dig them; instead they use ground squirrels' burrows and sometimes also share them with yellow mongooses that live in small family groups

their own expense: when they are guarding, they not only expend energy and lose valuable foraging time, but also expose themselves to predators. But are they really being altruistic?

My research group investigates conflicts and co-operation in meerkat societies, and as part of this work, I focus on sentinels. One of the main questions I am investigating is why some meerkats spend more time on guard than others. An answer to a simple question like this can give us valuable insights into the evolution of social behaviour. 'Why are some humans more social than others?' and 'How did our sense of community and helping others initially evolve?' we may ask eventually. Until then, we study model animals, such as

meerkats, to give us preliminary answers and to help us formulate and test theories.

Flower keeps guard from trees, logs, bushes, grass tufts or even human heads. The average height of the posts from which meerkats keep guard is around 60 cm although the bravest sentinels will climb trees up to six metres high. The height of the sentinel's post also varies with the vegetation cover; during the rainy season when grass is tall, sentinels guard from higher posts so that they can see above the grass. This reflects the fact that the behaviour of wild animals is affected by their environment; when studying behaviour, it is often important to consider the environmental effects.

Meerkats are an excellent model species for studying behavioural biology and ecology because they can be habituated to close observation by humans; they are also diurnal and forage in a relatively open habitat and are hence easy to follow and observe on foot. The aspect of their lives that interests evolutionary biologists the most is their sociality. Why do they live in groups? Why do the young adults stay in the group and why do they help each other? What are the evolutionary conflicts among individuals living in groups and how are these resolved?

Benefits of group living

For meerkats, group living makes sense because there is little available land for establishing their own territories, most of the appropriate habitat having already been taken by rival groups, and the harsh desert environment makes it difficult to survive alone. All adult meerkats contribute to co-operative behaviours; the main ones are pup feeding, sentinel duty, burrow maintenance and, for females, allolactation (lactating for another meerkat's pups). Co-operation increases the pups' survival, development and subsequent reproductive success, which benefits the group as a whole, because larger groups are more likely to survive.

Sentinel behaviour also differs between individual meerkats. Some sentinels will go on guard more often, and guard longer and from higher posts: this is why we consider them to be 'supersentinels' – although we don't actually know if these individuals are also the most efficient in detecting predators. The longer they stay on guard, the more likely they are to announce their alertness when protecting the group, so that the group can relax. Supersentinels are also likely to be animals that are usually more vigilant; even when they are not on sentinel duty, they often stop while foraging for food to briefly

check the surroundings for anything suspicious. It seems that these supersentinels also have higher levels of the stress hormone cortisol. This raises the question of whether this hormone is the cause or the effect of their behaviour. Future research could address this by observing how an

Meerkat guarding from the top of a dry branch

Costs of group living

There is a trade-off for individuals between the benefits and costs of group living. One of the main costs of group living is the prevention of reproduction: the dominant breeding pair accounts for around 80% of the offspring born to the group. Dominant females try to weight the reproduction in their own favour, so that they produce as many offspring as possible; subordinate females are commonly expelled from the group by the dominant female in the latter half of her pregnancy to prevent infanticide by subordinates. Subordinate females are also evolutionarily driven to reproduce, in spite of attempts by the dominant female to prevent this from happening. Similarly, subordinate males try to find receptive females from neighbouring groups and thus enhance their reproductive success.

The exact nature of these within- and between-group conflicts and resolutions is a subject of continuing research. Currently, scientists are looking at the way in which different hormones such as oxytocin (the 'trust' hormone) affect social behaviour and conflicts within the group. Others are examining the influence of an individual meerkat's personality on its behaviour and decisions.

increase or decrease in cortisol levels – by introducing the hormone into the animal's system or blocking it through the introduction of another molecule – changes meerkats' behaviour.

But why do we devote so much time to elucidating meerkat behaviour? Studying specific behaviours such as guarding is like fitting a single piece of puzzle into the larger picture of the evolution of social behaviour. Eventually we would like to understand how, why and when co-

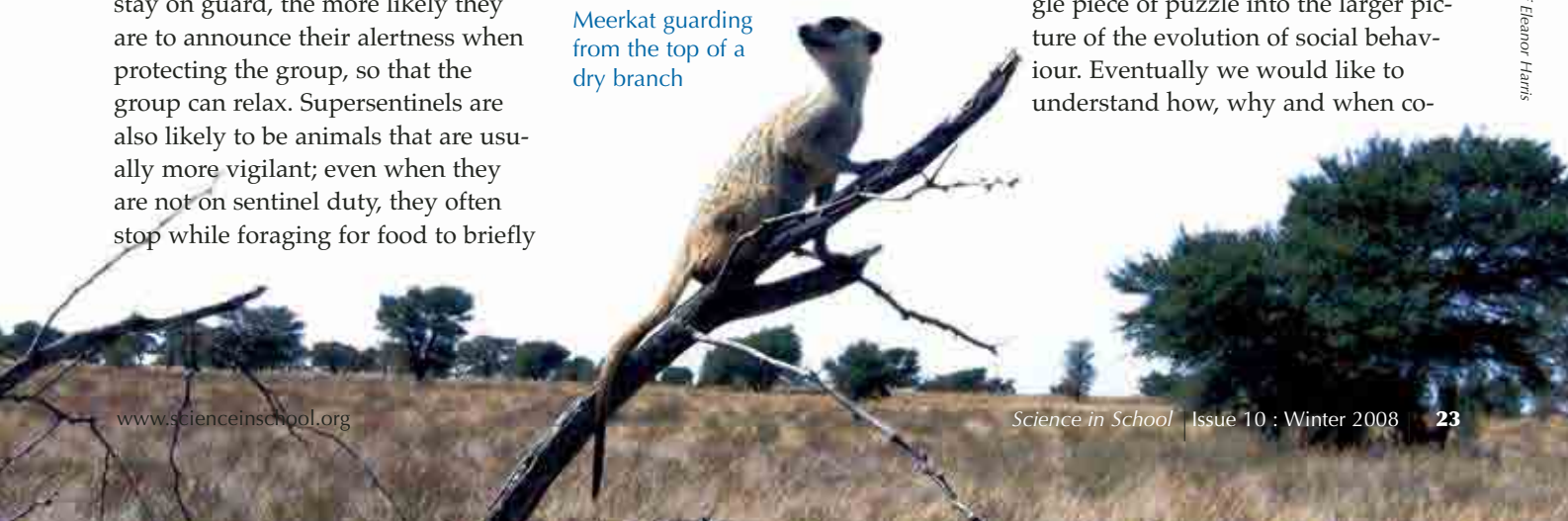


Image courtesy of Eleanor Harris



Meerkats emerging from a bolthole after a predator alarm

operation evolved in animals and in our own species. We would like to know why we are so different from other animals. We would like to probe deeper into the evolution of life on our planet and to satisfy our thirsty curiosity. "Why?" It's the question that drives science.

Meerkats are an excellent model system to test hypotheses arising from the theory of evolution. One of the biggest unsolved problems in evo-

lutionary biology is the existence of altruistic behaviours in humans and animals. Darwin's theory of natural selection argues for the survival of the fittest through competition for limited resources (food, mates, space). Yet, we find animals such as meerkats cooperating happily; they baby-sit and feed (even lactate for) other meerkat's pups, dig burrows together and guard the whole group from predator attacks. How can Darwin's theory explain the observed harmonious lives of meerkats?

After 15 years of detailed study of meerkats, Professor Tim Clutton-Brock^{w3} of Cambridge University and his colleagues say that meerkats are not that altruistic after all. There is a lot of selfish behaviour going on. A classic example, published in the journal *Science*, is the finding that meerkat sentinels guard from safe sites, and only once their bellies are full (Clutton-Brock et al, 1999). Moreover, being the first to spot predators means that in most cases they are the first to escape them too. This suggests that direct, selfish benefits are the

main causes of the evolution of this social, apparently altruistic behaviour. However, we still don't know exactly why meerkats guard and why some are just so super at it. The current hypothesis is that good foragers – meerkats that are the most efficient at capturing prey – are also the best sentinels, because they spend less time foraging and thus have more time and energy to spend on other activities. But the evidence is still too scarce to support this. My research might help elucidate some of the answers to these questions. I just hope they're not doing it only for the cameras!

References

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Web references

w1 – For more information about the Kalahari Meerkat Project see: www.kalahari-meerkats.com



Meerkats sunning themselves

Image courtesy of Eleanor Harris



Mobbing a snake:
Mobbing is used to gather information about a threat and to chase off potential predators

w2 – To watch a video clip of meerkat sentinels on the Discovery Channel website, see:

<http://animal.discovery.com/fansites/meerkat/video/video.html>
(note that you may have to watch an advertisement before the video clip appears)

w3 – For more information about the work of Tim Clutton-Brock's research group, see:

www.zoo.cam.ac.uk/zoostaff/larg/Pages/

Resources

For more information about meerkats, see:

The Fellow Earthlings' Wildlife Center, which specialises in caring for meerkats:

www.fellowearthlings.org

The East Coast Meerkat Society:

www.meerkatsrule.org

Mico Tatalovic is studying for a master's degree (MPhil) in the Department of Zoology at the University of Cambridge, UK. Originally from Croatia, he was awarded a scholarship, first to study at the University of Oxford, UK, and then at Cambridge.



REVIEW

This article provides some basic information about meerkats and addresses various aspects of their social behaviour, with an emphasis on the sentinels. The article is interesting, sometimes even humorous, just like the animals it talks about. It makes good material for discussions/debates on issues such as the evolution of co-operation in animals and in humans, and how animal and human altruism compare and contrast. The issue of social behaviour also creates the opportunity for interdisciplinary studies.

The article could give rise to many comprehension questions, including:

1. Why do researchers consider meerkats to be excellent model species for studying behavioural biology and ecology?

2. What are the benefits and the costs of group living for meerkats?
3. Why does Professor Tim Clutton-Brock say that meerkats are not altruistic?
4. Which main co-operative behaviours do adult meerkats contribute to?
5. How does the height of the sentinel's post vary according to the environmental conditions present at the time?
6. Why are meerkats considered an excellent study system to test hypotheses arising from the theory of evolution?

Michalis Hadjimarcou, Cyprus

The LHC: a step closer to the Big Bang

On 10 September 2008 at 10:28 am, the world's largest particle accelerator – the Large Hadron Collider – was switched on. But why? In the first of two articles, **Rolf Landua** from CERN and **Marlene Rau** from EMBL investigate the big unresolved questions of particle physics and what the LHC can tell us about the early Universe, starting 10^{-12} seconds after the Big Bang.

Image courtesy of CERN



Technicians inspect the first magnets in the LHC tunnel

When the Universe was formed 13700 million years ago in the Big Bang, an immense concentration of energy was transformed into matter within less than a billionth of a second. The temperatures, densities and energies involved were extremely high. According to Einstein's law $E=mc^2$, to create a matter particle of a certain mass (m), you need a corresponding amount of energy (E), with the speed of light (c) defining the exchange rate of the transformation. So the high energies shortly after the Big Bang could have created particles of very large mass. Physicists have proposed these hypothetical heavy particles to explain open questions about the creation and composition of our Universe.

To investigate these theories, scientists have built the Large Hadron Collider (LHC). If a type of particle can be created in the LHC, the world's largest particle accelerator, then it is assumed to have existed shortly after the Big Bang. The LHC will collide particles using the highest

kinetic energies that are currently technically possible (these energies correspond to those that are calculated to have existed 10^{-12} seconds after the Big Bang), crashing the particles into each other with close to the speed of light. This should result in new particles of higher mass than any previous experiments have achieved, allowing the physicists to test their ideas. Despite suggestions by the media, however, the energy of collisions in the LHC will be about 10^{75} times lower than in the Big Bang, so fears that a 'Small Bang' could be recreated are unfounded.

The building blocks of matter: the standard model

Since the days of the Greek philosophers, people have wondered what our world is made of. Is it possible to explain the enormous diversity of natural phenomena – rocks, plants, animals (including humans), clouds, thunderstorms, stars, planets and much more – in a simple way? The

The standard model of particle physics

Image courtesy of CERN

The infographic illustrates the Standard Model of Particle Physics, showing the hierarchy from matter to quarks and the forces that govern them.

Matter particles

All ordinary particles belong to this group.

These particles interact just after the Big Bang. Now they are found only in cosmic rays and accelerators.

Force particles

Force particles transmit the four fundamental forces of nature through gravitons, gluons, photons and W/Z bosons.

LEPTONS

Electron Fundamental building block of atoms. It has a charge of -1 .	Electron neutrino Particulate with no electric charge, and possibly no mass. It flows through your body every second.
Muon A heavier version of the electron. It has the same structure of a lepton.	Muon neutrino Created along with muons when cosmic particles strike.
Tau Heavier still. It is extremely unstable. It was discovered in 1975.	Tau neutrino Not yet discovered but believed to exist.

QUARKS

Up Has an intrinsic charge of $2/3$. It is electrically positive. It is the most common quark.	Down Has an electric charge of $1/3$. It is electrically negative. It is the second most common quark.
Charm A heavier version of the up. Discovered in 1974.	Strange A heavier version of the down. Discovered in 1964.
Top Heaviest still.	Bottom Heavier still, but very unstable. It is the heaviest quark. It was discovered in 1975.

Force particles

- Gluons**: Carriers of the strong force between quarks. They are responsible for the explosive release of nuclear energy.
- Photons**: Particles that make up light. They carry the electromagnetic force. Electricity, magnetism and chemistry are all the results of electromagnetic forces.
- Intermediate vector bosons (W and Z)**: Carriers of the weak force. Some forms of radio-activity are the result of the weak force.
- Gravitons**: Carriers of gravity. All the weight we experience is the result of the gravitational force.

Image courtesy of CERN

theories and discoveries of physicists over the past century have given us an answer: everything in the Universe is made from a small number of building blocks called matter particles, governed by four fundamental forces. Our best understanding of how these are related to each other is encapsulated in the standard model of particles and forces (see image). Developed in the early 1970s, it is now a well-tested theory of physics.

Matter particles come in two different types: leptons and quarks. Both are point-like (no bigger than 10^{-19} m, the ten-thousandth part of an atom's diameter). Together, they form a set of twelve particles, divided into three families, each consisting of two leptons and two quarks. The fundamen-



A welder making the very first interconnection between two cryomagnets for the LHC. The 1700 interconnections between superconducting magnets for the whole collider required 123 000 separate welding and assembly operations

tal family, consisting of an up-quark, a down-quark, an electron and a neutrino (the two leptons) is sufficient to explain our visible world. The eight matter particles in the other two families are not stable, and seem to differ from the fundamental family only in their larger mass. While the 2008 Nobel Prize for Physics was awarded for explaining why these other matter particles might exist¹, physicists are still trying to work out why there are exactly eight of them.

Matter particles can ‘communicate’ with each other in up to four different ways, by exchanging different types of messenger particles named bosons (one type for each of the four interactions), which can be imagined as little packets of energy with specific properties. The strength and the range of these four interactions (the fundamental forces) are responsible for the hierarchy of matter.

Three quarks are bound together by the short-range *strong interaction* to form hadrons (particles formed of quarks) – the protons (two up- and one down-quark) and neutrons (one up- and two down-quarks) of the atomic nucleus. Up-quarks have an electric charge of $+2/3$, down-quarks of $-1/3$, which explains the positive charge of protons and the uncharged state of neutrons.

How are the electrons then attracted to the nucleus to form an atom? Since protons have a positive electric charge and electrons a negative electric charge, they attract each other via the long-range *electromagnetic interaction*, forcing the light electrons into an orbital around the heavy nucleus. Several atoms can form molecules, which are the material basis of life.

Since all these particles have a mass, they also attract each other through *gravitation* – but this long-range force, the third type of interaction, is so very weak (about 38 orders of magnitude weaker than electromagnetism) that it only plays a role when many particles pull together.

The combined gravitational attraction of all protons and neutrons of Earth is what keeps you from floating off into space.

Finally, there is the *weak force* (actually stronger than gravity, but the weakest of the other three) – with a very short range – which allows the transformation of one type of quark into another, or of one type of lepton into another. Without these transformations, there would be no beta-decay radioactivity, in which a neutron is converted into a proton, i.e. a down-quark is transformed into an up-quark (for a discussion of beta-decay radioactivity, see Rebusco et al, 2007). Furthermore, the Sun would not shine: stars draw the energy they radiate from the process of fusion (for a further explanation, see Westra, 2006), in which a proton is turned into a neutron by the transformation of an up-quark into a down-quark – in other words, the reverse of beta decay.

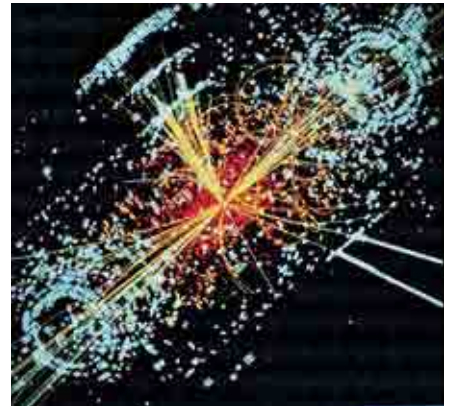
Although the standard model has served physicists well as a means of understanding the fundamental laws of Nature, it does not tell the whole story. A number of questions remain unanswered, and experiments at the LHC will address some of these problems.

A ‘massive’ problem – the Higgs field

One of the open questions is: why do particles (and therefore matter) have mass? If particles had no mass, no structures could exist in the Universe, because everything would consist of individual massless particles moving at the speed of light. However, the mass of particles causes mathematical problems.

In the 1960s, an idea was developed to explain the weak force and the electromagnetic force within the same powerful theory, which described electricity, magnetism, light and some types of radioactivity as all being manifestations of a single underlying

Image courtesy of CERN



This track is an example of simulated data modelled for the CMS detector. Here, a Higgs boson is produced which decays into two jets of hadrons and two electrons. The lines represent the possible paths of particles produced by the proton-proton collision in the detector, while the energy these particles deposit is shown in blue

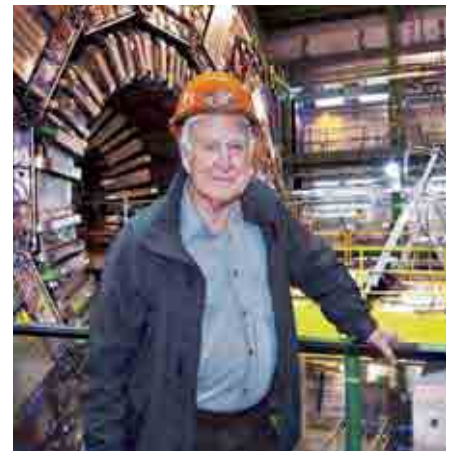


Image courtesy of CERN

Peter Higgs visits the CMS experiment, which may find the elusive Higgs boson

force called, unsurprisingly, the electroweak force. But in order for this unification to work mathematically, it required the force-carrying particles to have a mass. However, it was unclear how to give these particles a mass mathematically. So in 1964, physicists Peter Higgs, Robert Brout and François Englert came up with a possible solution to this conundrum. They suggested that particles

THE HIGGS MECHANISM

IMAGES COURTESY OF CERN

① TO UNDERSTAND THE HIGGS MECHANISM, IMAGINE THAT A ROOM FULL OF PHYSICISTS QUIETLY CHATTERING IS LIKE SPACE FILLED ONLY WITH THE HIGGS FIELD.

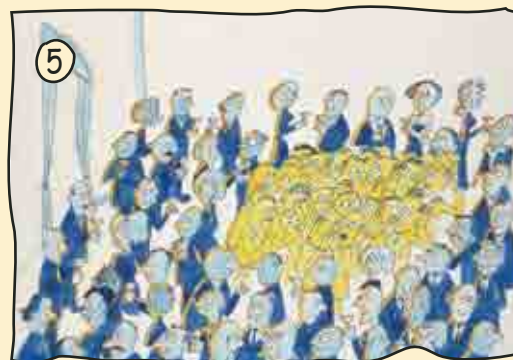


② A WELL KNOWN SCIENTIST, ALBERT EINSTEIN, WALKS IN, CREATING A DISTURBANCE AS HE MOVES ACROSS THE ROOM, AND ATTRACTING A CLUSTER OF ADMIRERS WITH EACH STEP.

③ THIS INCREASES HIS RESISTANCE TO MOVEMENT - IN OTHER WORDS, HE ACQUIRES MASS, JUST LIKE A PARTICLE MOVING THROUGH THE HIGGS FIELD.



IF A RUMOUR CROSSES THE ROOM ...



⑤ IT CREATES THE SAME KIND OF CLUSTERING, BUT THIS TIME AMONG THE SCIENTISTS THEMSELVES. IN THIS ANALOGY, THESE CLUSTERS ARE THE HIGGS PARTICLES.

acquired mass by interaction with an invisible force field called the Higgs field. Its associated messenger particle is known as the Higgs boson. The field prevails throughout the cosmos: any particles that interact with it (this interaction can be imagined as a kind of friction) are given a mass. The more they interact, the heavier they become, whereas particles that never interact with the Higgs field are left with no mass at all (see cartoon).

This idea provided a satisfactory way to combine established theories

with observed phenomena. The problem is that no one has ever detected the elusive boson. The difficulty in finding it (if indeed it exists) is that the theory does not predict its mass, so it has to be searched for by trial and error.

Using high-energy particle collisions, physicists create new particles – and search among them for the Higgs boson. The search has been on for the past 30 years, using higher and higher energies, but the particle is still to be found – presumably the energies used

so far have not been high enough. As it stands, the Higgs particle must have a mass at least 130 times that of the proton. Scientists believe that the energy generated by the LHC – seven times higher than that used in any other collisions so far – should suffice to detect the Higgs boson.

Two of the experiments at the LHC, called ATLAS and CMS, will search for traces from the decay of the Higgs particle, which is believed to be very unstable. Proving its existence would be a great step in particle physics,

since it would complete our understanding of matter. If, however, the Higgs boson is not found, this will mean that it is either even heavier than the LHC can detect, or simply that it does not exist after all. In that case, one of the competing theories that have been proposed may turn out to be true instead. Otherwise, theoretical physicists would be sent back to the drawing board to think of a completely new theory to explain the origin of mass.

The dark side of the Universe

There is another important aspect of particle physics that the standard model cannot explain: recent observations have revealed that everything we 'see' in the Universe (stars, planets, dust) accounts for only a tiny 4% of its total mass and energy (in the form of radiation and vacuum fields, such as the Higgs field). Most of the Universe, however, is made up of invisible substances that do not emit electromagnetic radiation – that is, we cannot detect them directly with telescopes or similar instruments. These substances only interact with 'normal' matter through gravity, not through the other three fundamental forces. We can, therefore, only detect them through their gravitational effects, which makes them very difficult to study. These mysterious substances are known as dark energy and dark matter (as discussed in Warmbein, 2007, and Boffin, 2008).

Recent observations suggest that dark matter makes up about 26% of the Universe. The first hint of its existence came in 1933, when astronomical observations and calculations of gravitational effects revealed that there must be more 'stuff' present in and around galaxies than telescopes could detect. Researchers now believe not only that the gravitational effect of dark matter allows galaxies to spin faster than would be expected from their observable mass, but also that the gravitational field of dark matter

deviates the light from objects behind it (gravitational lensing; for a brief description of gravitational lensing, see Jørgensen, 2006). These effects can be measured, and they can be used to estimate the density of dark matter even though we cannot directly observe it.

Image courtesy of NASA, M. J. Jee and H. Ford (Johns Hopkins University); image source: Wikimedia Commons



Composite image showing a ghostly 'ring' of dark matter in the galaxy cluster Cl 0024+17 (ZwCl 0024+1652). Photograph taken using the Hubble Space Telescope

But what is dark matter? One idea is that it could consist of *supersymmetric particles* – a hypothesised full set of particle partners for each of the twelve particles described in the standard model (see diagram on page 31). The concept of supersymmetry postulates that for each known matter and messenger particle (e.g. the electron and the photon – the messenger particle of the electromagnetic force), there is a supersymmetric partner (in this case, the *s*-electron and the photino). In a supersymmetric world, these would have identical masses and charges to their partners in the standard model, but their internal angular momentum (called spin, measured in units of Planck's constant) would differ by $1/2$ unit. Matter particles

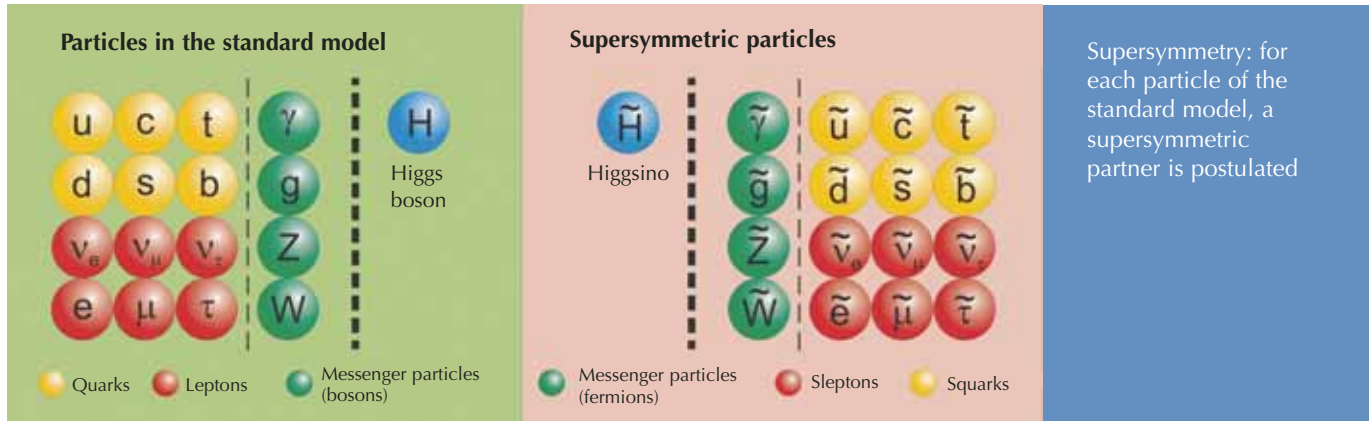
normally have a spin of $1/2$, while messenger particles have a spin of 1. Changing the spin by $1/2$ unit would transform matter particles into messenger particles, and vice versa.

But what does supersymmetry have to do with dark matter? If the theory of supersymmetry is correct, then the

Big Bang should have produced many supersymmetric particles. Most of them would have been unstable and decayed, but the lightest supersymmetric particles could have been stable. And it is these lightest supersymmetric particles which may linger in the Universe and cluster into big spheres of dark matter, which are thought to act as scaffolding for the formation of galaxies and stars inside them.

However, none of those supersymmetric particles have yet been detected – again, perhaps because their masses are so large that they are outside the range of particle accelerators less powerful than the LHC, as with the Higgs boson. So if they existed, even the lightest ones would have to

Image courtesy of CERN



Supersymmetry: for each particle of the standard model, a supersymmetric partner is postulated

be very heavy: rather than having the same mass as their supersymmetric partners (as originally proposed), they would have to have much higher masses. Supersymmetry is also used as a possible explanation for other, more complex puzzles in particle physics. So if any of the LHC experiments can detect and measure the properties of these particles, it would mean a significant advance in our understanding of the Universe.

The lost anti-world?

Now we have heard about matter, dark matter and dark energy – but in the early Universe, there was even more: we have good reasons to believe that a tiny fraction of a second after the Big Bang, the Universe was filled with equal amounts of matter and antimatter. When particles are produced from energy, as in the Big Bang or in high-energy collisions, they are always created together with their antimatter counterparts. As soon as the antimatter particle meets a matter particle, both are annihilated, and the annihilation process transforms their mass back into energy. So, in the Big Bang, both matter and antimatter should have been produced in equal amounts, and then have wiped each other out entirely. Yet, while all the antimatter from the Big Bang disappeared, a small amount of matter was left over at the end of the process: this is what we consist of today. How could this have happened?

Antimatter is like a mirror image of matter. For each particle of matter, an antiparticle exists with the same mass, but with inverted properties: for example, the negatively charged electron has a positively charged antiparticle called the positron. Antimatter was postulated in 1928 by physicist Paul Dirac. He developed a theory that combined quantum mechanics and Einstein’s theory of special relativity to describe interactions of electrons moving at velocities close to the speed of light. The basic equation he derived turned out to have two solutions, one for the electron and one that described a particle with the same mass but with positive charge (what we now know to be the positron). In 1932, the evidence was found to prove these ideas correct, when the positron was discovered to occur naturally in cosmic rays. These rays collide at high energy with particles in the Earth’s atmosphere: in these collisions, positrons and anti-protons are generated even today.

For the past 50 years and more, laboratories like CERN have routinely produced antiparticles in collisions and studied them, demonstrating to very high precision that their static properties (mass, charge and magnetic moment) are indeed similar to those of their matter particle counterparts. In 1995, CERN became the first laboratory to artificially create entire anti-atoms from anti-protons and positrons.

If the amounts of matter and antimatter were originally equal, why did they not annihilate each other entirely, leaving nothing but radiation? The fact that matter survived while antimatter vanished suggests that an imbalance occurred early on, leaving a tiny fraction more matter than antimatter. It is this residue from which stars and galaxies – and we – are made. Physicists today wonder how this imbalance could have arisen.

One of the LHC experiments (LHCb) seeks a better understanding of the disappearance of antimatter by studying the decay rates of b quarks – which belong to the third quark family (see the diagram of the standard model on page 27) – and comparing them with those of anti-b quarks. It is already known that their decay rates are different, but more detailed measurements are expected to give valuable insights into the precise mechanisms behind this imbalance.

The primary soup

To answer all the above questions, physicists will collide protons in the LHC. However, for part of the year, beams of lead ions will be accelerated and collided instead, and the products of these collisions will be analysed by ALICE, the fourth large experiment in the LHC (besides ATLAS, CMS and LHCb).

About 10^{-5} seconds after the Big Bang, at a ‘later’ phase of the Universe, when it had cooled down

to a 'mere' 2000 billion degrees, the quarks became joined together into protons and neutrons that later formed atomic nuclei (see the image of the History of the Universe). And there the quarks remain, stuck together by gluons, the messenger particles of the strong force (see the diagram of the standard model on page 27). Due to the fact that the strength of the strong force between quarks and gluons increases with distance, in contrast to that of other forces, experi-

ments have not been able to prise individual quarks or gluons out of protons, neutrons or other composite particles, such as mesons. Physicists say that the quarks and gluons are *confined* within these composite particles.

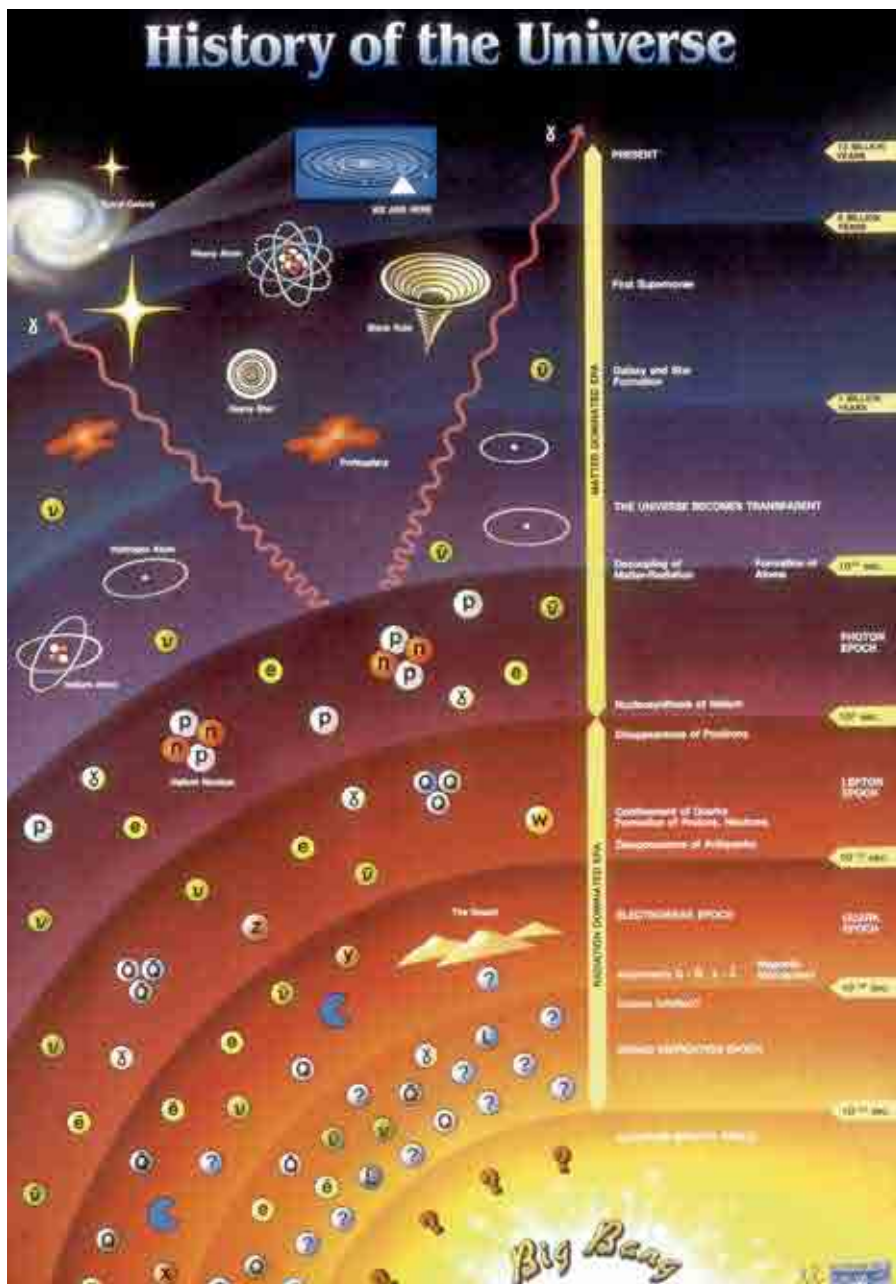
Suppose, however, that it *were* possible to reverse this process of confinement. The standard model predicts that at very high temperatures combined with very high densities, quarks and gluons would exist freely in a new state of matter known as

quark-gluon plasma, a hot, dense 'soup' of quarks and gluons. Such a transition should occur when the temperature exceeds around 2000 billion degrees – about 100 000 times hotter than the core of the Sun. For a few millionths of a second, about 10^{-6} s after the Big Bang, the temperature and density of the Universe were indeed high enough for the entire Universe to have been in a state of quark-gluon plasma. The ALICE experiment will recreate these conditions within the volume of an atomic nucleus, and analyse the resulting traces in detail to test the existence of the plasma and study its characteristics.

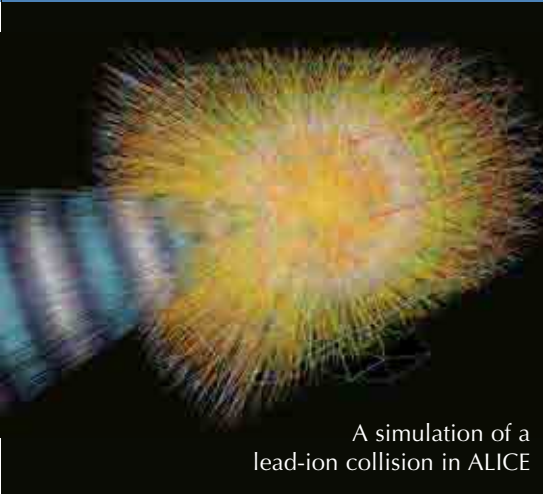
In the second article (Landua, 2008), Rolf Landua introduces the LHC technology and the four large experiments, ATLAS, CMS, LHCb and ALICE.

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The stages of development of the Universe from the Big Bang to the present day



A simulation of a lead-ion collision in ALICE

Image courtesy of CERN

www.scienceinschool.org/2006/issue3/fusion

Web references

w1 – The 2008 Nobel Prize in Physics was awarded jointly to Yoichiro Nambu ‘for the discovery of the mechanism of spontaneous broken symmetry in sub-atomic physics’ and to Makoto Kobayashi and Toshihide Maskawa ‘for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature’. For more details of their work, see:
http://nobelprize.org/nobel_prizes/physics/laureates/2008/press.html

Resources

A much more detailed account of the standard model and the LHC experiments can be found in Rolf Landua’s German-language book:
 Landua R (2008) *Am Rand der Dimensionen*. Frankfurt, Germany: Suhrkamp Verlag

The NASA website has a good description of the Big Bang theory:
http://map.gsfc.nasa.gov/universe/bb_theory.html

The Particle Adventure website provides teaching activities, including a good explanation of the standard model:
<http://particleadventure.org>

To find out more about the Higgs boson, see:
 The Heart of the Matter: Inside CERN:

www.exploratorium.edu/origins/cern/ideas/higgs.html

National Geographic’s interactive pages on the Higgs boson:
<http://ngm.nationalgeographic.com/2008/03/god-particle/particle-interactive.html>

The National Geographic corresponding article:
<http://ngm.nationalgeographic.com/2008/03/god-particle/achenbach-text>

To learn more about antimatter, see:

The Live from CERN website, which explains what antimatter is, where it is made, and how it is already part of our lives:
<http://livefromcern.web.cern.ch/livefromcern/antimatter>

The CERN website, with information on *Angels and Demons* and scientific background material on antimatter:
<http://public.web.cern.ch/Public/en/Spotlight/SpotlightAandD-en.html>

The official website of the *Angels and Demons* film:
<http://www.angelsanddemons.com>

A portal to the top ten antimatter websites: www.anti-matter.org

An online video by BBC/OU/VEGA explaining antimatter:
www.vega.org.uk/video/programme/14

For an introduction to supersymmetry, see:
http://hitoshi.berkeley.edu/public_html/susy/susy.html

To find out more about dark matter and dark energy, see:

A media package for teaching dark matter provided by the Perimeter Institute for Theoretical Physics:
http://www.perimeterinstitute.ca/Perimeter_Explorations/The_Mystery_of_Dark_Matter/The_Mystery_of_Dark_Matter

A video about evidence for dark matter, revealed by the Hubble

Space Telescope, on the Space.com website:

www.space.com/common/media/video.php?videoRef=150407Dark_matter

A video describing physicist Patricia Burchat’s search for dark matter and dark energy:
www.ted.com/index.php/talks/patricia_burchat_leads_a_search_for_dark_energy.html

An article explaining dark energy on the *Physics World* website:
<http://physicsworld.com/cws/article/print/19419>

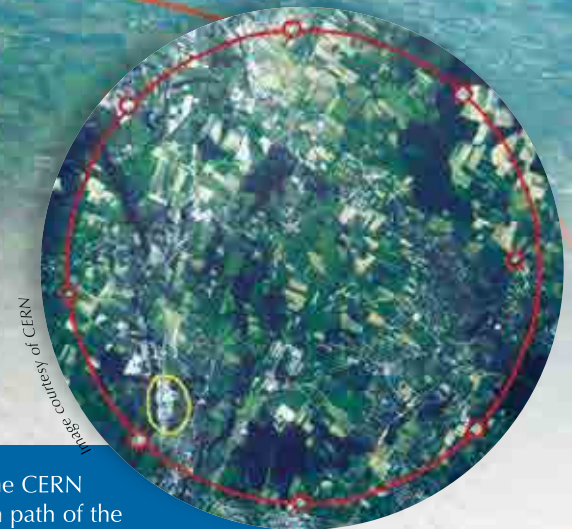
For information on the quark-gluon plasma, including a comic (available in English, French, Italian and Spanish) on the soup of quarks and gluons, see the children’s corner of the ALICE experiment website:
<http://aliceinfo.cern.ch/Public/Welcome.html>

Rolf Landua is the Head of Education at CERN, where he has been working since 1980. A German particle physicist, he is the co-initiator of the Antimatter Factory at CERN and led the ATHENA project that created millions of anti-hydrogen atoms in 2002. He is secretly famous as the model for the character of Leonardo Vetra, an antimatter physicist from CERN who is murdered in the first pages of Dan Brown’s bestseller *Angels and Demons*, which is being turned into a Hollywood film due for release in May 2009. He runs courses at CERN for physics teachers from across Europe, is a regular interview partner on radio and TV and has recently released a German-language book on CERN particle physics (*Am Rand der Dimensionen, On the Border of the Dimensions*, see resources). For his commitment to fostering science education in schools, he received the 2003 European Physical Society’s communication award.



The LHC: a look inside

In the second of two articles, **Rolf Landua** from CERN takes us deep below the ground to visit the largest scientific endeavour on Earth – the Large Hadron Collider and its experiments.

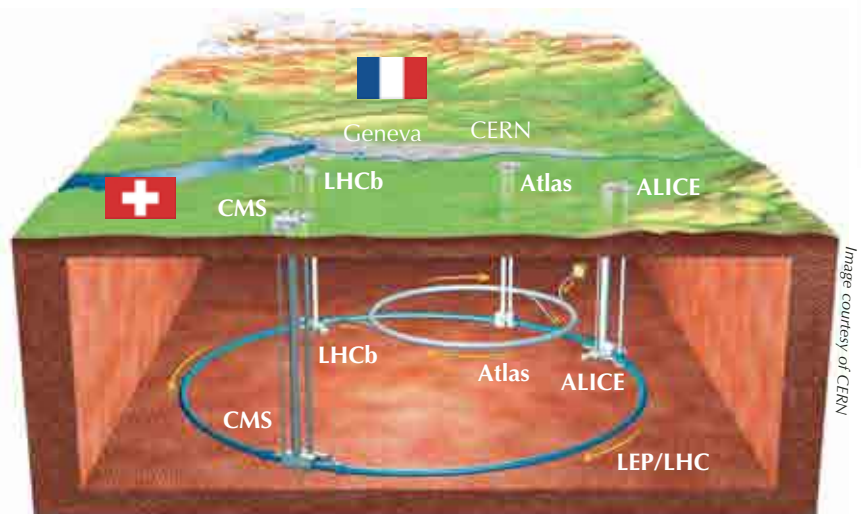


This aerial view of the CERN site shows the 27 km path of the tunnel that houses the LHC. The ring stretches from Geneva airport, which can be seen on the lower left (in yellow), to the French countryside

The accelerator

The Large Hadron Collider^{w1} (LHC) at the European Organization for Nuclear Research (CERN) is a gigantic scientific instrument spanning the Swiss-French border near Geneva, Switzerland. The world's largest and most powerful particle accelerator, it is used by almost 10 000 physicists from more than 80 countries to search for particles to unravel the chain of events that shaped our Universe a fraction of a second after the Big Bang. It could resolve puzzles ranging from the properties of the smallest particles to the biggest structures in the vastness of the Universe.

The design and construction of the LHC took about 20 years at a total cost of €3.6 billion. It is housed in a 27 km long and 3.8 m wide tunnel



The LHC experiments

about 100 m underground. At this level, there is a geologically stable stratum, and the depth prevents any radiation from escaping. Until 2000, the tunnel was the home of the Large Electron-Positron (LEP) storage ring, which was built in 1989. This earlier accelerator collided electrons with their anti-particles, positrons (for an explanation of antimatter, see Landua & Rau, 2008), to study the properties of the resulting particles and their interactions with great precision.

There are eight elevators leading down into the tunnel, and although

many years. The LHC will mainly perform proton-proton collisions, which will be studied by three of its four detectors (ATLAS, CMS, and LHCb). However, for several weeks per year, heavy ions (lead nuclei) will be accelerated and collided instead, to be studied mainly by the dedicated ALICE detector.

Like any other particle accelerator, the LHC has three main components: the beam pipes, the accelerating structures, and the magnet system (see diagram on page 36). Inside its two beam pipes, each 6.3 cm in diameter, proton

The second part of an accelerator consists of its accelerating structures. Before protons (or heavy ions) are introduced into the two LHC beam pipes, they are accelerated in smaller accelerators (connected to the LHC) to about 6 % of their final energy. Inside the LHC, the particles acquire their final energy from eight accelerating structures (accelerator cavities).

Every time the particles run through these cavities, they are accelerated by a strong electric field of about 5 MV/m. The functionality of the accelerators is comparable to surf

While the LHC was being built, technicians used various means of transport to move around the 27 km tunnel. Alongside the technician, two LHC magnets can be seen, before they were connected together. The blue cylinders contain the magnetic yoke and coil of the dipole magnets, together with the liquid helium system required to cool the magnet so that it becomes superconducting

Image courtesy of CERN



the ride is only one stop, it takes a whole minute. To move between the eight access points, maintenance and security people use bicycles to move around the tunnel – sometimes for several kilometres. The LHC is automatically operated from a central control centre, so once the experiments have started, engineers and technicians will only have to access the tunnel for maintenance.

The actual experiment is a rather simple process: the LHC will collide two hadrons – either protons or lead nuclei – at close to the speed of light. The very high levels of energy involved will allow the kinetic energy of the colliding particles to be transformed into matter, according to Einstein's law $E=mc^2$, and all matter particles created in the collision will be detected and measured. This experiment will be repeated up to 600 million times per second, for

(or heavy ion) beams travel in opposite directions (one direction in each pipe) in an ultra-high vacuum of 10^{-13} bar, comparable to the density of matter in outer space. This low pressure is necessary to minimise the number of collisions with resting gas molecules and the subsequent loss of the accelerated particles.

The protons are supplied from a hydrogen gas bottle. Hydrogen atoms consist of a proton and an electron. Scientists remove the electrons using an electric discharge, after which the protons are guided towards the accelerator through electric and magnetic fields. For the LHC beam, 300 trillion protons are required, but since a single cubic centimetre of hydrogen gas at room temperature contains about 60 million trillion protons, the LHC can be refilled 200 000 times with just one cubic centimetre of gas – and it only needs refilling twice a day!

on the sea (see diagram on page 37): a bunch of protons, about 100 billion of them – the surfers – ride together on an enormous electromagnetic wave and gain kinetic energy. Each wave accelerates one bunch of protons, and each of the two beams consists of 2800 discrete bunches, one every seven metres. After 20 minutes, they reach their final energy, while doing 11 245 circuits of the LHC ring per second. In those 20 minutes, the protons cover a distance further than from Earth to the Sun and back.

They enter the LHC at 99.9997828 % of the speed of light. After acceleration, they reach 99.9999991 %. This is about the maximum speed that can be reached, since nothing can move faster than light, according to the theory of relativity. Although it might seem like an insignificant gain in speed, at close to the speed of light, even a small acceleration results in a

The principle of a particle accelerator with its three main components: the beam pipes, the acceleration elements, and the bending magnets

Image courtesy of DESY

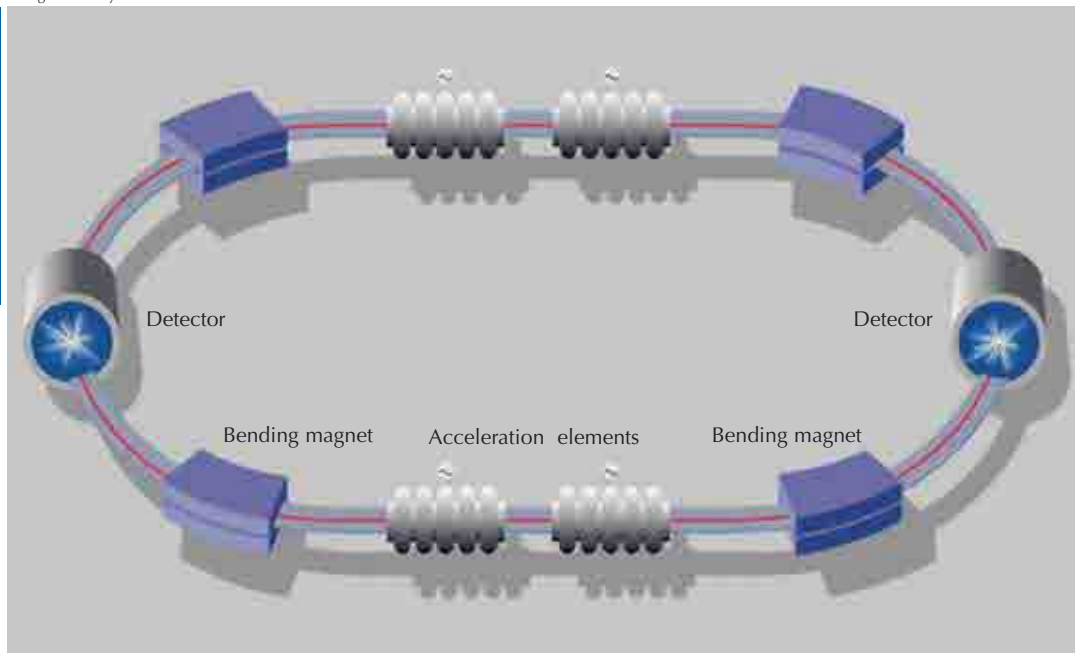


Image courtesy of CERN



Cross-section of LHC prototype beam pipes showing the beam screens. Slits in the screens allow residual gas molecules to be pumped out and frozen to the walls of the ultra-cold beam pipe. Beam screens like these have been designed to line the beam pipes, absorbing radiation before it can hit the magnets and warm them up, an effect that would greatly reduce the magnetic field and cause serious damage

large gain in mass, and this is the important part. A motionless proton has a mass of 0.938 GeV (million electron volts). The accelerators bring them to a final mass (or energy, which in this case is practically the same thing) of 7000 billion electron volts (7 tera-eV or 7 TeV). If you could – hypothetically – accelerate a person of 100 kg in the LHC, his or her mass would end up being 700 t.

Without external forces, the protons would fly in a straight line. To give them a circular trajectory, the pipes are surrounded by a large magnet system that deflects the protons' path – these magnets are the third part of every particle accelerator. The larger the mass of a particle becomes, the stronger the magnets need to be to keep it on track. This is where the limitations of a particle accelerator lie, since at a certain magnetic energy, the material of the magnetic coils cannot resist the forces of its own magnetic field anymore. The magnets used in the LHC have been specially designed: the dominant part of the magnet system consists of 1232 dipole magnets, each with a length of about 16 m and a weight of 35 t, which cre-

ate a maximum magnetic field of 8.33 tesla – 150 000 stronger than Earth's magnetic field.

The magnets have a special two-in-one design: they contain two magnet coils on the inside, each surrounding one of the two beam pipes. The current runs through the coils to create two magnetic fields, pointing down-

LHC superconducting accelerator cavity in the LHC tunnel



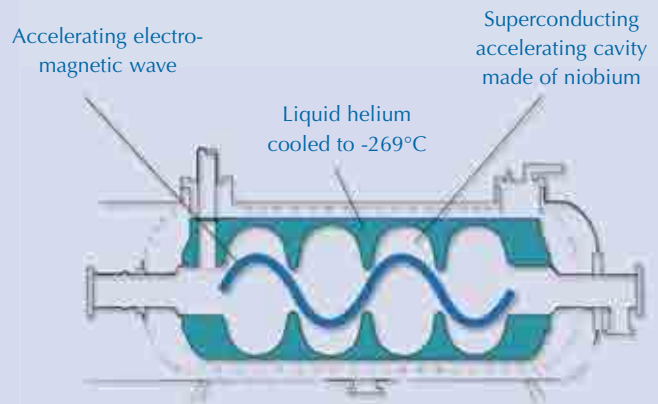
Image courtesy of CERN

The superconducting accelerating cavity acts like the surf of the sea



Image courtesy of CERN

The use of superconductivity to increase performance and considerably reduce electricity consumption



wards in one pipe and upwards in the other. This is how two particles (protons or lead nuclei) of the same charge can follow the same track in opposite directions – one in each beam pipe.

In addition to the dipole magnets, there are quadrupole magnets (with four magnetic poles) for focusing the beams, and thousands of additional smaller sextupole and octupole magnets (with six or eight magnetic poles each, respectively) for correcting the beam size and position.

All magnet coils and the accelerator cavities are built from special materials (niobium and titanium) that become superconducting at very low temperatures, conducting electricity to produce the electric and magnetic fields without resistance. To reach their maximum performance, the magnets need to be chilled to -271.3°C (1.9K) – a temperature colder than outer space. To cool the magnets, much of the accelerator is connected to a distribution system of liquid nitrogen and helium (see box on page 45). Just one-eighth of the LHC's cryogenic distribution system would qualify as the world's largest fridge.

Around the ring are four points at which the chain of magnets is broken: they contain the four huge caverns for the LHC experiments and their detec-

tors. Here, the trajectories of the inner and outer beams are made to cross each other and swap places in special X-shaped beam pipes. In all four

The 15-m long LHC cryodipole

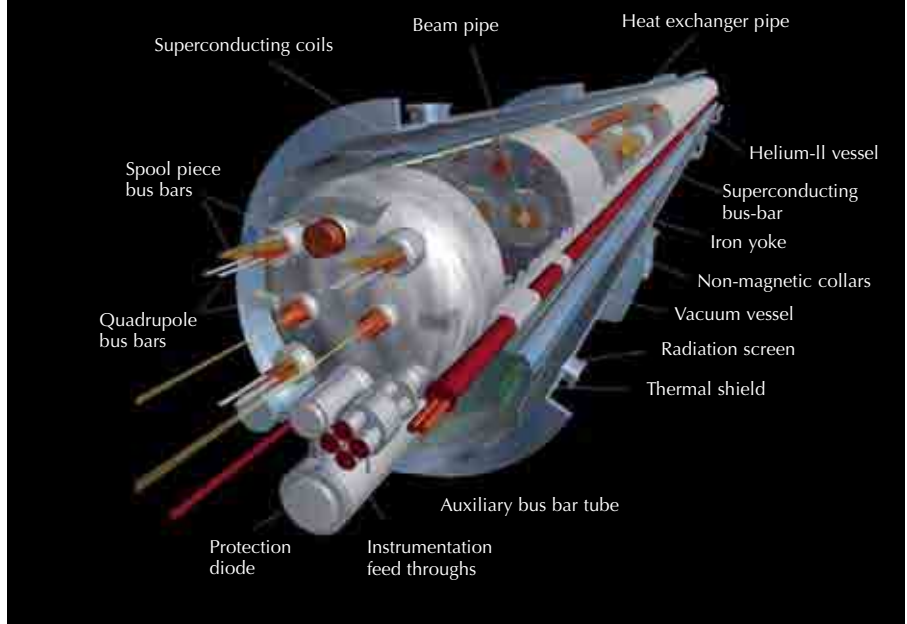


Image courtesy of CERN

This computer-generated image of an LHC dipole magnet shows some of the parts vital for the operation of these components. The magnets must be cooled to 1.9 K so that the superconducting coils can produce the required 8 T magnetic field

X-shaped pipes, the beams cross at an angle of 1.5 degrees, allowing the beams to be brought into collision.

Huge detectors – described below – surround the collision points. To increase the probability of particle collisions, the bunches of particles are squeezed, by special magnets just in front of each collision chamber, to a diameter of $16\ \mu\text{m}$ – thinner than a human hair – and 80 mm in length. The beams are so tiny that the task of making them collide is akin to firing needles from two positions 10 km apart with such precision that they

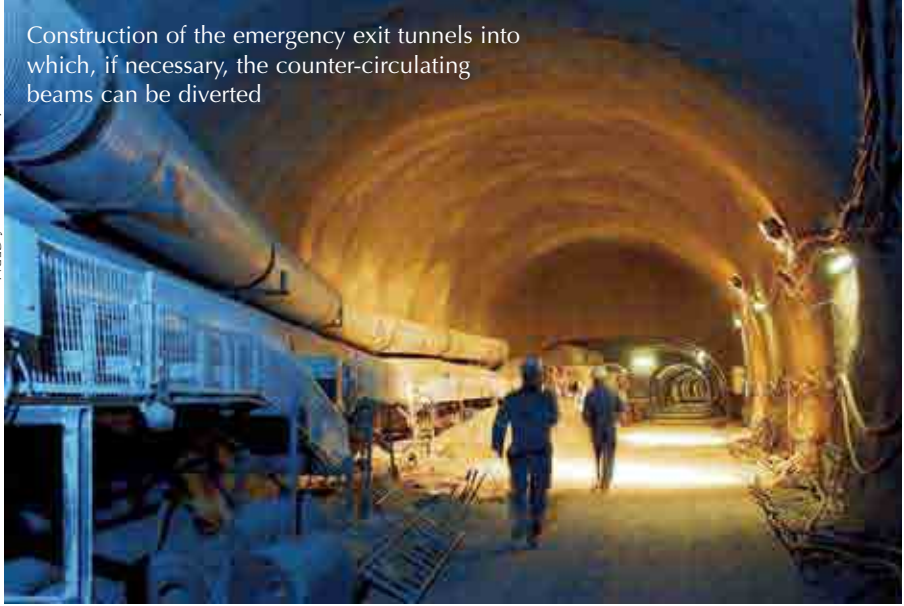
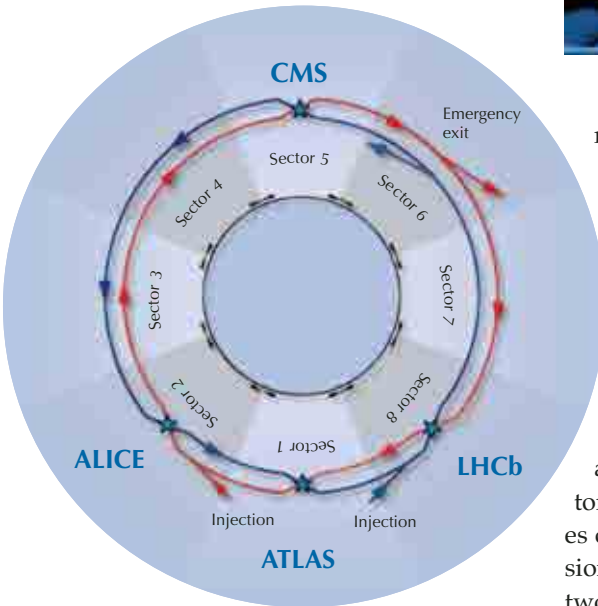


Image courtesy of CERN

Construction of the emergency exit tunnels into which, if necessary, the counter-circulating beams can be diverted



meet halfway! However, the LHC technology manages this intricate task. Nonetheless, even in these focused beams of particles, the density is still very low – 100 million times lower than that of water – so most of the particles pass straight through the other bunch of particles without colliding or even slowing down. Thus, although there are 100 billion protons in each bunch, when two bunches collide, only about 20 particle collisions occur. Since collisions between two bunches occur 31 million times per second (2800 bunches \times 11 245 turns of the LHC ring per second), this still gives about 600 million proton collisions per second when the LHC is operating at maximum intensity.

ring (i.e. in less than a thousandth of a second) the beam will be deflected into a kind of emergency exit, where it is absorbed by graphite plates and concrete before it can cause any further damage (see image above and diagram on the left).

The cold boxes are major components of the LHC cryogenic system. This photo shows the top of the first cold boxes to be delivered to CERN



Image courtesy of CERN



Image courtesy of John O'Neill; image source: Wikimedia Commons

Sextupole magnets are used for correcting the beam size and position

A single bunch of protons travelling at full speed has the same kinetic energy as a one-tonne elephant running at 50 km/h, and the entire energy contained in the beam is 315 megajoules (MJ), enough to melt nearly 500 kg of copper. Therefore, considerable efforts have gone into the security of the LHC. Should the beam become unstable, this will be immediately detected by the beam sensors, and within the next three laps around the



Who works on the LHC?

Liz Gregson from Imperial College London, UK, talks to some of the CERN employees.

Katharine Leney, ATLAS physicist

Katharine is doing a PhD in physics on the search for the Higgs boson, working on the ATLAS detector. She is also developing a tool to look at conditions within the detector, to ensure that the data obtained will be usable.

"It's a really exciting time to be here, working alongside some of the world's top physicists." In addition to her research, she has recently become a CERN guide, showing visitors the experiments and explaining the work that scientists do there.

Dr Marco Cattaneo, project co-ordination

Marco was born in Italy and moved to the UK at the age of ten. Today he lives in France, works in Switzerland, and has a Swiss-British wife and two children who can speak three languages fluently. "When

asked what I am, I can only answer European!" he says. He has been at CERN since 1994. He is deputy project leader on the

software and computing project for the LHCb experiment. His main job is to co-ordinate the work of around 50 physicists who develop software that enables reconstructions of the original trajectories of the particle collisions recorded by the detector. This is then integrated into a single reconstruction programme, so that others can study the characteristics of the collision event. Marco enjoys the work atmosphere at CERN: "It attracts about 50 percent of the world's particle physics community, meaning that the vast majority of people working at CERN are highly skilled in their field and very motivated by their work. It is not unusual to be on first-name terms with Nobel laureates."

This text was first published in the Imperial College London alumni magazine Imperial Matters.



Dr Marco Cattaneo

Image courtesy of Marco Cattaneo

Image courtesy of Mike Flowerdew

Katharine Leney

BACKGROUND

The experiments

The LHC will collide two protons at a total kinetic energy of $7 + 7 = 14$ TeV (or two lead ions at a total energy of 1140 TeV), and then detect and measure the new particles produced when the kinetic energy is transformed into matter.

According to quantum physics, these collisions will generate all particles of the standard model (as described in Landua & Rau, 2008) with certain probabilities. However, the probability of generating the heavy particles that scientists are actually looking for is very low. Few

of the particle collisions will be hard enough to produce new, heavy particles. Theory predicts that Higgs bosons (to learn more about the Higgs boson, see Landua & Rau, 2008) or other completely new phenomena that are being searched for will be produced only very rarely (typically once in 10^{12} collisions), so it is necessary to study many collisions in order to find the 'needle in a million haystacks'. That is why the LHC will be run for many years, 24 hours a day.

The events (an event is a collision with all its resulting particles) are

studied using giant detectors that are able to reconstruct what happened during the collisions – and to keep up with the enormous collision rates. Detectors can be compared to huge three-dimensional digital cameras that can take up to 40 million snapshots (with digitised information from tens of millions of sensors) per second. The detectors are built in layers, and each layer has a different functionality (see diagram on page 40). The inner ones are the least dense, while the outer ones are denser and more compact.

The heavy particles that scientists hope to produce in the LHC collisions are predicted to be very short-lived, rapidly decaying into lighter, known particles. After a hard collision, hundreds of these lighter particles, for example electrons, muons and photons, but also protons, neutrons and others, fly through the detector at close to the speed of light. Detectors use these lighter particles to deduce the brief existence of the new, heavy ones.

The trajectories of charged particle are bent by magnetic fields, and their radius of curvature is used to calculate their momentum: the higher the kinetic energy, the shallower the curvature. For particles with high kinetic energy, therefore, a sufficiently long trajectory must be measured in order to accurately determine the curvature radius. Other important parts of a detector are calorimeters for measuring the energy of particles (both charged and uncharged). The calorimeters too have to be large enough to absorb as much particle energy as possible. These are the two principle reasons why the LHC detectors are so large.

The detectors are built to hermetically enclose the interaction region in order to account for the total energy and momentum balance of each event and to reconstruct it in detail. Combining the information from the different layers of the detector, it is possible to determine the type of particle which has left each trace.

Charged particles – electrons, protons and muons – leave traces through ionisation. Electrons are very light and therefore lose their energy quickly, while protons penetrate further through the layers of the detector. Photons themselves leave no trace, but in the calorimeters, each photon converts into one electron and one positron, the energies of which are then measured. The energy of neutrons is measured indirectly: neutrons transfer their energy to protons, and these protons are then detected.

Muons are the only particles that reach (and are detected by) the outermost layers of the detector (see diagram below).

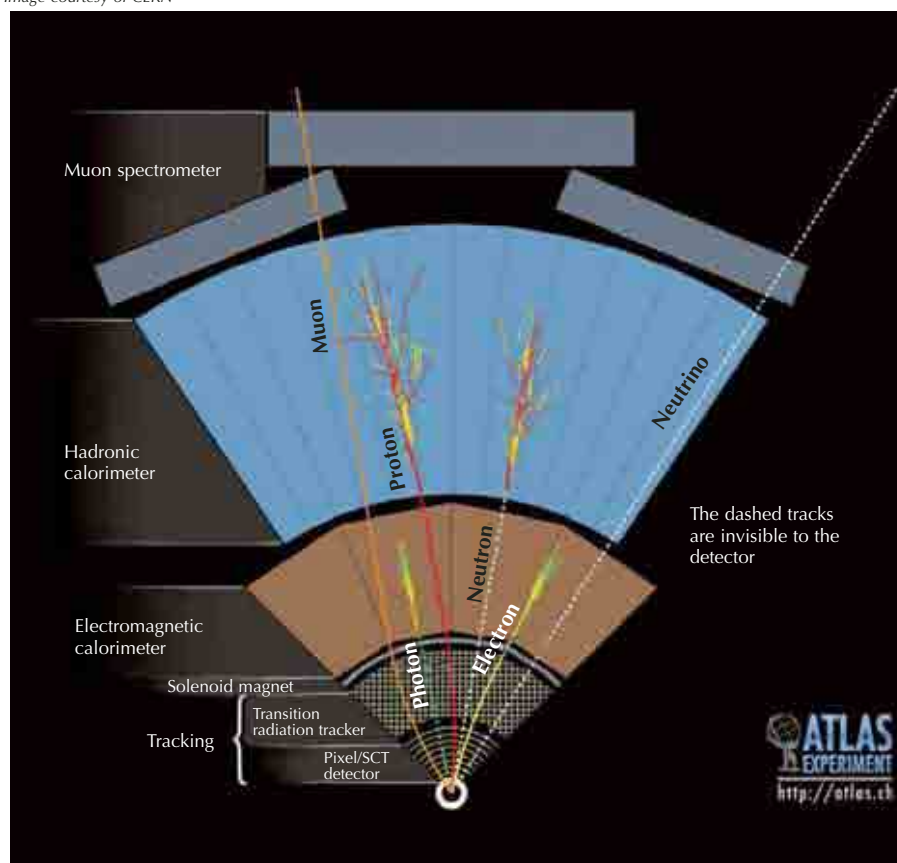
Each part of a detector is connected to an electronic readout system via thousands of cables. As soon as an impulse is registered, the system records the exact place and time and sends the information to a computer. Several hundred computers work together to combine the information. At the top of the computer hierarchy is a very fast system which decides – in a split second – whether an event is interesting or not. There are many different criteria to select potentially significant events, which is how the enormous data of 600 million events per second that are investigated in detail.

The LHC detectors were designed, constructed and commissioned by

international collaborations, bringing together scientists from institutes all over the world. In total, there are four large (ATLAS, CMS, LHCb and ALICE) and two small (TOTEM, LHCf) experiments at the LHC. Considering that it took 20 years to plan and construct the detectors, and they are intended to run for more than 10 years, the total duration of the experiments is almost equivalent to the entire career of a physicist.

The construction of these detectors is the result of what could be called a ‘group intelligence’: while the scientists working on a detector understand the function of the apparatus in general, no one scientist is familiar with the details and precise function of each single part. In such a collaboration, every scientist contributes with his or her expertise to the overall success.

Image courtesy of CERN



A computer-generated image of the ATLAS detector, showing the different layers and the passage of different particle types through the layers

Image courtesy of CERN



The control centre of the accelerators, the cryogenic distribution system and the technical infrastructure on the CERN site

(see diagram on page 34). Having two independently designed detectors is vital for cross-confirmation of any new discoveries. The ATLAS and the CMS collaborations each consist of more than 2000 physicists from 35 countries.

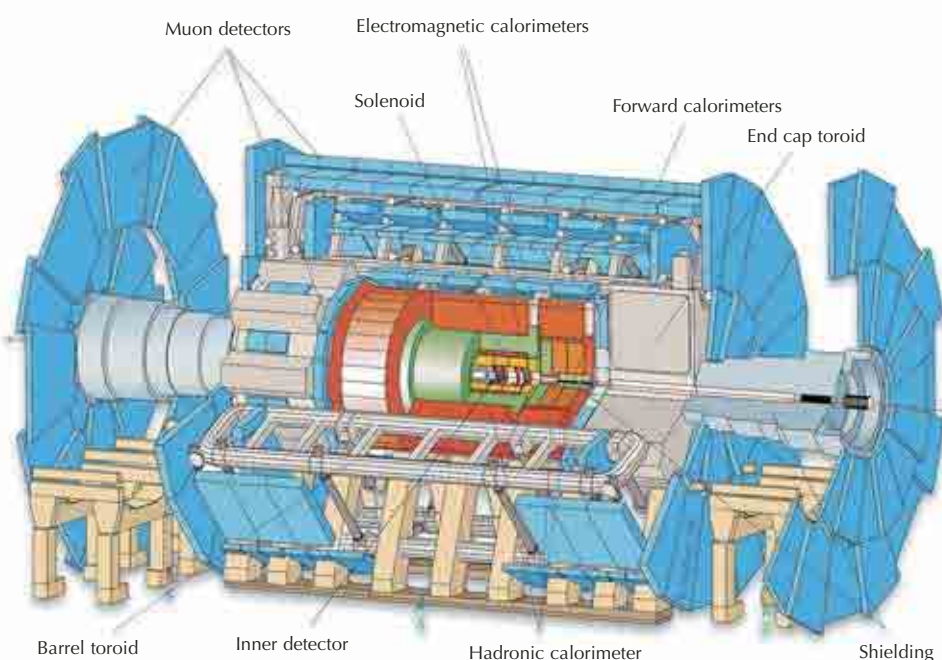
The ATLAS detector has the shape of a cylinder 25 m in diameter and 45 m in length, about half as big as Notre Dame Cathedral in Paris, France, and weighing the same as the Eiffel Tower (7000 t). Its magnetic field is produced by a solenoid in the inner part and an enormous doughnut-shaped toroid magnet further outside (see diagram below).

The CMS detector also has a cylindrical shape (15m in diameter and 21m in length) and is built around a superconducting solenoid magnet generating a field of 4 tesla, which is confined by a steel yoke that forms the bulk of the detector's weight of 12 500 t. While ATLAS was constructed in situ, the CMS detector was constructed at the surface, lowered underground in 15 sections and then assembled (see diagram on page 42).

ATLAS and CMS

The two largest experiments, ATLAS^{w2} (A Toroidal LHC ApparatuS) and CMS^{w3} (Compact Muon Solenoid),

are general-purpose detectors optimised for the search for new particles. ATLAS and CMS are located on opposite sides of the LHC ring, 9 km apart



The ATLAS detector will be the largest of its type in the world when its construction is completed; the people in the diagram are to scale

Detector characteristics	
Width:	44m
Diameter:	22m
Weight:	7000t

CERN AC - ATLAS V1997

Image courtesy of CERN

Image courtesy of CERN



View of the CMS detector at the end of 2007

LHCb

The LHCb^{w4} experiment will help us to understand why we live in a universe that appears to be composed almost entirely of matter but no antimatter. It specialises in investigating the slight differences between matter and antimatter by studying a type of particle called the bottom quark, or b quark (see Landua & Rau, 2008, for an explanation of antimatter and quark types). To identify and measure the b quarks and their antimatter counterparts, the anti-b quarks, LHCb has sophisticated movable tracking detectors close to the path of the beams circling in the LHC.

ALICE

ALICE^{w5} (A Large Ion Collider Experiment) is a specialised detector for analysing the collisions of lead ions (see diagram on page 44). For a few weeks each year these, rather than protons, will be collided in the LHC. Within the dimensions of an atomic nucleus, this will create conditions that prevailed about a millionth of a second after the Big Bang, when the temperature of the entire Universe was about 100 000 times hotter than the interior of the Sun. These conditions might create

ATLAS beam pipe installation



Image courtesy of CERN

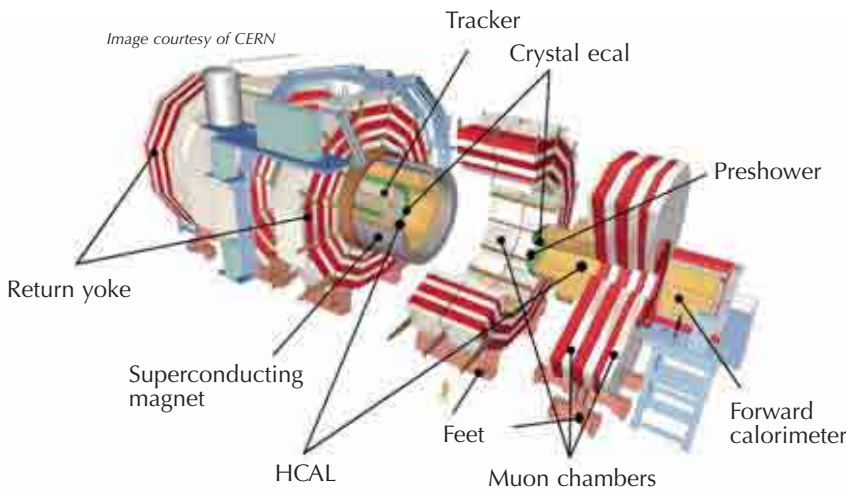


Image courtesy of CERN

The setup of the CMS detector

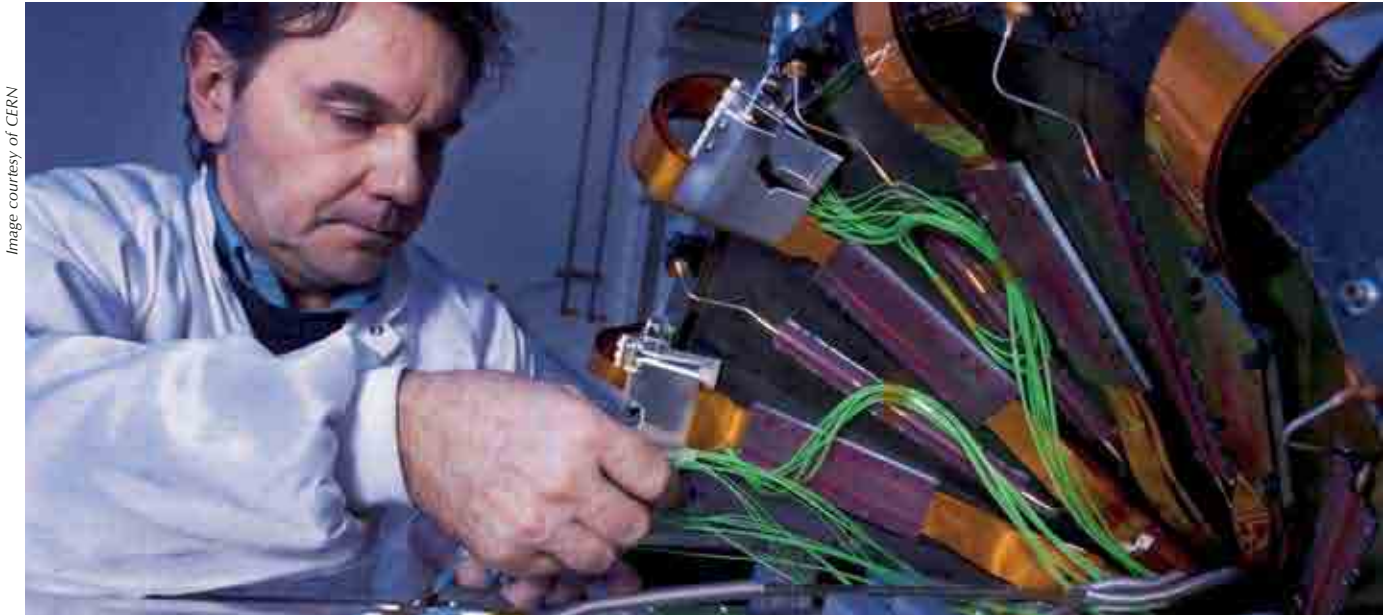


Image courtesy of CERN

Integration of the ALICE experiment's inner tracker

a state of matter called a quark-gluon plasma, the characteristics of which physicists hope to study (for a further explanation of the quark-gluon plasma, see Landua & Rau, 2008).

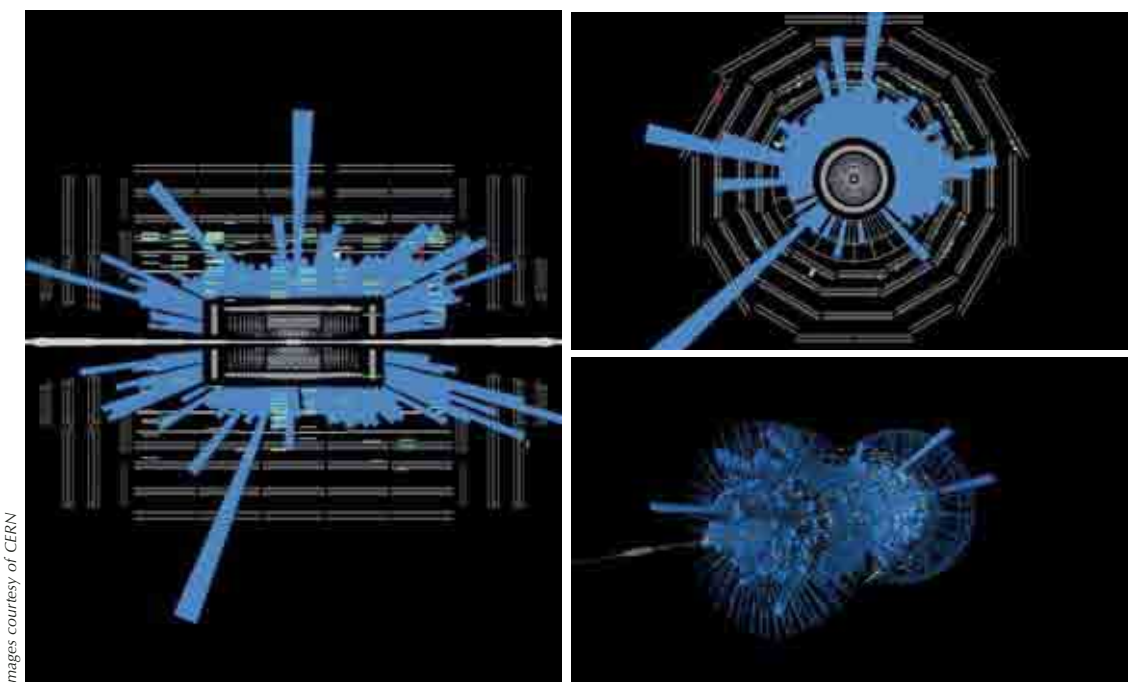
The data challenge

The LHC will produce roughly 15 petabytes (15 million gigabytes) of data annually – enough to fill more

than 3 million DVDs. Thousands of scientists around the world want to access and analyse these data, so CERN is collaborating with institutions in 33 countries to operate a distributed computing and data storage infrastructure: the LHC Computing Grid (LCG).

The LCG will allow data from the LHC experiments to be distributed around the globe, with a primary

backup kept at CERN. After initial processing, the data will be distributed to eleven large computer centres. These tier-1 centres will make the data available to more than 120 tier-2 centres for specific analysis tasks. Individual scientists can then access the LHC data from their home country, using local computer clusters or even individual PCs.



Images courtesy of CERN

Image courtesy of CERN

One of the first images from CMS, showing the debris of particles recorded by the detector's calorimeters and muon chambers

The ALICE experiment will study the collisions of beams of lead nuclei in an attempt to produce a new state of matter known as quark-gluon plasma

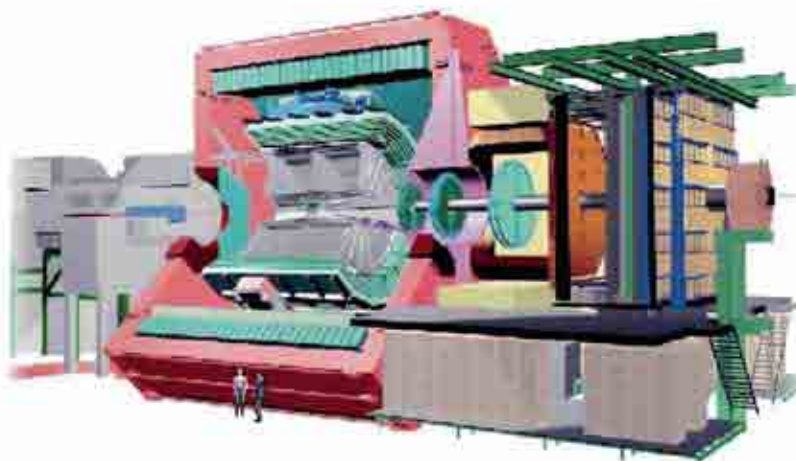


Image courtesy of CERN

In the first article of this pair (Landua & Rau, 2008), Rolf Landua and Marlene Rau introduce the particle physics behind the LHC.

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<http://cdsweb.cern.ch/record/1092437/files/CERN-Brochure-2008-001-Eng.pdf>

A video of the Large Hadron Collider can be viewed here:
www.youtube.com/watch?v=j50ZssEojtM

w2 – For more information on the ATLAS experiment, see:
<http://atlas.ch>

w3 – For more information on the CMS experiment, see:
<http://cms-project-cmsinfo.web.cern.ch/cms-project-cmsinfo/index.html>

w4 – For more information on the LHCb experiment, see:
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w5 – For more information on the ALICE experiment, see:
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Resources

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Image courtesy of CERN

The leading members of the LHCb magnet project; also visible are the coils of the detector's huge dipole magnet. April 2004



As we go to press: a helium leak in the LHC

BACKGROUND

At mid-day on 19 September 2008, nine days after start-up, an incident occurred in one of the eight sectors (sector 3-4) of the LHC. The cause was a faulty superconducting electrical connection between two of the LHC magnets. When the electrical current increased above 9000 A, part of the cable developed an electrical resistance which resulted in a large release of resistive electric power in the cable. Within one second, an electrical arc punctured the helium enclosure and released more than one tonne of liquid helium into the insulation vacuum of the cooling system. Since several magnets share a common insulation vacuum, the resulting large increase in pressure led to mechanical damage of up to 24 dipole magnets and 5 quadrupole magnets.

As we go to press, sector 3-4 has been warmed up so that repairs can take place. At least 29 magnets will have to be taken out, brought to the surface, repaired and tested, then re-installed and re-connected. The beam pipes will have to be carefully cleaned as well. While these repairs would take not more than a few weeks in a conventional particle accelerator, the complexity of the superconducting installations of the LHC requires several months of work, plus about six weeks to cool the magnets in this sector back down to a temperature of 1.9 K. It is foreseen that the LHC will be restarted and carry out its first collisions in 2009.

The CERN website devotes a substantial amount of space to the LHC; see: <http://public.web.cern.ch/public/en/LHC>

The CERN pages offer a wealth of teaching material on particle physics and accelerators: <http://education.web.cern.ch/education/Chapter2/Intro.html>

Among the teaching material on the CERN website is an online LHC game in English, French, German and Italian: <http://microcosm.web.cern.ch/microcosm/LHCGame/LHCGame.html>

The LHC UK website includes materials about the LHC for teachers and students: www.lhc.ac.uk

A much more detailed account of the standard model and the LHC experiments can be found in Rolf Landua's German-language book: Landua R (2008) *Am Rand der Dimensionen*. Frankfurt, Germany: Suhrkamp Verlag

Rolf Landua is the Head of Education at CERN, where he has been working since 1980. A German particle physicist, he is the co-initiator of the Antimatter Factory at CERN and led the ATHENA project that created millions of anti-hydrogen atoms in 2002. He is secretly famous as the model for the character of

Leonardo Vetra, an antimatter physicist from CERN who is murdered in the first pages of Dan Brown's best-seller *Angels and Demons*, which is being turned into a Hollywood film due for release in May 2009. He runs courses at CERN for physics teachers from across Europe, is a regular interview partner on radio and TV and has recently released a German-language book on CERN particle physics (*Am Rand der Dimensionen, On the Border of the Dimensions*, see resources). For his commitment to fostering science education in schools, he received the 2003 European Physical Society's communication award.



Practical demonstrations to augment climate change lessons

Image courtesy of the University of Bristol



Tim Harrison and Dudley Shallcross with dry ice reacting in alkaline water

Dudley Shallcross and **Tim Harrison** from Bristol University, UK, illustrate chemistry experiments relevant to climate change.

Images courtesy of Tim Harrison



To produce soot, a beaker is filled with water and washing-up liquid. Adding a few pieces of calcium carbide (CaC_2) liberates bubbles of acetylene. If ignited, this foam gives a yellow flame with smuts of carbon

There are a number of chemicals that are important to consider for climate change, either as contributors to global warming (soot and carbon dioxide) or as alternative fuels (methanol and hydrogen). In the second of two articles (see also Shallcross & Harrison, 2008), we present several classroom demonstrations and experiments to introduce these materials and describe how they can be used to enliven climate change lessons.

Safety note: Local rules and regulations on health and safety should be applied before trying these out. Always practice the experiments before presenting them in front of students.

Soot / particulate carbon

Soot fits into the category of airborne particulate matter^{w1}. Particles are considered hazardous when they are less than five micrometres in diameter, as they are not filtered out by the upper respiratory tract before entering the lungs.

Black carbon will enhance global warming, but not all particles in the atmosphere do. It all depends on their optical properties: if the particles are very reflective, like a mirror (e.g. sea-salt particles), they can reflect incoming solar radiation back to space and decrease the radiation that reaches Earth, causing a reduction in surface temperature. If they are dark, such as soot, they will absorb incoming radiation and enhance warming.

Soot is a product of incomplete combustion, for example in car motors, central heating or power stations. There are a number of reactions that can produce soot. The simplest teacher demonstration is to burn small pieces of expanded polystyrene packaging, holding them with tongs over a

heatproof mat. The yellow flame produced is very smoky, and the smoke contains black specks of carbon. However, this is not a suitable reaction for students to perform, as the polystyrene drips molten droplets of burning material; instead, the teacher should demonstrate.

If a class experiment to produce soot is needed, the combustion of freshly prepared acetylene (ethyne, C_2H_2) gas is an entertaining reaction. Take a 250 ml glass beaker, place it on a heatproof mat and half fill the beaker with water. Add a good squirt of washing-up liquid to the water and also a few pieces of calcium carbide (CaC_2). The reaction is immediate, liberating bubbles of acetylene. The teacher or student can then use a lit splint, taper or match to ignite the foam. This burns dramatically with a yellow flame with smuts of carbon (see images above).

Safety note:

As with all experiments, safety glasses must be worn.

If the beaker is over-filled or too much calcium carbide is used, the bubbles can overflow onto the heatproof mat. These bubbles can also combust! Bubbles may continue to be ignited by others burning near them. This may go on for 30 seconds or so. Leave any used beaker in a fume cupboard until all the ethyne gas has been produced and the bubbling stops.

The residual solution is mainly alkaline calcium hydroxide solution.

Solubility of CO_2 in water / precipitation of calcium carbonate

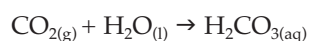
If dry ice is available, an interesting experiment can be performed to demonstrate the solubility of carbon dioxide in water. This can be used to introduce a discussion about

A methanol whoosh bottle ignited in a darkened room

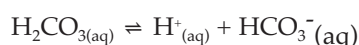
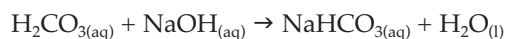


Image courtesy of the University of Bristol

the uptake of carbon dioxide (CO_2) by the oceans as a possible mechanism for removing carbon dioxide from the atmosphere. For this very visually impressive reaction, add a handful of dry ice (take care to avoid cold temperature burns) to a large (1 l) beaker of water that has been made alkaline ($\text{pH} = \sim 12$) with sodium hydroxide (NaOH) solution, and to which a small volume of universal (pH) indicator has been added. Apart from the impressive condensation of water vapour, forming a cloud above the beaker, the formation of carbonic acid (a weak acid) causes a series of colour changes to the indicator from purple through to orange (see image on page 46). For a more impressive cloud, use hot water, as there is more water vapour to condense. The condensation is caused by very cold carbon dioxide gas produced when the dry ice sublimates, using energy from the much hotter water. Some of the carbon dioxide dissolves in the water.

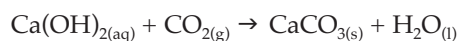


The carbonic acid formed neutralises the sodium hydroxide, forming sodium hydrogen carbonate.

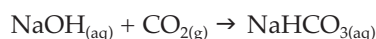


Excess $\text{H}_2\text{CO}_{3(\text{aq})}$ is acidic because it dissociates in water, releasing hydrogen ions.

A small piece of dry ice placed in lime water (calcium hydroxide solution, $\text{Ca}(\text{OH})_{2(\text{aq})}$) can also be used to show the precipitation of carbon dioxide as calcium carbonate. The oceans of the world dissolve carbon dioxide gas and can precipitate calcium carbonate, which is used in shell construction by numerous creatures. The rate of dissolution is too slow to compensate for the increase in atmospheric carbon dioxide:



If no dry ice is available, then a 2 l drinks bottle could be filled with carbon dioxide gas and about 30 cm^3 of 2 mol dm^{-3} sodium hydroxide can be added. Place the top on the bottle and shake. The bottle should start to collapse as the carbon dioxide gas reacts with the sodium hydroxide, thus reducing the pressure inside the bottle. The solution forms exothermically so that it gets warm. This shows that carbon dioxide gas is acidic. This has implications for the change in the ocean's pH as the high concentrations dissolve over time.



Safety note:

Lime water (calcium hydroxide solution) is an alkaline solution, as is sodium hydroxide solution; safety glasses must be worn.

Dry ice (solid carbon dioxide) is -78°C or less and will cause cold burns. Great care must be exercised in handling the solid. The use of suitable gloves is recommended. Dry ice should not be kept in a screw-top container because of the risk of explosion.

Methanol whoosh bottle

Methanol is a biofuel, an alternative to fossil or nuclear fuels, and this experiment can be used to demonstrate its combustion. In addition to being a renewable fuel, methanol has the advantage over fossil fuels of not releasing 'stored' carbon dioxide into the atmosphere; instead, it merely recycles carbon dioxide that is in the environment anyway.

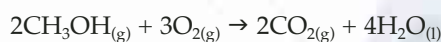
Methanol vapour (which is toxic) can be ignited inside an 18 l plastic water bottle of the type used in water dispensers. Note that after the experiment, the container will no longer be fit for its original purpose!

Pour around 20 ml of methanol (methyl alcohol, CH_3OH) into a dry 18 l water canister and shake to vaporise. Pour out the surplus liquid methanol. In a warm room, you will be able to feel the pressure of the vapour if you hold your hand over the bottle mouth. Put the bottle behind a transparent safety screen on the floor and away from any overhead heat, flame, flash sensors or curtains. Put a lighted taper or match to the mouth of the water bottle, holding it at arm's length. A blue flame will erupt with a loud roar as the methanol completely combusts.

Safety notes: Avoid methanol coming directly into contact with your skin, as it is toxic. Any liquid methanol must be poured out of the container away from any flame source.

The water canister cannot subsequently be used for drinkable water.

The water bottle must be dry, as the tops of wet bottles tend to melt during the combustion!



Hydrogen-filled balloons

This teacher demonstration could be used to introduce hydrogen as an alternative fuel to replace fossil fuels, and especially to raise the question of whether the combustion product is a greenhouse gas.

One way to demonstrate that hydrogen is a fuel, is to fill a balloon with hydrogen and tether it to a chair placed away from sensors and flammable materials (such as posters, blinds or curtains) using a piece of thin string. Ignite the balloon using a lit taper or match, fastened to the end of a metre ruler or a long pole at arm's length. Students should remain several metres away, as, during the resultant explosion, bits of the rubber balloon tend to fly in all directions. Those with sensitive hearing should

place their hands over their ears. The flame and heat energy liberated are spectacular and should lead to discussion of hydrogen's suitability as a fuel.

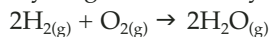


Image courtesy of the University of Bristol

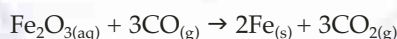
A 3 l hydrogen balloon on ignition

Safety note:

If in any doubt about the volume of flame produced, perform the experiment outside and away from glass windows.

The reduction of iron oxide on a match head

The use of blast furnaces in the iron and steel industries contributes to the atmospheric concentration of carbon dioxide. The crucial reaction, which reduces iron oxide to pure iron by means of carbon monoxide, is:



Students can mimic this reaction on the head of a match.

Moisten an unlit match with water and roll into sodium carbonate (Na_2CO_3) powder, and then in iron oxide powder (Fe_2O_3), so that both stick to the match head. Use a second match to ignite the first and let it burn for a moment or two. Crunch the first match head onto a watch glass or Petri dish. Drag a magnet against the underside of the watch glass; the small particles of iron formed will be visible as they follow the magnet's pull. Try this with the starting materials, to show that no magnetic materials were initially present.

The match provides both the energy for the reaction and the carbon monoxide as a reducing agent. The sodium carbonate acts as a flux material.

Safety note:

Spilled iron oxide or sodium carbonate powders should be wiped up with a cloth. Do not blow them away, as – like any other fine powder – they pose a respiratory hazard.

Students, unless warned, could burn themselves on the hot match heads!

Further experiments

Other experiments that can be performed as part of a project about climate change include:

- The use of Grätzel cells to show the generation of electricity from sunlight, using the colorant molecules in materials such as blackcurrants
- The use of alcohol burners to determine the energy stored in simple alcohols
- The preparation of biodiesel from vegetable oils
- The generation of electricity from alcohols using a fuel cell

Reference

Shallcross D, Harrison T (2008) Climate change modelling in the classroom. *Science in School* 9: 28-33. www.scienceinschool.org/2008/issue9/climate

Web references

w1 – For more information about particulate matter, see the Wikipedia page:

<http://en.wikipedia.org/wiki/Particulate>

w2 – Why not discuss how to teach climate change with other teachers across Europe? Join the *Science in School* online discussion forum: www.scienceinschool.org/forum

Resources

Harrison T, Shallcross D, Henshaw S (2006) Detecting CO₂ – the hunt for greenhouse-gas emissions. *Chemistry Review* 15: 27-30

Johnson S (2008) Planting ideas: climate-change activities for primary



REVIEW

Climate change should certainly be one of the topics of today's science teaching at all school levels throughout Europe. Particularly after Al Gore's documentary, *An Inconvenient Truth*, the topic has gained worldwide recognition. Useful materials with usable background information for science teachers, though, are not always readily available. However, this article – the second of two – offers some dramatic and enjoyable demonstrations.

If further articles follow, there is the chance of starting a European-wide discussion on how best to implement the topic of climate change and global warming in European science classes^{w2}.

Tobias Kirschbaum,
Germany

www.scienceinschool.org/climatechange

Numerous notes on air pollution, climate change and ozone depletion notes for schoolteachers by the authors can be found online at: www.chemlabs.bristol.ac.uk/outreach/resources/Atmos.html

An excellent source of graphics and data relating to climate change can be found on the website of the GRID-Arendal collaborating centre of the United Nations Environment Programme:

www.grida.no/climate/vital/index.htm

For data from the Earth Station research laboratory Global Monitoring Station, see: www.cmdl.noaa.gov

The website of the Intergovernmental Panel on Climate Change, which includes the Climate Change 2007 report and other data, can be found here: www.ipcc.ch

Dudley Shallcross is the Professor in Atmospheric Chemistry and Tim Harrison is the School Teacher Fellow at the School of Chemistry at the University of Bristol, UK. The latter is a position for a secondary-school teacher that was created to bridge the gap between secondary schools and universities, and to use the resources of the School of Chemistry to promote chemistry regionally, nationally and internationally.

For more information about modelling climate change or about the post of School Teacher Fellow please contact Dudley Shallcross (d.e.shallcross@bristol.ac.uk) or Tim Harrison (t.g.harrison@bristol.ac.uk).



school. *Science in School* 10: 55-63 www.scienceinschool.org/2008/issue9/psclimate

Pacala S, Socolow R (2004) Stabilisation wedges: solving the climate problem for the next 50 years with current technologies. *Science* 305: 968-972. doi: 10.1126/science.1100103

Shallcross D (2006) Dirty Air. *Education in Chemistry*, Sep. www.rsc.org/Education/EiC/Restricted/2006/Sept/DirtyAir.asp

For a full list of *Science in School* articles about climate change, see:

Better milk for cats: immobilised lactase used to make lactose-reduced milk

Dean Madden from the National Centre for Biotechnology Education (NCBE), University of Reading, UK, suggests an experiment to make lactose-free milk – useful both for cats and for the 75% of the world’s human population that are intolerant to this type of sugar.



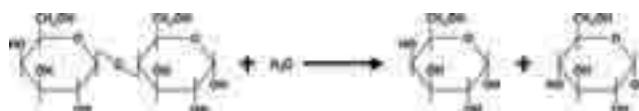
Aims

This simple practical investigation introduces students to the principles of digestion and enzyme immobilisation. It can be used as the starting point for other, more advanced activities such as the regulation of lactase production in *Escherichia coli* (the *lac* operon), the evolution and social significance of lactose tolerance in humans, and the use of enzymes in food production.

Introduction

Lactase (beta-galactosidase) catalyses the hydrolysis of lactose to glucose and galactose:

Lactose → D-glucose + beta-D-galactose

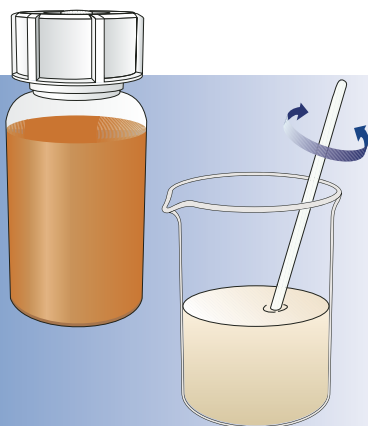


Both of these sugars taste sweeter and are more readily digestible than lactose. Despite their traditional fondness for milk, cats are unable to digest large amounts of lactose. Milk can be treated with the enzyme to make a lactose-reduced milk suitable for cats or for humans who are lactose intolerant¹.

Although the production of a special ‘cat milk’ may seem trivial, an estimated 75% of the world’s human population are lactose intolerant in adulthood – it is lactose tolerance that is unusual.

Commercially, milk is treated by injecting an enzyme into the carton as UHT milk is packaged, or by using an immobilised enzyme – an enzyme that has been trapped on an inert material so that it can be used repeatedly.

In this activity, students immobilise the lactase in calcium alginate beads held within a small column, over which the milk is passed.



Equipment and materials

Needed by each person or group:

Equipment

- Small piece (about 1 cm²) of nylon gauze, e.g. net curtain
- 10 ml plastic syringe (without a needle)
- 4 mm diameter aquarium airline or silicone tubing, about 7 cm long, to fit syringe
- Aquarium airline tap or adjustable laboratory tubing clip (Hoffman clip)
- Retort stand, boss and clamp (to support enzyme column)
- 2 small beakers (100 ml) or disposable plastic cups
- Tea strainer
- Glass stirring rod

Materials

- 2 ml lactase enzyme (Novozymes^{w3} Lactozym[®])
- 8 ml 2% sodium alginate solution
- 100 ml 1.5% calcium chloride solution
- 50 ml milk (*not* UHT milk)
- Semi-quantitative glucose test strips (e.g. Roche Diabur-Test 5000 or Ames Diastix)

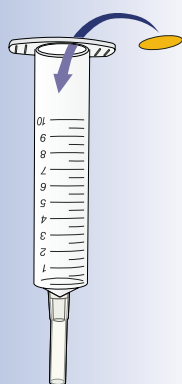
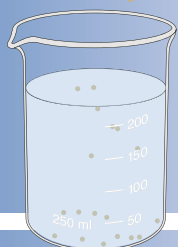
Note: All solutions must be made using distilled or deionised water. Sodium alginate is not readily soluble, and requires both warm water and stirring to dissolve.

Preparation and timing

This activity takes about 40 minutes. The sodium alginate takes some time to dissolve, so the solution is best prepared before the lesson. The immobilised enzyme may be prepared in advance if desired: the beads should be refrigerated, although they will not keep for more than a few days.

Procedure

1. Mix the enzyme with the sodium alginate solution, then draw it up into a 10 ml syringe.
2. Add the alginate-enzyme mixture a drop at a time from the syringe to the calcium chloride solution and observe the formation of small beads. Do not allow the tip of the syringe to come into contact with the calcium chloride solution, as this will cause the alginate to harden, blocking the outlet. The beads, which contain the enzyme immobilised in a matrix of calcium alginate, should be allowed to harden for a few minutes.
3. Attach a short length of tubing to the tip of a syringe barrel. Place a small disc of nylon gauze inside the barrel, to prevent the beads from blocking the syringe outlet.
4. Separate the beads of immobilised enzyme from the liquid with the tea strainer.
5. Carefully tip the beads into the syringe barrel.
6. Close the tubing on the syringe barrel using a tubing clip.



- Test the milk before treatment using the glucose test strips, to ensure that it does not contain any glucose.
- Pour a small volume of milk over the enzyme beads, then undo the clip and allow the treated milk to run into a small beaker.
- Test the milk leaving the column using the glucose test strips. If necessary, return the treated milk to the column until the desired concentration of glucose is achieved.

Safety guidelines

Do not consume the milk

The enzyme suggested for this work is safe to use, provided it is handled appropriately. Although Novozymes Lactozym® is a food-grade product, milk prepared using it should not be consumed. This is because the enzyme has not been handled aseptically, so it (and the product made using it) may have been contaminated.

Readers are advised to refer to any local safety guidelines and to carry out their own risk assessment for any practical work.

General enzyme safety guidelines

As enzymes are water-soluble, water should always be used for their removal if they are spilt.

Do not let liquid enzyme preparations dry up

If liquid preparations are allowed to dry up, there is a risk of dust formation. In susceptible people, the repeated inhalation of such dust may provoke asthma or a reaction similar to hay fever. Any spillage – on equipment, the floor or the bench – should be rinsed away immediately with water.

Avoid the formation of aerosols

If enzyme-containing aerosols are formed, there is a risk of inhalation of the enzyme. In susceptible people, the repeated inhalation of such aerosols may provoke asthma or hay fever. For this reason, enzyme preparations should never be sprayed.

Avoid direct skin and eye contact

If, by accident, you get liquid enzyme on your skin or in your eyes, the remedy is plenty of tap water. The same applies to clothing. In the event of a spill on clothes, rinse with water then wash as usual. This treatment will generally prove sufficient, but if symptoms develop in the respiratory passages, on the skin or in the eyes, consult a doctor immediately.

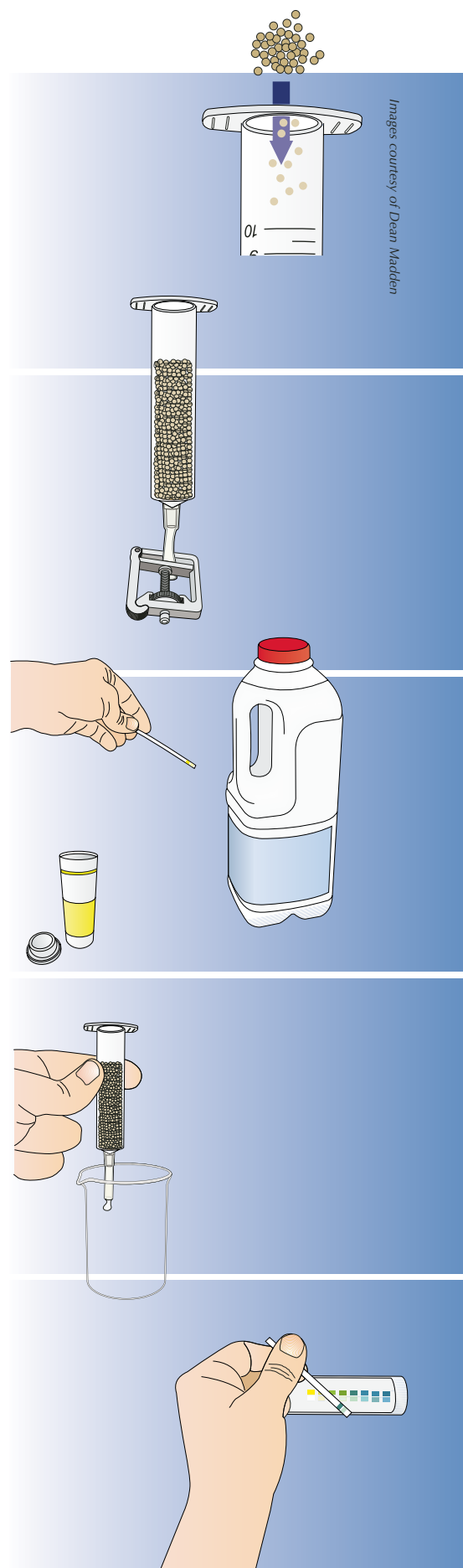
Troubleshooting

Some UHT milk will test positive for glucose, probably because the heat treatment hydrolyses some of the lactose. UHT milk should therefore be avoided.

Additional investigations

The immobilised enzyme column may also be used to treat whey, producing a sweet whey syrup which is widely used in confectionery (it is usually described on labels as 'hydrolysed whey syrup' or just 'whey syrup').

Lactase is strongly inhibited by galactose (one of the products of its action on lactose). As a result, the flow rate of the substrate over the column is critical to the rate of the enzyme-catalysed reaction: too fast and there isn't time for the reaction to occur; too slow and galactose will accumulate and then inhibit the



reaction. Students can therefore investigate the effect of the flow rate on the conversion of lactose to glucose and galactose.

Suppliers

The NCBE^{w2} supplies Novozymes enzyme products^{w3} to schools and colleges in the UK. Similar arrangements may exist in other countries.

Storage of materials

The enzyme preparations should be stored, undiluted, at 3-4 °C.

Web references

w1 – A comprehensive description of lactose intolerance can be found on Wikipedia:

http://en.wikipedia.org/wiki/Lactose_intolerance

w2 – The National Centre for Biotechnology Education (NCBE) in the UK offers educational resources and practical training for teachers in several European Union countries. See: www.ncbe.reading.ac.uk

w3 – For the website of Novozymes A/S, Denmark, see: www.novozymes.com

w4 – This and other protocols are available for download from the *Volvox* website: www.eurovolvox.org

Resources

Bayless TM, Paige DM, Ferry GD (1971) Lactose intolerance and milk drinking habits. *Gastroenterology* **60**: 605–608.

Richmond ML, Gray JI, Stine CM (1981) Beta-galactosidase: Review of recent research related to technological application, nutritional concerns and immobilization. *Journal of Dairy Science* **64**: 1759–1771.

Woodward J (ed; 1985) *Immobilised enzymes and cells: a practical approach*. Oxford, UK: Oxford University Press. ISBN: 0947946217. (An academic laboratory manual describing methods of immobilising enzymes and cells)



REVIEW

This is one of a series of excellent biotechnology protocols from the NCBE, which bring the theory to life and illustrate many useful industrial applications of biotechnology at the laboratory scale and in short timeframes. The protocols are available to download from the *Volvox* website^{w4}.

Teachers will benefit greatly in their treatment of biotechnology from using this and similar protocols, and will be rewarded for the preparation required in stocking up on the necessary materials by the way in which the practical sessions bring the theory to reality. All of the protocols give satisfaction to the student investigators as they produce tangible results that are relevant to their everyday lives. Try it and see!

Marie Walsh,
Republic of Ireland

Acknowledgements

This practical protocol was adapted for the *Volvox* project^{w4}, which is funded under the Sixth Framework Programme of the European Commission.

Dean Madden is a biologist working for the National Centre for Biotechnology Education (NCBE) at the University of Reading, UK. The NCBE was established in 1984 and has since gained an international reputation for the development of innovative educational resources; its materials have been translated into many languages including German, Swedish, French, Dutch and Danish.



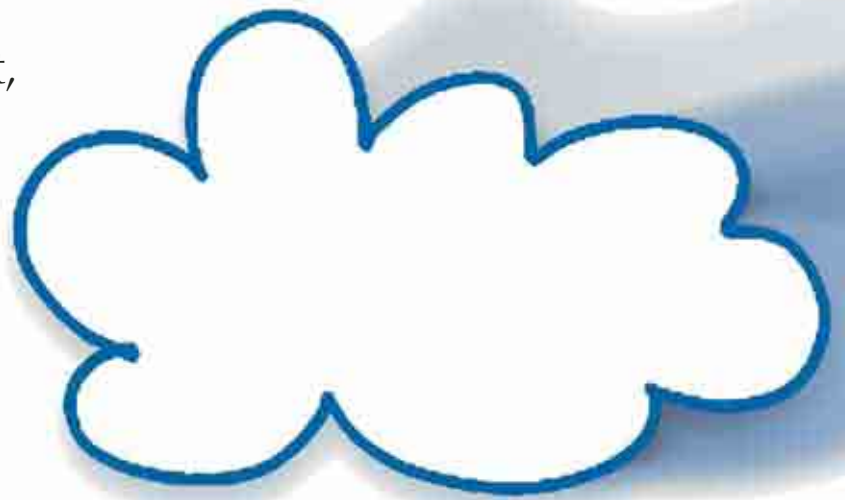
Image courtesy of Dean Madden



Image courtesy of Dean Madden

Planting ideas: climate-change activities for primary school

Sue Johnson from the Institute of Education, London University, UK, introduces the Plant Scientists Investigate project, and presents three plant-related activities for primary-school children. Compare the carbon dioxide concentrations of inhaled and exhaled air, visualise your own oxygen consumption or weigh up the importance of plant conservation versus economic development.



Plant Scientists Investigate: at school and in the botanic garden

The Plant Scientists Investigate project promoted collaboration between botanic gardens and local primary schools between 2005 and 2007. From Austria, Bulgaria, Italy and the UK, primary-school teachers, head teachers, representatives of national school boards (county advisors in the UK) as well as botanic garden educators have worked together to develop an enquiry-centred teaching resource.

Key features of the teaching materials are that they engage children in

working like scientists, encourage them to use reasoning skills and scientific thinking, maximise group discussion, and generate their own questions and ideas. By making observations and creating experiments or models, pupils derived a deeper understanding of plants and were able to explain their ideas and make more effective arguments when presenting their work.

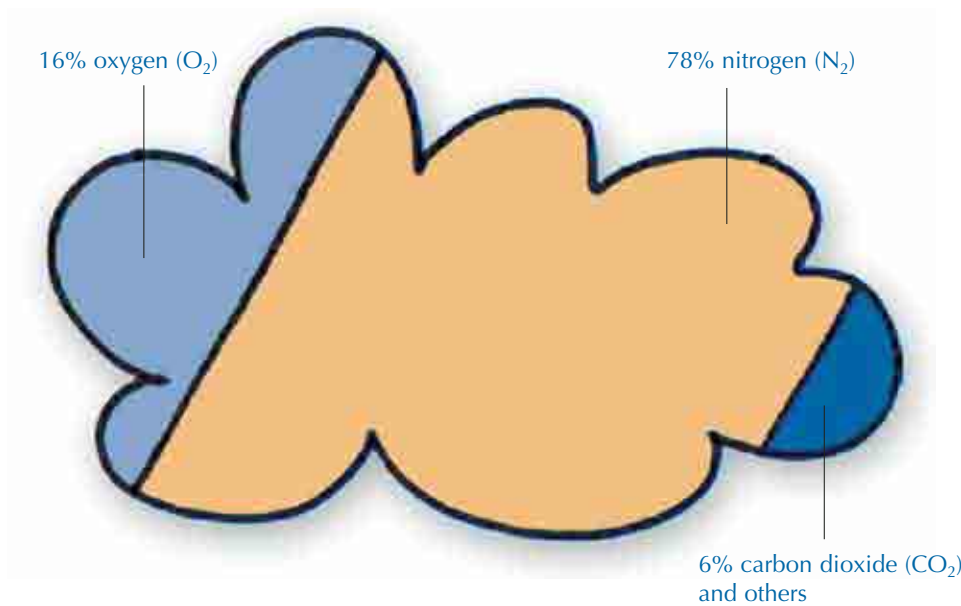
The Plant Scientists Investigate website^{w1} is divided into four topics: conservation, art, food, and experiments about plant growth. Ready-to-

use teaching materials on these topics have been designed to overcome gaps in knowledge of teachers surveyed at the outset of the project. Each activity can be taught independently or in combination, and the content is easily adapted to a wide range of ages. All materials can be downloaded from the website.

Carbon dioxide in exhaled air

Overview

Children should already know that the air they exhale contains less oxy-



Constituents of exhaled air

gen than fresh air does. With this experiment, they can test if there is more carbon dioxide in exhaled air than inhaled air using a colour-change indicator.

Aim

To understand that the air people exhale contains more carbon dioxide (and less oxygen) than the air they inhale.

Timing

1 h 20 min

Materials per group

- 2 glass containers
- 2 straws
- 1 bike pump
- Tube with dissolved potash lye (10% KOH)
- Tube with colour indicator (phenolphthalein solution)
- Pipette
- Photocopies of Activity Sheets 1 and 2 (see pages 58, 59)
- Film on the Plant Scientists Investigate website^{w2} (optional)

Skills

- Precise working with a pipette and chemicals
- Observing

Keywords

- Exhaled air
- Carbon dioxide
- Oxygen
- Inhaled air

Cross-curricular links

Mathematics

Teaching sequence

1. Divide the children into groups and distribute Activity Sheet 1. To review the composition of air, children should colour in the different components of fresh air on the activity sheet (see teachers' notes on page 57). Exhaled air is missing 5% of the oxygen that makes up inhaled air. Ask children to consider what may replace this missing oxygen. Ask them to consider how they could test their ideas. Scientists can use highly specialised machines in a laboratory

to test, but we can still investigate air using basic equipment.

2. Tell the children that the next experiment can test whether there is more carbon dioxide in exhaled air. A colour-change indicator will show if the carbon dioxide concentration in the liquid is increasing.
3. Distribute the necessary materials (except for the chemicals and air pumps).
4. If this is the first time that children have used a pipette, show them how to use it properly by practising pipetting water and releasing it drop by drop.
5. Go through appropriate health and safety measures with the children. As they will be working with chemicals, it is very important for them to work carefully and precisely. If there is some liquid left in the pipette, it should be dripped back into the small jar (tubes). Only then should the tubes with chemicals be distributed.
6. Ask the children to follow the instructions on the activity sheet

- on how to use the colour-change indicator.
- Before carrying out the experiment, the children should discuss what they want to find out, i.e. to investigate if the carbon dioxide content of exhaled air is different from fresh air. The pink solution (phenolphthalein) changes colour when it comes into contact with carbon dioxide.
 - The children should carry out the first part of the experiment. Discuss what happened and why it happened.
 - Ask the children to think about how to get fresh air into the second jar. Let them work in pairs to come up with ideas and then come together as a class to decide what to do. Distribute Activity Sheet 2 and the air pumps. The children should pump fresh air into the second jar. Note: the colour is not going to change (or should change only slightly).
 - Discuss with the children what the experiment is designed to find out. It can show that there is more carbon dioxide in exhaled air than in fresh air.
 - Complete the drawing with the fresh air.
 - Ask the children to summarise two things which they discovered during the experiment.

The change in colour of the indicator

Teachers' notes

A film demonstrating how to run this activity is available on the Plantscave website in the media gallery^{w2}.

Fresh air consists of 78% nitrogen, 21% oxygen and 1% of other gases (including carbon dioxide and others). Oxygen is necessary for every burning process, whether burning a candle or burning food at a cellular level.

Health and Safety

Because 10% KOH is corrosive, it should not come into contact with skin or the eyes. Children should use gloves, or this specific part of the activity should be carried out only by the teacher. Regulations on the control of substances hazardous to health (COSHH) will apply. After the experiment, the solutions in the jars can be disposed of down the drain.

For preparation and experiment methodology, see Activity Sheets 1 and 2.

Explanation

KOH produces a slightly alkaline solution, which is coloured pink by an indicator. Exhaled carbon dioxide produces carbonic acid in the water, so the alkaline solution turns acidic (changing the pH value). The pink solution becomes colourless when exhaled air is added to the solution.



Image courtesy of PSI



Activity sheet 1: Carbon dioxide in exhaled air

Using different colours, show what makes up the air in these clouds.

Fresh air



Exhaled air



Carry out the following experiment:

1. Take two glass containers and fill each with 200 ml water.
2. Add 20 drops of 10% potash lye to both containers.
3. Clean the pipette in the sink or a glass with fresh tap water.
4. Add 20 drops of indicator and stir it with a straw.

What are we trying to investigate with this experiment?

5. One person in the group should breathe through a straw, using strong breaths, into one of the containers.
6. Write down what happens and why.





Children enclosing an area of the school grounds that will produce sufficient oxygen, by way of photosynthesis, for one person for one day

My own oxygen consumption

Overview

This activity will demonstrate to children how much green space is needed to produce enough oxygen for one person for one day.

Aims

- To work out the relationship between our daily oxygen requirements and the quantity of plants necessary to produce this volume of oxygen.
- To understand that all green plants produce oxygen.
- To understand the importance of the rainforests and seaweed for the maintenance of the gas balance in the atmosphere.

Timing

30 min

Material

- String
- Wooden sticks

Keywords

- Plants
- Humans
- Oxygen

- Carbon dioxide
- Rainforests
- Seaweed
- Atmosphere

Cross-curricular links

Mathematics

Teaching sequence

1. Walk with the children to a lawn or other green space outdoors. Ask children if they have any idea how much oxygen we consume every day.
2. Explain that studies have shown that a human needs, on average, 360 litres of oxygen per day.
3. Review what children have learned so far about how plants produce oxygen (what a plant needs for photosynthesis). Emphasise that all green plants produce oxygen.
4. Children should guess how large a piece of lawn needs to be to provide enough oxygen for one human to live for one day. Let the children mark out their estimated area using the string.

5. Explain that an area of grass of about 3 m² provides the daily oxygen needs of one human. Each group should then mark out this area of grass to visualise the area of plants that each one of them needs to produce his or her daily intake of oxygen.
6. How big must the area be so that the whole class or the whole school has enough oxygen?
7. Discuss the following points:
 - Humans and animals live in cities where there is little green space but they still need to breathe. How can this happen?
 - What happens in winter, when many trees shed their leaves?
 - How can we still breathe at night if light is needed to produce oxygen?
 - The rainforests and seaweeds (algae) in the sea produce and release enough oxygen to maintain the gas balance in the atmosphere. Rainforests and seaweeds are the lungs of Earth. What would happen if the rainforests or seaweeds died because of pollution?

A new ski run?

Overview

This activity puts children in a real-life situation where plant conservation and economic development clash. In an alpine setting, children play the part of citizens in a ski resort where new plans for ski slopes threaten an area rich in biodiversity. In this role play, children will develop abilities to discuss complex problems, examine pros and cons, and make decisions – and by doing so accept that one often has to compromise.

Aims

- To resolve complex problems, and help children to accept that compromise is often necessary.
- To understand that extinction is a problem linked with human action, but that humans can also help to conserve and protect threatened species.

Timing

2 h

Skills

- Reasoning
- Problem solving
- Argumentation
- Communication skills

Material

- Role play material (downloadable online^{w3})
- Character cards (downloadable online^{w3})
- Sticky labels
- Coloured pens
- Photocopy of Activity Sheet 3 (see page 62)
- Paper (A2 size)

Keywords

- Biodiversity
- Impact of human activity
- Land management

Cross-curricular activity

- Personal, social and health education
- Citizenship
- Literacy, specialised language, slogans (genre writing)
- Art

Teaching sequence

A new ski run?

This game is a role play, based around characters in a society: the mayor, hotel managers, botanists, ski-run builder, foresters and wildlife rangers. The plot is about economic development in the countryside; building a new ski slope. The full

story, character cards and instructions for running the game can be downloaded from the media gallery on the Plantscave website^{w2}.

1. Give each child a card that describes their role at least one day before the activity so that they can begin to empathise with the character. Consider the ability level needed for each role and assign roles accordingly.
2. Each child writes their character name on a sticky label and wears it during the role play.
3. They sit in a semicircle to represent a real open public meeting.
4. The mayor convenes the meeting at which every role player sets out his or her case for or against the construction of a new ski slope. The mayor must guarantee order and must let all representatives speak.
5. Because of the complex issues discussed, the mayor declares a citizens' referendum in which every character has a vote.
6. Before any vote is made, each group has to develop marketing or promotional materials, e.g. posters, to persuade the citizens to vote for their cause. These posters/leaflets should be distributed and the representatives should have time to read them.
7. A secret ballot is taken.
8. The result of the vote is read out by the mayor. In the case of a split decision, the mayor has the deciding vote.
9. The outcome should be discussed by everyone.
10. Children should fill in Activity Sheet 3 to summarise their opinions.

The role-play game, with children making posters to support their opinions about the ski-run development



Image courtesy of PSI



Activity sheet 3: Will the new ski run be built?

Name: _____

Date: _____

My character is: _____

I am / am not in favour of the new ski run (circle one option)

The final decision about the ski run proposal is:

What in your opinion are the pros and cons of this decision?



Web references

- w1 – All teaching materials from Plant Scientists Investigate can be downloaded here:
www.plantscafe.net
- w2 – The film depicting the ‘Carbon dioxide in exhaled air’ activity can be downloaded here:
www.plantscafe.net/en/experiments/gallery.php?module=enex02
- w3 – For the ‘A new ski run?’ activity, the full story, character cards and instructions for running the game can be downloaded here:
www.plantscafe.net/en/conservation/gallery.php?module=enco10

Resources

- Other *Science in School* articles related to climate change (mostly for secondary school) include:
- Benestad R (2007) What do we know about climate? The evidence for climate change. *Science in School* 7: 49-51.
www.scienceinschool.org/2007/issue7/climate
- Benestad R (2008) What do we know about climate? Investigating the effects of anthropogenic global warming. *Science in School* 8: 48-51.
www.scienceinschool.org/2008/issue8/climate

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Sedwick C (2008) What killed the woolly mammoth? *Science in School* 9: 18-21. www.scienceinschool.org/2008/issue9/woollymammoth

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Shallcross D, Harrison T (2008) Practical demonstrations to augment climate change lessons. *Science in School* 10: 46-50. www.scienceinschool.org/2008/issue10/climate

For a full list of *Science in School* articles about climate change, see: www.scienceinschool.org/climatechange

The lead members of the Plant Scientists Investigate project were:

Suzanne Kapelari, Institute of Botany, University Innsbruck, Austria

Sue Johnson, Institute of Education, London University, UK

Costantino Bonomi, Natural History Museum Trento, Italy

Gail Bromley, Royal Botanic Gardens Kew, London, UK

Krassimir Koshev, University Botanic Gardens Sofia, Bulgaria

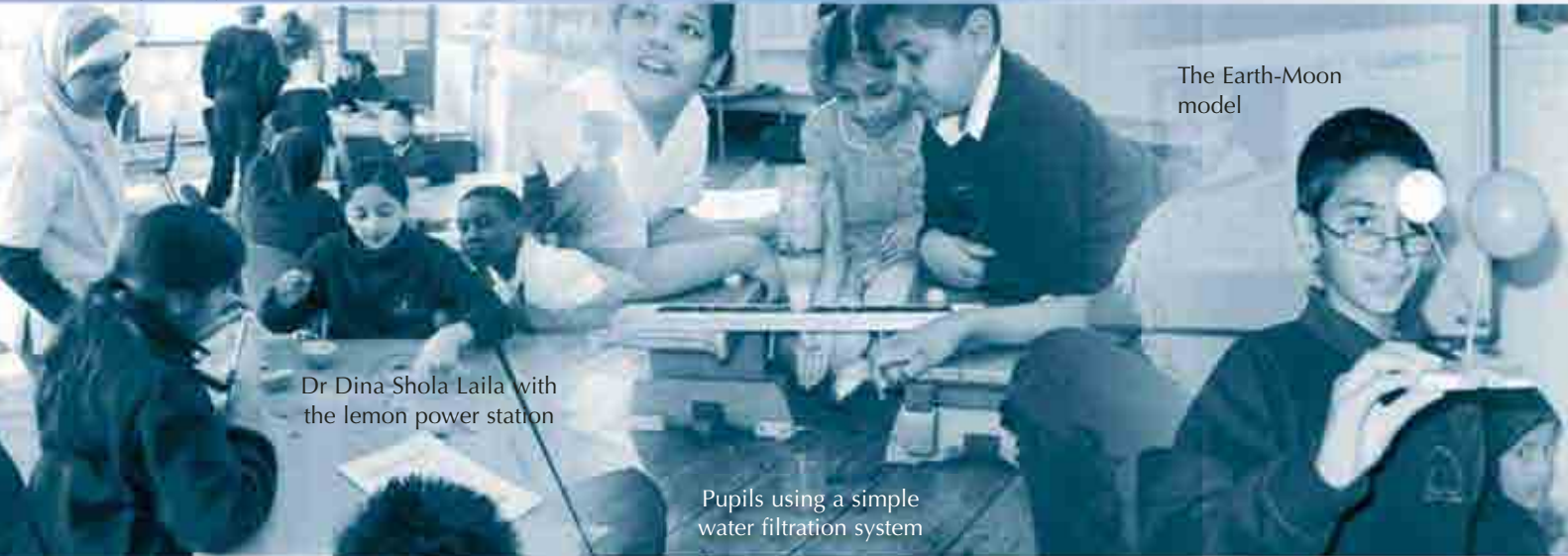


Field work to increase children's knowledge and enthusiasm for conserving plants – plants that might otherwise be destroyed by human activity, such as the ski-run development



Image courtesy of PSI

Images courtesy of the Next Generation project



Dr Dina Shola Laila with the lemon power station

Pupils using a simple water filtration system

The Earth-Moon model

Science for the Next Generation: activities for primary school

The Next Generation project promotes a better understanding of the wonderful world of science to primary-school children. A team of post-doctoral scientists from Imperial College in London, UK, worked with the teachers from Salisbury Primary School in East London to develop a series of practical two-day science workshops. These workshops provide exciting hands-on experiments using everyday household materials to help the children explore the simple science principles that are found all around them. Below are three of the activities for you to use in your classroom.

Water filtration system

This experiment looks at solids and liquids and examines how to separate

them, placing what pupils have learned in the classroom into a real-world setting. Pupils learn how to design and build a simple water filtration system using a variety of materials. Each material is suited to separating different sized solids and dissolved particles from water. The pupils learn, through trial and error, what each material is most appropriate for.

To put the topic into context, you will need to give the pupils a brief introduction to the importance of treating wastewater so that it is safe to be released into rivers. Wastewater treatment is typically a three-stage process consisting of preliminary treatment to screen out large solid impurities, primary sedimentation to

remove impurities through sorption to solids, and secondary treatment to break down or degrade the remaining impurities using micro-organisms.

This experiment investigates the physical process of removing solid impurities of varying sizes and the chemical process of removing dissolved particles by sorption to charcoal. The pupils can discuss what makes water dirty, emphasising key terms such as solid waste, dissolved impurities, filtration and micro-organisms.

The experiment investigates the primary treatment, i.e. the removal of solid impurities. A worksheet is provided for the pupils to complete in support of this experiment.

Wayne A Mitchell, Debonair Sherman, Andrea Choppy and Rachel L Gomes from the Next Generation project describe some of their science activities to introduce primary-school children to the science all around us.

Materials

- Cotton wool
- Sand
- Charcoal (preferably powdered, or buy charcoal pieces and grind them up)
- Gravel
- Plastic glasses
- An empty water bottle with the bottom cut off
- A support system for the water bottle, e.g. a plank of wood with a hole
- Dirty water (water with instant coffee, flour and charcoal pieces added)
- An empty container for used materials and dirty water
- Stopwatches

Method

1. The pupils should set up their filtration system, placing the empty water bottle upside-down into the support system. We used a plank of wood between benches or tables.
2. For each filtration system, give the pupils the four materials (cotton wool, sand, ground charcoal and gravel) in separate glasses along with a glass of the dirty water.
3. Let the pupils choose the order in which to pack layers of the materi-

- als into the water bottle. Have them note the order of the packing material and predict how effectively the filtration system will remove impurities from the water. Ask the pupils to measure the time taken for the water to pass through the system and to predict how this affects the cleaning process.
4. When the filtration system is packed with the materials, the pupils can add the dirty water. Depending on the packing, it can take a while for the water to pass through the packing layers. Often, the pupils forget to place an empty glass underneath but they will learn for the next time!

Through trial and error, and observation, the pupils will learn that the best approach for cleaning the water is to pack the materials in order of size. The cotton wool needs to be placed at the bottom (in the neck of the bottle), to prevent the other packing materials from falling through. Above the cotton wool comes the ground charcoal, then the sand, and then the gravel. (As an optional extension to this exercise, the thickness of the layers can also be varied to see how this affects the purification process.)

From this experiment, the pupils will learn that each packing material is suited to different types of solid impurities in the dirty water and, when combined to make an effective water filtration system, must be packed in order of size. The sand and gravel separate or filter out solids of different sizes (sand removes the smaller particles). The powdered charcoal adsorbs the dissolved coffee, taking away the colour. Additionally, by the time the dirty water has reached the charcoal, it is trickling very slowly, which gives it more time in contact with the charcoal. The longer the dirty water is in contact with the powdered charcoal, the more time the charcoal has to adsorb the colour. The cotton wool prevents any of the other filtration materials from falling out of the bottle.

This experiment demonstrates that impurities in dirty water can be removed by using a series of barriers, which use either physical (filtering by gravel and sand) or chemical (sorption using powdered charcoal) processes to remove the impurities. This type of treatment would not be effective on micro-organisms, however. Can you think what could work well instead?



Worksheet: Water filtration system

Name: _____

Date: _____

Class: _____

What makes water dirty?

1. _____

2. _____

3. _____

4. _____

A water filter can be made using what four objects?

1. _____

2. _____

3. _____

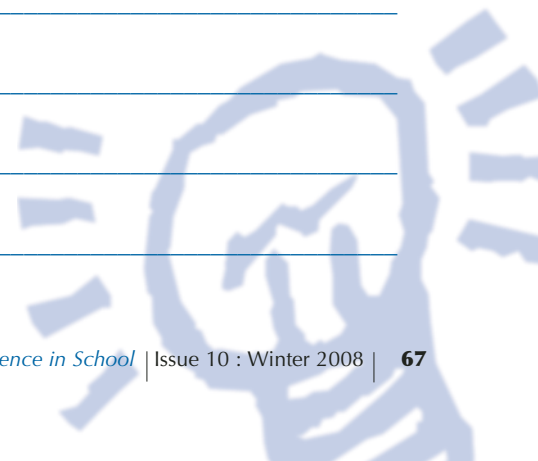
4. _____

Draw a picture of your water filtration system and add labels to explain:

Part of the water filtration system	What does it do?
Bottle	
Cotton wool	
Charcoal	
Sand	
Gravel	

How does a water filtration system work?

Why is it important to clean water?



Construction of an Earth-Moon orbital model

The construction of the Earth-Moon orbital model will help pupils understand the basic movements of planets in space and provide them with a lasting – and homemade – reminder of the activity. The orbital can be used to introduce the principle of planetary movement around the Sun and also the orbit of the Moon around Earth.

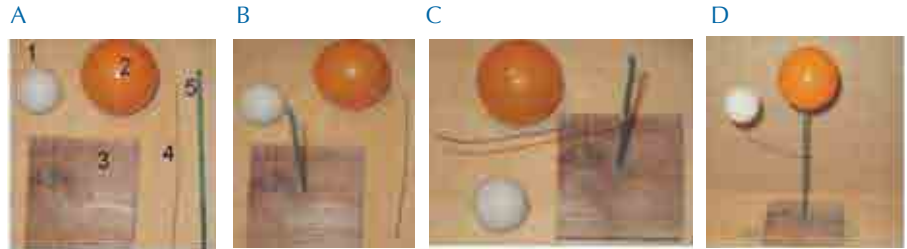
Furthermore, by using an external light source such as a desk lamp, pupils can examine the phases of the Moon as well as the concepts of solar and lunar eclipses.

Apparatus

- A piece of copper wire (10-15 cm long by 3 mm thick)
- A small wooden stick (15-18 cm long by 5 mm thick)
- 2 table-tennis balls (or use polystyrene balls of different sizes)
- A wooden base (10 x 5 x 1cm)
- A drill and a 5 mm drill bit

How to construct the Earth-Moon orbital

1. Drill a hole through the centre of the wooden base.
2. Insert the 15 cm stick into the hole.
3. Secure the copper wire to the middle of the stick by making two complete turns. The wire should remain firmly connected to the stick.
4. Using a pointed object (such as a small nail), make a small incision into the two table-tennis balls.
5. Place one table-tennis ball (representing either a planet or the Moon) on the free end of the copper wire – which will act as the orbital arm – and the second ball (representing either the Sun or Earth) on top of the wooden stick. Adjust the copper wire with the table-tennis ball to a position where the two balls are lined up with each other. If correctly constructed, the orbital arm will rotate around the central ball.



Images courtesy of the Next Generation project

Earth-Moon orbital construction: **A)** Apparatus needed for the Earth-Moon orbital; **B)** Insert the wooden stick into the wooden base; **C)** Attach the copper wire to the stick; **D)** Attach the balls to the stick and the copper wire

The model can be used to demonstrate the Moon's orbit around Earth or different planets in the Solar System orbiting the Sun.

Using an external light source to represent the Sun, the relative positions of the Moon and Earth can be used to examine the different phases of the Moon. For example, ask the class to observe what happens when the Moon is placed between the light source and Earth (no sunlight reflected from the Moon can be seen from Earth – no moon in the night sky), or when Earth is between the light and the Moon (all the sunlight reflected from the Moon can be seen from Earth – full moon). By placing the Moon in different positions relative to Earth (e.g. change the position by 45 degrees), the class can describe the amount of moonlight seen from Earth. This can be used to explain the different phases of the Moon.

Another suggested project is to ask the class to draw the shape of the Moon every night for one month; the drawings can then be used to chart the different phases of the Moon.

To investigate planetary movement around the Sun, additional orbitals can be attached to represent further planets and allow the class to examine the effects of planetary distance from the Sun on the planets' temperature, or the amount of time to complete one rotation of the Sun.

A useful website to accompany this project is the National Schools' Observatory demonstration of phases of the Moon^{w1}.

Yeast balloon

This experiment can be used to investigate topics including micro-

organisms and gases all around us. Pupils are encouraged to design an experiment to test different variables which affect yeast's ability to grow, and to investigate a by-product of this process, carbon dioxide.

Start by asking the children for their ideas on how humans use yeast and other micro-organisms as part of our everyday lives. Provide pictorial examples such as blue cheese, bread, beer, compost heaps and bacterial cultures. These examples demonstrate that micro-organisms are important for human survival. Ask the children what they think micro-organisms need to survive, and how humans have used this knowledge. You will need to explain that gas is produced as a result of yeast growth; ask the children if they know which gas is produced.

Ask the children to design an experiment that tests the conditions needed for yeast to survive, using the apparatus listed below. After they have planned their experiments, provide the children with the apparatus. They can use a variety of approaches to measure the gas produced, such as using string to measure the circumference of the balloon, or bubbling the gases into an inverted measuring cylinder filled with water to measure the volume.

Apparatus

- Three large balloons
- Three 500 ml plastic bottles
- Water
- Three 7 g packets of yeast
- Sugar
- Vinegar
- A thermometer

Table 1: Examples of experiments and demonstrations developed as part of the Next Generation project

Experiment/Demonstrations	Topic	Scientist
Water filtration system	Solids and liquids: how to separate them	Arun Arora
Woodlouse and maggot race	Movement and growth	Rachel Gomes
Liquid nitrogen	Solids and liquids: changing states	Gavin Jell
Lemon power station	Interdependence and adaptation	Dina Shola Laila
Pondweed and light	Interdependence and adaptation	Wayne Mitchell
Slinky soundwave	Changing sounds	Valerie Nadeau
Glitterbug	Micro-organisms	Catherine Reynolds
Heat in space	Earth, Sun and Moon	Berangere Tissot

- String
- A ruler
- Artificial sweetener (optional)

Method

1. Divide the class into groups.
2. Each group should design an experiment to test one or more variables affecting carbon dioxide production by yeast. To ensure a fair test, one condition must always remain the same; for example, you can change the amount of yeast placed into two bottles while making sure that the amount of water and temperature remains the same in both.
3. Pupils can choose to change variables including:
 - Temperatures ranging from room temperature to 60 °C
 - Amount of sugar
 - Type of sugar (e.g. artificial sweeteners)
 - Acidity of environment (vinegar).
4. Each group of pupils should draw up their experimental plan and hypothesis before starting their experiment. Encourage the pupils to make predictions of what they would expect to happen.
5. Once the groups have prepared their experimental plan, supply each group with 2 or 3 plastic bottles and balloons.
6. Pupils should measure and record the exact changes made to each variable.

7. The pupils can measure the amount of carbon dioxide evolved either by measuring the diameter of the balloon or by dipping the balloon into a measuring cylinder of water to calculate its volume.
8. The class could have a competition to see who can get the most carbon dioxide out of their yeast.

Allow the experiments to run for about 20 minutes before discussing the results. Pupils should state whether the results of their experiments agree with their predictions.

Ask the children as a group to identify the best conditions for yeast growth; they should suggest warm water and sugar. The pupils can also discuss what conditions prevented the growth of yeast: no sugar, cold water, or the presence of acids. What would happen if you use honey instead of sugar?

You can extend the lesson by investigating the nature of the gas produced – by weighing the balloon, or testing the effect of the gas on lit and glowing splints. The pupils could also try experiments to demonstrate how micro-organisms contribute to the gases all around us.

A description of the experimental set-up is available on the Exploratorium website^{w2}.

More activities from the Next Generation project

The table above shows some of the other activities developed as part of the project. More information on the

science activities used in the project, is available on the Next Generation website^{w3}.

The Next Generation project fosters close working partnerships between scientists and teachers. Delivering science in an engaging and informative manner is the catalyst to encouraging a better and wider understanding of science for our children. In time, it is hoped that some of the pupils involved will become the next generation of scientists, sparking interest in science among future children.

If you would like more information about the Next Generation project, please contact Wayne Mitchell (w.mitchell@imperial.ac.uk).

Web references

w1 – The National Schools' Observatory website includes a demonstration of phases of the Moon over time:
www.schoolsobservatory.org.uk/astro/esm/moonphs.shtml

w2 – The website of the Exploratorium in San Francisco, USA, includes further instructions for the yeast balloon experiment:
www.exploratorium.edu/cooking/bread/activity-yeast.html

w3 – The Next Generation website includes information about many science activities developed for primary schools: www.ng-project.com



Nanotechnology in school

Matthias Mallmann from NanoBioNet eV explains what nanotechnology really is, and offers two nano-experiments for the classroom.

Nanotechnology has become a popular buzzword in science and politics. This key technology is considered not only a major source of innovation in technology, medicine and other fields, but also one of the main challenges for the 21st century. European universities and high-level vocational training programmes already cover this technology extensively. However, although the word nanotechnology will be familiar to many high-school students, the subject is not widely taught in European schools. This article outlines several initiatives to increase awareness of nanotechnology among European science teachers, and details two nanotechnology experiments for the classroom.

What is nanotechnology?

Nanotechnology is not really anything new. It deals with entities and processes on the scale of 10^{-9} m (1 nanometre), which is the dimension of molecules and atoms – a scale that chemists, biochemists and cell biologists have worked with for centuries.

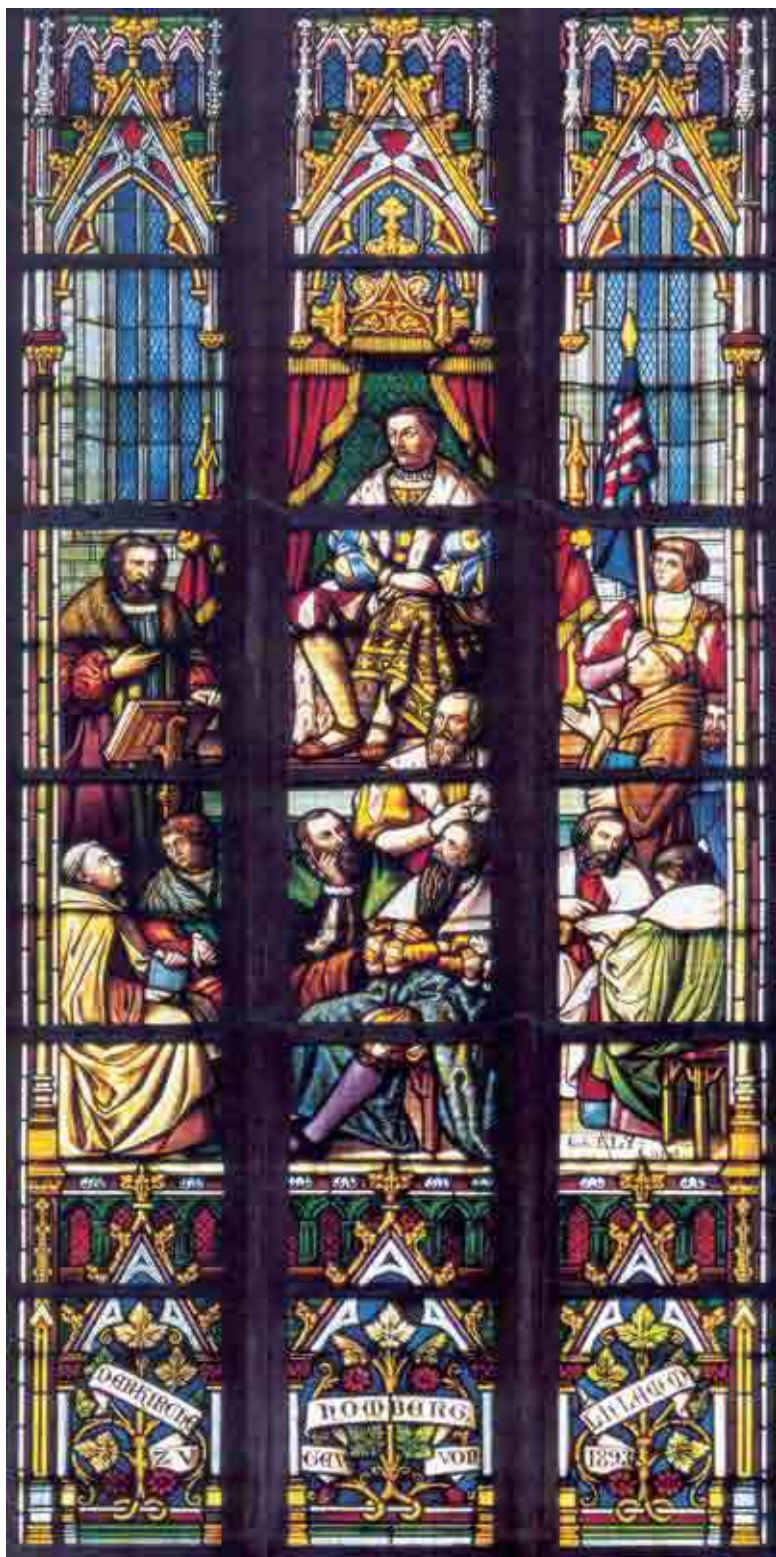
At the nanoscale, the properties of a material may change. For example, hardness, electrical conductivity, colour or chemical reactivity of minuscule particles of materials are related to the diameter of the particle. Specific functionalities, therefore, can be achieved by reducing the size of the particles to 1-100 nm.

A well-known application of early nanotechnology is the ruby red colour that was used for stained glass windows during the Middle Ages (see image on

page 71). The colour is a result of gold atoms clustering to form nanoparticles instead of the more usual solid form. These small gold particles allow the long-wave red light to pass through but block the shorter wavelengths of blue and yellow light. The colour, therefore, depends both on the element involved (gold) and on the particle size; silver nanoparticles, for example, can give a yellow colour.

What is new, though, is the multidisciplinary approach and the ability to 'look' at these entities. The atomic force microscope, which was developed in the late 1980s, allows scientists to view structures at a nanometric scale and to handle even single atoms via scanning probe microscopy. Now biologists can discuss steric effects of cell membranes with chemists, while physicists provide the tools to watch the interaction *in vivo*. Nanoparticles play an important role in the pharmaceutical industry (delivering active agents to the required part of the body), in the production of emulsion paint and cosmetics and in the optimisation of catalysts. Nanotechnology, therefore, has combined all natural sciences and creates cross-links between the different disciplines.

Living cell on an artificial nano substrate



Medieval stained glass windows using nanotechnology

the University of Cambridge^{w4}, offer visits to schools, interactive lectures, seminars and workshops.

Additionally, there are many online resources that provide information, films and games for schools and students^{w5}.

To fill this gap, the NanoBioNet eV^{w6} not only provides vocational courses and training for teachers, but has developed a multilingual (German, English and French) experimental kit (the NanoSchoolBox^{w7}) to teach school students about nanotechnology. Some of the experiments in the NanoSchoolBox are suitable for demonstration experiments; others can be integrated without too much preparation into hands-on lessons under the guidance of the teacher.

The experimental school kit includes 14 experiments and five exhibits which deal with the following topics:

- The lotus effect and technical applications of nanolayers
- Functionality through nanotechnology (showing different effects of nanotechnological coatings, such as scratch resistance, fire protection and the increase in electrical conductivity through indium tin oxide)
- Use of titanium dioxide in nanotechnology
- Ferrofluids
- Nano-scaled gold clusters



Pupils at the Saarlaboratory

Initiatives for schools

Some materials are already available to support science teachers in introducing their students to nanotechnology, although the materials tend only to be published in the national language. For example, the German Saarlaboratory Initiative^{w1} offers lab

days for whole school classes, while some European science museums and science centres^{w2} have exhibitions about nanotechnology or, like the German Nanotruck^{w3}, bring people closer to the subject using touring exhibitions that can be booked for public events. Some universities, like

Image courtesy of NanoBioNet eV

Image courtesy of Lehrstuhl für physikalische Chemie, Universität des Saarlandes



Images courtesy of NanoBioNet eV

Ferrofluids and the magnetic field

Although the experiments are intended principally for chemistry lessons, the interdisciplinary structure of nanotechnology means that some of them are also suitable for physics or biology classes. Below are two examples.

Ferrofluids

Ferrofluids are colloidal dispersals of extremely small ferromagnetic particles (i.e. particles that can be permanently magnetised by an external magnetic field), such as cobalt, nickel or iron, suspended in a hydrocarbon liquid. The particles are coated with a surfactant to prevent them from clumping together. Ferrofluids are the only magnetic materials in liquid form.

The NanoSchoolBox includes both ferrofluids for performing the experiment and instructions for making your own ferrofluids in the laboratory. Ferrofluids may also be bought from FerroTec GmbH⁸.

In this simple experiment, the ferromagnetic particles align themselves with the magnetic field lines around a magnet, thus making the magnetic field visible.

Materials

- Ferrofluid
- Empty crimp-top glass tube
- Tenside solution (surfactant)
- Magnet
- Pipette
- Water

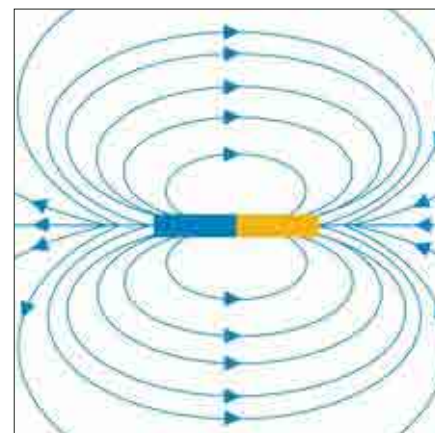
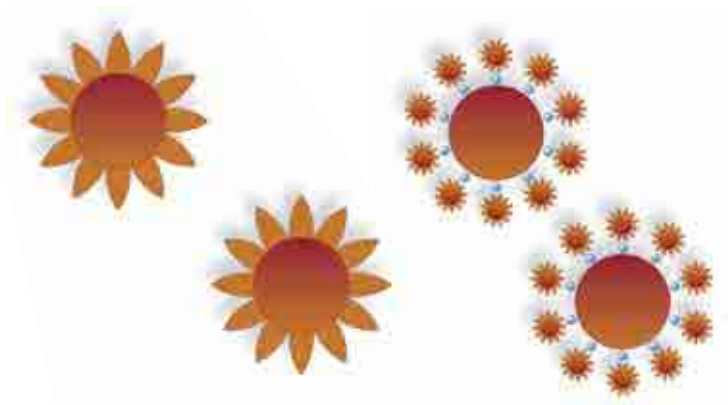
Procedure

1. Fill the tube three-quarters full of water and add 2-5 drops of tenside solution (surfactant).
2. Carefully use the pipette to add a few drops of ferrofluid, which will settle at the bottom.
3. Close the tube tightly.
4. Bring the magnet close to the ferrofluid.

As the particles try to align themselves with the magnetic field, a typical 'porcupine' is formed, the prickles representing the magnetic field lines (see images above). Surface tension of the fluids and gravity counteract the magnetic field with the result that ordered structures are created in the liquid as a reaction to the three forces.

5. Try moving the ferrofluid through the water with the aid of the magnet. Depending on whether the magnet is held parallel or vertically to the surface of the ferrofluid, the orientation of the magnetic field changes and, consequently, the orientation of the fluid changes.
6. Shake the tube gently to disperse the ferrofluid in the water. As the ferroparticles do not dissolve, they eventually settle at the bottom. You can accelerate this process with the aid of a magnet, observ-

Diagram showing the composition of ferrofluid particles



Magnetic field lines

Image courtesy of NanoBioNet eV

Image courtesy of NanoBioNet eV

ing beautiful effects. To achieve this, draw the magnet past the side of the tube quickly and away again. In this way, you accelerate the ferrofluids and produce streaks, clouds, and so forth.

Safety notes

- Ferrofluids must be handled with great care and in a clean environment because they leave permanent stains.
- Wear a laboratory coat, gloves and protective goggles. If your skin comes into contact with a ferrofluid, wash the area with soap.
- Keep ferrofluids in a sealed container at all times in order to prevent evaporation.
- The ferrofluid and the materials soiled with the substance should be disposed of in the same way as motor oil (as hazardous waste or at a collection point) and not poured down the sink.

Nanoscale gold

Research scientists use the light-absorbing property of gold particles to detect biomolecules. For example, antibodies can be tagged by coupling them with gold particles. When a white light is shone on them, the red colour of the metal particles is visible. This is applied in some cases in home



BACKGROUND

Further information

For further information, please contact
 NanoBioNet eV:
www.nanobionet.de
 Email: info@nanobionet.de
 Tel: +49 (0)681 685 7364

pregnancy tests, in which gold nanoparticles are finely distributed on the test strip.

The UltiMed® pregnancy test, for example, relies on this principle to detect human chorionic gonadotropin (hCG), a hormone released early in pregnancy by the fertilised egg and the lining of the uterus. hCG consists of two subunits: a and b. On the test strip, a-subunits of hCG are immobilised, forming a line that will turn red to indicate a pregnancy. Elsewhere in the strip, colloidal gold particles are tagged with monoclonal antibodies specific to the b-subunit of hCG.

When the strip is dipped in urine, the liquid allows the tagged gold particles to move through the strip by

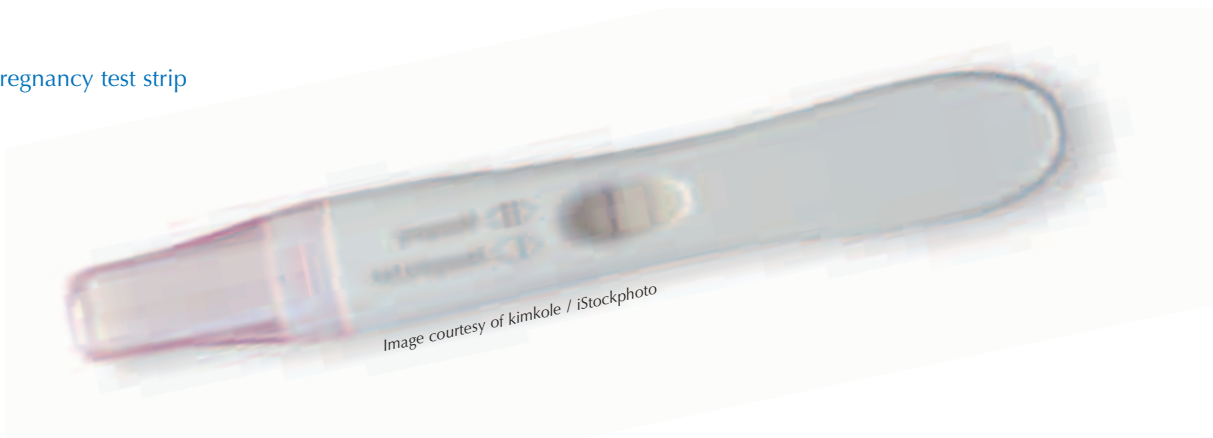
capillary action. If the urine contains hCG (i.e. if the woman is pregnant), b-subunits of hCG bind to the tagged gold particles. When the b-subunits bound to the gold reach the immobilised a-subunits, the a- and b-subunits bind together, forming a gold-hCG complex. If the concentration of hCG is high enough, the complex is visible as a red line, indicating that the woman is pregnant. Further gold particles bind to a second line, indicating that the test (whether positive or negative) was correctly performed.

In the following experiment, we will produce nanoscale gold clusters, which are easily detected by their typical ruby-red colour. One way of producing nanoscale gold, described here, is the citrate method. This involves producing either colloidal gold or gold clusters in a solution.

A cluster, or nanoparticle, is a collection of 3 to 50 000 atoms. The diameter of the gold nanoparticles is generally between 12-18 nm. If the clusters are spatially distributed in another physical medium, the entire system is known as a colloid.

The experiment is based on a redox reaction of tetrachloraurate (also known as tetrachlorauric acid or tetrachlorauric (III) acid trihydrate), in which gold ions are reduced to atomic gold clusters. The reductant sodium

Pregnancy test strip



citrate (also called trisodiumcitrate dihydrate) not only reduces the gold but also acts as a dispersion medium to stabilise the gold clusters that are created. By adding the reductant, the atomic coagulation of the metal ions is halted and the result is a colloidal cluster enclosed by a ligand case.

Those colloids are detected by the Tyndall effect. This occurs when light is shone through a colloidal suspension: the light path can be seen in the liquid as visible light is scattered by suspended, microscopically small particles, the diameter of which is in the order of magnitude of the wavelength of visible light (400-800 nm). In contrast, when light is shone through a solution without colloids (e.g. ink), the light passes through without being scattered, so the light path is not visible.

Materials

- Auric chloride solution, HAuCl_4 (0.1 g auric chloride in 20 ml H_2O)
- Citrate solution, $\text{C}_6\text{H}_5\text{Na}_3\text{O}_7 \times 2 \text{H}_2\text{O}$ (5.7 g in 0.5 l H_2O , filtered)
- Distilled water
- Hotplate or immersion heater
- Something for stirring (spoon, stirrer or similar), ideally a heatable magnetic stirrer
- 1 fireproof glass beaker (50-100 ml)
- Thermometer (up to 100 °C)
- Laser pointer (optional)

Safety note: Auric chloride is caustic and harmful if swallowed.

Procedure

1. Add 0.5 ml (approx. 15 drops) auric chloride solution to 28 ml distilled water.
2. Heat the solution to 100 °C on the stirrer or hot plate.

3. Once the solution reaches 100 °C and starts to bubble, add 1.5 ml citrate solution as quickly as possible, stirring vigorously.

The initial red colour of the auric chloride solution intensifies until it becomes a deep red. At temperatures between 85 and 90 °C, it will take approximately 5 minutes until the colour changes; at 100 °C, the reaction is even faster.

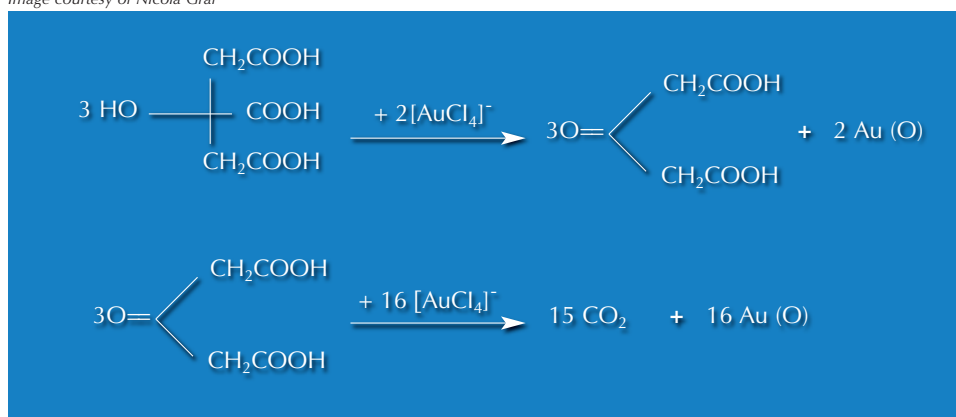
Depending on the size of the particles formed, you may get a violet colour instead of red.

4. The gold colloids can be detected through the Tyndall effect. Use the laser pointer to shine light sideways through the solution. The light path can be observed as it passes through the solution.

Additional experiments

For comparison, repeat the experiment with 0.5 ml auric chloride solution and 50 ml distilled water.

Image courtesy of Nicola Graf



Chemical equation for the production of gold clusters

Image courtesy of NanoBioNet eV



The Tyndall effect in a gold colloid solution

- w5 – For a list of useful links about nanotechnology for schools, see: www.nanoscience.cam.ac.uk/schools/links.html
- w6 – The NanoBioNet eV website can be found at: www.nanobionet.de
- w7 – For more information on the NanoSchoolBox, see: www.nanobionet.de/12105_11931.htm
- w8 – Ferrofluids may be ordered from FerroTec GmbH: www.ferrofluid.de
- w9 – For more information on Nano2Life, the first European Network of Excellence in nanobiotechnology, see: www.nano2life.org

Resources

For a further medieval application of nanotechnology, see:

Capellas Espuny M (2003) Renaissance artists decorated pottery with nanoparticles. *ESRF Newsletter* 38: 4-5. www.esrf.eu/UsersAndScience/Publications/Newsletter

Matthias Mallmann is responsible for the vocational training activities in the German NanoBioNet eV network. He is also in charge of communication within the EC-funded network of excellence Nano2Life^{w9}.



Compare the time needed for the colour change to occur.

If you increase the citrate concentration in a further experiment, the colloids will have a deep violet colour, a result of colloids of a different size forming.

Web references

- w1 – The German-language website for the Saarlabor Initiative can be found here: www.saarlab.de
- w2 – The website for Ecsite, the European network of science centres, can be found here: www.ecsite.net
- w3 – The Nanotruck website (in German or English) can be found here: www.nanotruck.de
- w4 – For more information on nanoscience from the University of Cambridge, see: www.nanoscience.cam.ac.uk/schools



In spite of being a popular buzzword, looked on favourably by European citizens (see Eurobarometer 2005 survey), nanotechnology means something more futuristic than real to most people, including students.

Matthias Mallmann's article, starting from ancient stained-glass windows, addresses the topic in a friendly way. Beginning with the resources for teaching nanotechnology available in Europe, he then presents new didactical material (NanoSchoolBox) by means of some hands-on experiences that can be performed with it.

I recommend this article to upper secondary-school science teachers willing to introduce nanotechnology by linking it to real-life applications. The material is also suitable for students interested in deepening their understanding of the topic with the help of the quoted web resources.

The style and level of detail are suitable for non-native English speakers provided they have a scientific background. The examples and suggestions given make it possible to use the article for linking different science subjects (physics, chemistry, biology) or for widening the activity to aspects related to history or to active citizenship (the safety issues).

Giulia Realdon, Italy

REVIEW

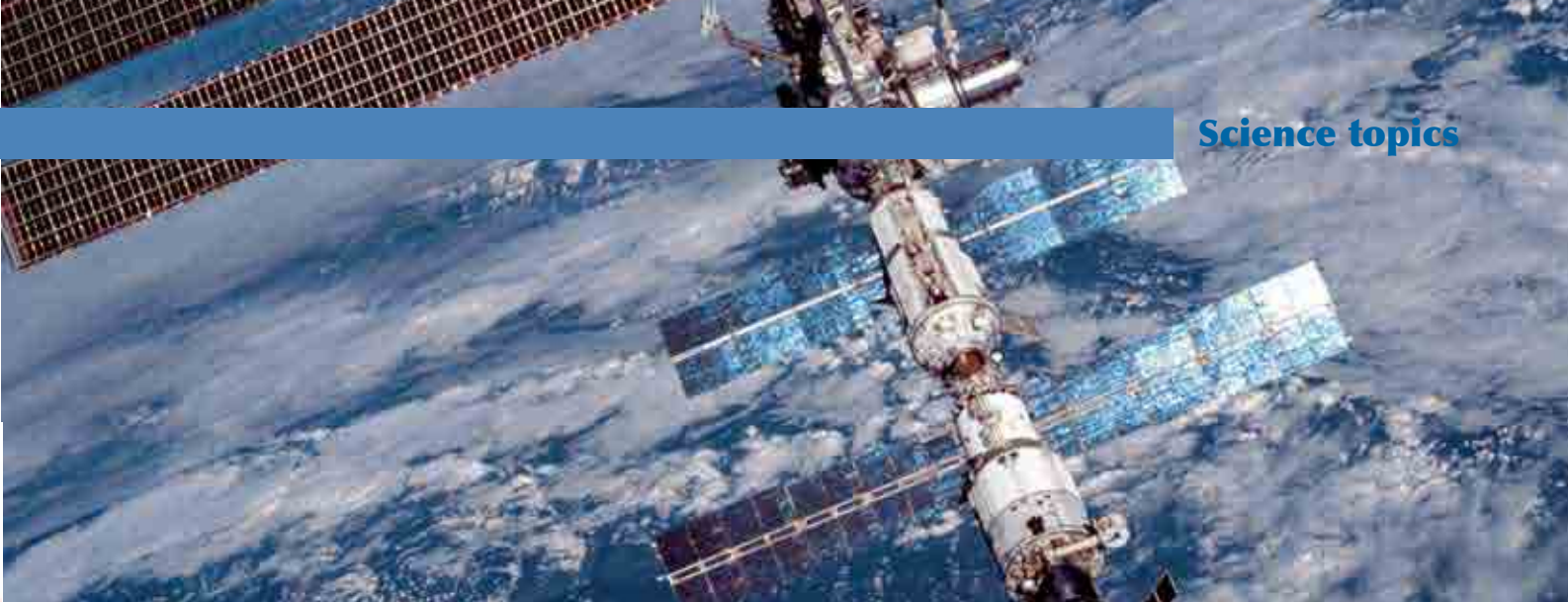
The International Space Station: life in space

Image courtesy of ESA



A large window installed in the Kibo laboratory provides views of Earth

How do astronauts eat, sleep and wash? Can you get 'seasick' in space? In the second of two articles about the ISS, **Shamim Hartevelt-Velani**, **Carl Walker** and **Benny Elmann-Larsen** from the European Space Agency investigate.



The ISS on 20 August 2001

Image courtesy of ESA

Life on board the Station

By Shamim Hartevelt-Velani and Carl Walker

What is life like for the astronauts on board the International Space Station (ISS)? The Earth environment that most resembles the microgravity experienced on the ISS is water – which is why astronauts train in large swimming pools. Inside the ISS, astronauts can play with floating drops of water and, instead of walking, can push themselves off the walls and drift through the air.

Astronauts experience 16 sunrises and sunsets in one day, as the ISS orbits Earth every 90 minutes. This is difficult to adapt to, and they sleep an average of 5-6 hours per day instead of the 7-8 hours of sleep they enjoy on Earth. They do, however, observe a strict work/sleep schedule. Lack of sleep can, of course, be caused by the excitement of the first steps in ‘weightlessness’, the magnificent views of Earth and the darkness of the cosmos.

The crews spend around 160 man-hours per week doing scientific experiments; the rest of their time is spent on maintenance, Station control activities and spacewalks. Spacewalks (or extra-vehicular activities, EVAs) are necessary for construction, maintenance and for the installation of scientific components outside the Station. Sunday is generally a day of rest, although some experiments continue to run and must be monitored.

The astronauts need to take good care of themselves on board, and their health and safety are priorities. They must be in good physical and mental condition. They eat three meals a day, and mealtimes are important for the crew to socialise. There is a kitchen area where food can be heated, a fridge-freezer and a table. There are tethers on the floor to hook feet onto, to keep astronauts in a sitting position, but often they eat while floating around. Velcro is used to secure the various food containers on the table

and prevent them from floating off. Most of the food is freeze-dried, frozen, thermostabilised or ready to eat. These treatments and the conditions of ‘weightlessness’ mean that the taste of food is often impaired (somewhat like trying to eat when you have a heavy cold).

The range of nationalities on board means that the diet has to be carefully chosen. Astronauts can state their own dietary preferences before beginning their stay on the ISS, but they are free to change their minds during a mission, as long as the nutritional value (2800 calories per day) is maintained. Food is periodically delivered from Earth in cargo spacecraft (such as ESA’s ATV or Russian Progress vehicles).

There are also dehydrated foods and drinks which are reconstituted by adding water. Syringes are used to rehydrate single portions of food to avoid waste: water is a precious commodity. Transporting water to the ISS

Italian ESA astronaut Paolo Nespoli, STS-120 mission specialist, rests in his sleeping bag in the Harmony node of the ISS while Space Shuttle Discovery is docked with the Station

Crew member Greg Chamitoff plays a game of chess in the Harmony node of the ISS



Images courtesy of ESA



Italian ESA astronaut Paolo Nespoli seen during a meal on board the ISS



Images courtesy of ESA



ESA astronaut Kuipers and his NASA colleague Foale eat Dutch cheese for breakfast on board the ISS

Leopold Eyharts undergoes physical training in the ISS

is very expensive, so some water is recycled from the cabin itself by condensation. Because water needs to be conserved, non-foaming toothpaste is preferred. Wet wipes are used for personal hygiene. Astronauts will have their first shower when they return to Earth.

There is no 'up' or 'down' in space. Sleeping involves wrapping yourself in a sleeping bag attached to the wall. The astronauts use ear plugs to keep out the noise of the life-support systems that are continuously running, as well as sounds caused by the thermal expansion and contraction of the ISS itself. They try to secure their free-floating arms, which could end up blocking the air tubes that circulate

the air in the ISS and cause a dangerous build-up of carbon dioxide in one place.

The temperature is maintained at a comfortable level by the air-conditioning system so astronauts can wear light clothing. Air pressure is kept the same inside as on Earth. During launch and landing, or when performing spacewalks outside the ISS, astronauts wear special pressurised spacesuits to protect them from the extreme conditions.

The men and women chosen as astronauts work as a team. Their training helps them to cope with the lack of privacy and to be able to live in such an environment for months at a time. It becomes home for them.

Physiological effects of a 'weightless' environment

By Benny Elmann-Larsen, ESA Senior Physiologist

Humans and other living organisms have adapted to life on Earth for millions of years, in conditions that include Earth's gravity (1 g), a specific temperature and humidity range, and a certain oxygen pressure. These are 'normal' conditions for us.

When flying out into space, we are initially exposed to greater forces during launch. Modern jet fighter pilots can often be exposed to around 9 g (compared with 4 g during the Space Shuttle launch), which is considered the limit for what the human body can sustain for some seconds without harm.

On Earth, gravity helps us to tell what is up and down, and to feel if we are moving. The sensors in our balance and movement system (in particular the inner ear and eyes) use gravity as a reference. On an orbiting spacecraft, the lack of gravity makes it difficult to tell what is up or down.

During the first hours or days in 'weightlessness', astronauts often encounter a mismatch between sensors in their balance system, which coordinate inputs from their eyes and inner ears (registering movement and velocity) and from joints and muscles. In many astronauts, this causes something similar to motion sickness on Earth – which is also caused by confusion in the balance-movement-vision system. The astronauts feel unwell and nauseous until their body has 'learned' the new rules, i.e. has reprioritised the different nerve signals. Eventually, a stable condition is achieved in which the astronaut's visual input becomes dominant.

As the normal effect of gravity disappears in the spacecraft, everything in the body that is commonly influenced by gravity behaves differently as well. The loading of the bones is different since the skeleton does not have to carry a bodyweight, and the muscles have a much easier task moving the astronaut around.

The movement of blood in the circulatory system is also affected in space. The heart is a pump and a muscle at the same time: the muscle contractions push the blood around the body, and this circulation (which is influenced by gravity) ensures that the pump always has a supply of blood to move. If the return of blood to the heart is insufficient, it will pump smaller and smaller volumes, and eventually collapse.

What happens to the circulatory system in space is similar to what happens if you lie down on Earth. The circulation works best at a certain blood pressure (which is why we can

have problems if our blood pressure is too high or too low). When we lie down, blood returns to the heart more easily, so the heart does not need to pump as hard as when we are standing. If the circulatory system did not adjust to this new situation, blood pressure would increase. Therefore the arteries in the systemic system (carrying oxygenated blood from the heart to the rest of the body) relax, enabling the blood to flow with less overall resistance and returning the blood pressure to normal. When the heart fills with blood (diastole), the heart muscle relaxes more than it does when we are standing, resulting in a larger volume of blood being pumped per beat, but with fewer beats per minute.

This is very similar to what takes place when astronauts first enter weightlessness: the lack of gravity means that blood returns more easily to the heart – reducing the need for forceful pumping – and also shifts from the astronauts' legs into their chests and heads. Their faces tend to become puffy and their sinuses swell. This fluid shift initially increases the blood volume as more water enters the blood stream – mainly from the tissues in the legs. This extra water in turn thins the blood to some extent and, after a few days, the kidneys start to excrete more salt and water, to mimic the normal situation on Earth. Although the slightly puffy heads and stuffy sinuses may remain, the situation improves after the first few days.

(This process starts on the launch pad if the astronauts have to wait in their seats, lying on their backs, for two hours or more. When they finally get out of their seats in orbit, there is often a queue for the toilet!)

Upon return to Earth, gravity will pull those fluids back down into the legs (pooling) and away from the head, which could cause the astronauts to feel faint when they stand up. But as they also begin to drink more, their fluid levels return to normal in a couple of days.

ESA astronaut Hans Schlegel in Shuttle aft flight deck shortly after Atlantis undocked from ISS



Image courtesy of ESA



Image courtesy of ESA

Spacewalk to repair the Station's torn solar array

Finally, what makes an astronaut put up with the danger, the 'spacesickness', the cramped conditions and the lack of privacy? *Science in School* asked German astronaut Thomas Reiter.



Image courtesy of ESA

"[Being an astronaut] 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!

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

ESA astronaut Thomas Reiter assists NASA astronaut Jeff Williams with his spacesuit, preparing for an extravehicular activity

Shamim Hartevelt-Velani is a secondary-school teacher currently working under contract at ESA's European Space Research and Technology Centre (ESTEC), in the

Directorate of Human Spaceflight. She is the didactics specialist in the education team.

Carl Walker is ESA's corporate writer and editor, based at ESTEC. He

writes and edits a wide range of books and other communications materials about spaceflight and the European space programme.

Benny Elmann-Larsen is the



REVIEW

This is a very interesting article. The content is quite simple, which will make it readily accessible to non-specialists; I can see myself using it with students as a reading-for-information exercise. With the exception of the section on the effect on the circulatory system, the article would be suitable for most ages.

This article – the second of two – discusses a number of the medical and biological aspects of space flight – an area that many students are unaware of. The article shows the difficulties involved in manned space flights and how they can be tackled.

The resources linked in this article are very impressive and show ESA's commitment to education. They are well worth ordering or taking the time to download.

Mark Robertson, UK

- An interactive version of the ISS Education Kit is available for everyone at www.esa.int/spaceflight/education
 - A series of ISS DVD lessons covers topics relating to European school curricula. These are based on Project Zero Gravity and there are four in the series. The latest, Space Robotics, is now available to all school teachers in ESA member states and can be ordered free online: www.esa.int/spaceflight/education
 - A new DVD on the physics involved in the Automated Transfer Vehicle (ATV) is due to be released in 2008. DVDs can be ordered free by teachers: www.esa.int/spaceflight/education
 - ESA is also developing a series of online lessons for primary- and secondary-school students and their teachers. See: www.esa.int/SPECIALS/Lessons_online
 - A new Space Exploration Kit 1 for primary schools will be released in 2008.
 - Further details and education materials:
ESA Education website: www.esa.int/education
ESA Human Spaceflight Education website: www.esa.int/esaHS/education.html
- As part of the International Astronautical Federation's 2008 symposium, Celebrating Ten Years of the International Space Station, a panel of ISS crew members answered school-students's questions about living and working on the ISS. The video can be watched online:
www.iafastro.org/index.php?id=541



senior physiologist at ESA. He worked as the mission life scientist on two Spacelab missions (1985 and 1993), and two missions to the Space Station Mir (1994 and 1995), on the second of which he worked closely with Thomas Reiter. He managed the first European long-term space simulation bed-rest studies in 2000-2002 and is now editing the *Human Spaceflight Science Newsletter*, issued on behalf of the Research and Operations Department at ESA.

Resources

For the first of the two ISS articles, see:

Hartevelt-Velani S, Walker C (2008) The International Space Station: a foothold in space. *Science in School* 9: 62-65.
www.scienceinschool.org/2008/issue9/iss

For the complete interview with Thomas Reiter, and other related articles from *Science in School*, see:
Warmbein B (2007) Down to Earth: interview with Thomas Reiter. *Science in School* 5: 19-23.
www.scienceinschool.org/2007/issue5/thomasreiter/

Wegener A-L (2008) Laboratory in

space: interview with Bernardo Patti. *Science in School* 8: 8-12.
www.scienceinschool.org/2008/issue8/bernardopatti/

Williams A (2008) The Automated Transfer Vehicle – supporting Europe in space. *Science in School* 8: 14-20. www.scienceinschool.org/2008/issue8/atv/

Many hundreds of images, videos and animations about human spaceflight are available on the ESA website: www.esa.int/esa-mm/mmg.pl?collection=Human+Spaceflight and can be used for education purposes.

ESA has 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



Regensburg on the river Danube, Germany

Nadia at her desk

Image courtesy of Marlene Rau

Originally, Nadia Salem wanted to become a research biologist and find a cure for cancer. Today, she is a reporter for *Nano*, a daily science magazine on German-language TV. Nadia talked to **Marlene Rau** about the unpredictability of life and the joys of being a science journalist.

The winding road to science journalism

Sweetcorn

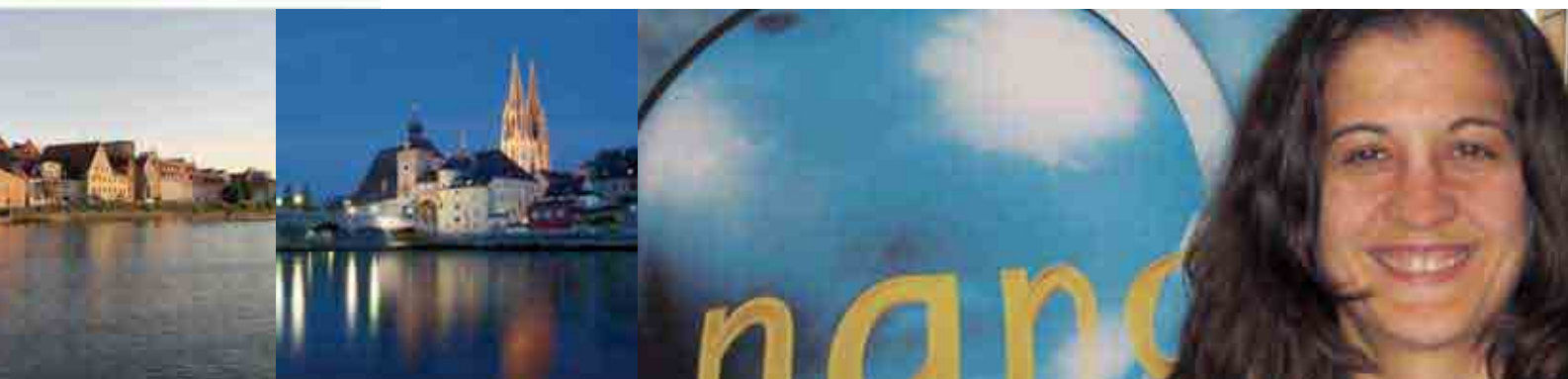


Image courtesy of Kilomb691; image source: Wikimedia Commons

Nadia has been interested in biology, and anatomy in particular, from an early age: “We used to have dogs when I was little, and I liked to run to the butchers to fetch them the cows’ hearts that we fed them, because I was intrigued by the course of the blood vessels. I also enjoyed dissecting frogs or any other dead animals I could find.” Her dearest memories from school are of teachers who were passionate about their subject, and whose enthusiasm was contagious. The biology lessons she

remembers best are those in which teachers either took the class on a field trip or let them do hands-on experiments. And such an experiment can be simple – just dissecting an earthworm and starting to understand how all body parts are assembled can be extremely fascinating.

It was clear Nadia would go on to study biology or medicine. Being a true Bavarian girl, she only managed to move 125 km, from Munich to Bavarian Regensburg, a university town famous for its medieval centre,



Images courtesy of Karsten Dörre; image source: Wikimedia Commons

Image courtesy of Marlene Rau

to study biology. “This is really *the* life science. You learn all the basics, from amoebae to humans and up to medical aspects. We had a lot of chemistry, physics and mathematics classes, too, and you start to understand how it all fits together. It was really rewarding, learning something about and for life.”

Nevertheless, you decided not to work as a scientist. When did things change?

“The disillusionment started when I realised that I found it all very tedious, really. You do experiments all day, and mostly go home with no results. Being a scientist sounds so exciting, when you look at the results, but getting there takes a lot of detailed painstaking work and you really have to specialise. I wanted results at the end of a day or week, not after years, so I decided I was not cut out to be a scientist. It was hard, after five years of studying, to admit to myself I did not really want to work as a biologist. I had to learn to separate my fascination for science from actually being a scientist, and found that there are other ways to work with science. It was not all bad, because I started asking myself what other talents I had which I was not using. These were a knack for communication, a quick grasp of things, and a love for telling stories.”

So science journalism was the obvious choice?

“My boyfriend said I should try journalism, since I talk all day anyway. Additionally, a friend of mine, who is now also part of the *Nano*^{w1} team, was studying journalism at Mainz University^{w2}. It sounded so cool that I wanted to go too. I have never once regretted it.

“There is something I would like to tell all young people: never let anyone discourage you from something you really want. Be brave and do not be afraid to take a side road in life or start something new. You will always learn something, for example ‘soft’

skills: dealing with people, structuring a project or simply being proud of having achieved something. To most employers, your personality and motivation are at least as important as your career path. So have the courage to be original and do not always assimilate to the rest.”

What was studying journalism like?

“At Mainz University, graduates of any other subject can do a two-year master’s degree in journalism. There is an admission test, and only about 25 people are admitted each year. The first year was dedicated to print and online media, the second to radio and TV. Learning groups are very small, and you are expected to work in your spare time – in the media, if possible. I got my first job only a month into studying, in the newsroom of a sports programme at the ZDF^{w3} (Zweites Deutsches Fernsehen, a publicly funded national German TV station, located in Mainz). We also had to do internships – and I tried to choose the ‘best of’s’, starting out at the dpa^{w4} (Deutsche Presse-Agentur, the biggest German press agency) to get an idea of how the original sources work, and then went on to do audiovisual work. I never worked for print media because I knew that was not my cup of tea, but I found both radio and TV attractive. Eventually, since my first job was in TV, this is where I ended up.”



Image courtesy of Christian Koehn; image source: Wikimedia Commons

The broadcasting center in Mainz

Image courtesy of Nano



The cockpit of the A380 as seen on Nano

What does it take to be a science journalist and what do you like about it?

“Basically you act as a translator: so many interesting but complex things happen in science, and someone needs to break them down for the public to understand. Of course, first I have to understand them myself, since I, too, know next to nothing about some areas of science. Being curious is important, but you also need a sixth sense for knowing which science stories are worth telling. Besides making science intelligible, you also have to highlight the connections, make it interesting and exciting,

The cockpit of the Airbus A380

engage the public, and tell a good story.

“The best part for me is that you get to meet all kinds of interesting people, and see and do things you would normally not have access to. Being a TV journalist opens doors. I have witnessed brain operations in the operating theatre, sat in the cockpit of an Airbus A380^{w5} (the biggest commercial aircraft ever) – these experiences are very rewarding.”

What does a working day look like for you?

“This week I am on news duty – there is a rota. You go through the agency news in the morning, then you find corresponding footage in the archives or maybe send out a team to shoot something up-to-date, edit the video sequences and prepare the text for the voice-over, which is done by a professional speaker. You produce a 1:30 minute clip to be ready by 2 pm, and if anything exciting happens during the day, there can be last-minute changes. It can get a bit hectic.

“Normal everyday work – unlike news duty, which the reporters have

Image courtesy of Nano



Inspecting GM sweetcorn, an excerpt from a Nano broadcast

to do about every three or four weeks, can look very boring from the outside. First you have the research phase, where you sit at your desk, search for information on the web, phone people and put things together. You find a topic, try to get a picture of the details involved, write a script, prepare and organise everything. You have to find the right people, the locations, and so on.

“One of my current topics is genetically modified (GM) sweetcorn, since it is now allowed to be sown in Germany. I am trying to find an ideal setup of two people – a farmer who

Image courtesy of Naddsy; image source: Wikimedia Commons



wants to use GM sweetcorn and who is the neighbour of an organic farmer. I want to see how they deal with it, with their different fears: the organic farmer who does not want his crops contaminated, and the GM farmer who is afraid that his crops will all be ruined by some pest – and therefore wants to use GM sweetcorn. We will use this framework to explain what GM sweetcorn actually is, whether you need to be afraid of it, and also that the ecological consequences are not clear.

“When everything is set up, you go out to do the shooting, which is the nice bit. You meet the camera team and the people being filmed, and try to convert your idea of the story into a nice film. As a reporter on location, you have to be a multitasking entertainer: if you go to a hospital, say, for a story on a new cure, the doctor will keep telling you complicated things, you have to make sure that the patient is physically and emotionally comfortable, the press officer will probably be there, then somebody



Image courtesy of Marlene Rau

Reporter Nadia Salem and cutter Matthias Stein in the cutting room



Nano and the Nano-Camp

Nano^{w1} is a daily science programme on 3sat^{w7}, a German-speaking TV station in Mainz that was founded in 1984 to broadcast cultural programmes. It is a publicly funded station, run by seven TV stations (German ZDF^{w3}, Austrian ORF^{w8}, Swiss SRG^{w9} and the regional TV stations of German ARD^{w10}). *Nano* has been on-air since 1 December 1999 and was the first daily science programme on German publicly funded TV. A team of 20 people, many of them scientists, works in the newsroom at the ZDF campus in Mainz, where the programme is produced. Science journalists from all seven TV stations meet for a daily video conference to agree on topics, for which they all supply footage. Three moderators, two of whom are physicists, take turns in presenting the 30-minute programme. A lot of the footage can be watched online, in the 3sat ‘Mediathek’^{w11}.

The ZDF campus can be visited free of charge, including a guided tour behind the scenes^{w12}. Special tours can be organised for school classes. ZDF also offers short internships for girls between 10 and 15 as a part of Girls’ Day^{w13}, a national German initiative aimed at starting more girls out on a career in science and technology. ZDF is also a partner of the Mentorinnen-netzwerk für Frauen in Naturwissenschaft und Technik^{w14}, a mentoring network for female school stu-

dents interested in science, university science students, and young scientists, in the federal state of Hessen, Germany.

Since 2002, *Nano* has also organised the *Nano-Camp*^{w15} every summer together with the Helmholtz Centre for Environmental Research^{w16} (UFZ). This is a one-week science camp for 12 German, Austrian and Swiss students aged between 16 and 18 years, co-funded by Germany’s centre of expertise for science communication, Wissenschaft im Dialog^{w17}, and the science journal *Bild der Wissenschaft*^{w18}. The students can apply individually and are chosen for their motivation. They have the opportunity to conduct their own research and are presented on TV in *Nano*. In 2008, the year of mathematics, they used applied mathematics: in the UFZ location in Leipzig they modelled climate predictions. Additionally, they drilled ten metres deep into the soil of Bitterfeld, an East German town infamous for its chemical industry and the environmental consequences thereof, to find out which microorganisms are decomposing the organic toxins. Since most terrestrial microbes are still unknown, this was cutting-edge research. Mathematics helped in the form of formulae and computer power, using the 3D-Cave – a virtual reality box – to visualise the invisible underground.



The Nano team in front of the broadcasting center in Mainz

from another department will turn up who also has a great idea for TV – you really need to have huge ears and eyes to communicate with everyone. And of course you have to keep an eye on the work of the camera team. You have to fulfil everyone’s need for information, without forgetting to check everything is done correctly and on schedule. You also have to be a bit of a psychologist, to put people at ease who may be shy in front of the camera, or to tell a worried doctor you will cut out embarrassing things he may have said or done. Although it looks as if the cameraman is doing all the work, it can actually be quite exhausting for the reporter, too. And then there are of course the days when nothing works – the train is late, the doctor is ill, the cameraman is in a bad mood – so you need to have some talent for improvisation, too.

“We usually make people the focus of our science stories. It is wonderful to meet all sorts of people and get a snapshot of their lives. Sometimes you see tragic stories, too – there was this guy in his mid-thirties, just two years older than me, who used to be a workaholic. Now he is paralysed, but fully conscious, suffering from a dis-

ease with no cure. To see that this can happen to someone your age, from one day to the next, really hits you and puts things into perspective. To see how such people cope inspires a lot of respect in me. Nevertheless, they are still just part of your work, rather than your life.

“Separating this is not always easy, though. But you have to be tough, even though it is hard – when the feature is done, it is done, and it was just another story. At least we are a respectable programme and we definitely try not to betray people’s trust. I try to console myself with the fact that if nobody were to report on this at all, no one would know, and that would not be good either, would it?”

“After we have done all the shooting, we need to look through all the footage. Most people find this extremely boring and try to postpone it, but of course it has to be done. Editing the material, however, is much more exciting, although it is very labour-intensive: for one minute of final video material, you can expect to spend at least one hour sitting at the cutting machine. You give the directions, and the cutter does the technical bit. Of course they also contribute their own ideas and, impor-

tantly, they are your first audience – if they don’t understand the story, you have probably done something wrong. When everything falls into place, and what you thought up in the planning phase actually works well, it is just great. As a last step, there is the voice-over, and at the end, you have a finished feature to be broadcast.”

What are your suggestions to anyone interested in becoming a science journalist?

“I think science journalism is booming. Every German TV station has its own science programme, but of course they are of different qualities and aimed at different audiences. I think people really want to know and understand, and the world is getting more and more complicated. So there is definitely a market, and I think it is a job for the future. Not only on TV, but also in other media and elsewhere: a press officer at a car company, for example, needs to be able to explain how a hydrogen engine works nowadays.

“I would advise anyone who wants to become a science journalist to first study a science – whichever science suits you best. It gives you an insight into the way scientists work, which you could never have otherwise. And while I of course do not remember the details of everything I learned, it is very valuable to have understood the basic principles. Nevertheless, I also know good science journalists who have never studied science – they were just always interested in the topic. Sometimes this may even be an advantage, because it is easier to step back and simplify a topic you are not too close to. But I personally find it very helpful to have studied biology.”

What are your own plans for the future?

“I think I will continue to work as a TV science journalist for a while – I really like my job. Additionally, I

oversee Mainz Campus-TV^{w6}, a university TV station run by students of all subjects, and I teach TV journalism to the master's students. I really enjoy that. Last year I also gave media training to scientists at the university. I didn't expect it to be so much fun! I first thought I would be able to tell them nothing interesting, but it turned out I did know many things that were useful to them. All they wanted to know was how to react when a reporter turns up and asks questions: what to tell them, how far to simplify, and things like that. Obviously, this is something I deal with every day, standing on the other side of things, thinking 'Gosh, can't you speak straight and stop using foreign words for once?' So this is another thing I would like to follow up on. And then, who knows? When I was 20, I would never have thought I would end up as a TV reporter, and yet 18 years later, here I am."

Web references

- w1 – For more information on the *Nano* TV science programme, see: www.nano.de
To watch a 'making of' movie, click on 'Making of "nano"' in the 'redaktion' section
- w2 – For more information on the master's of journalism degree at the

Johannes-Gutenberg-Universität Mainz, see: www.journalistik.uni-mainz.de

w3 – You can find the ZDF website here: www.zdf.de

w4 – The website of dpa, the German press agency, in German, English, Spanish and Arabian, can be found here: www.dpa.com

w5 – For more information on the Airbus A380, see: www.airbus.com/en/aircraftfamilies/a380/ or the corresponding Wikipedia entry: en.wikipedia.org/wiki/A380/

w6 – To find out more about Campus-TV, the TV station run by students of Mainz University, see: www.campus-tv.uni-mainz.de

w7 – The website of the German 3sat TV station, which produces *Nano*, can be found here: www.3sat.de

w8 – For more information on the Austrian TV station ORF, see: www.orf.at

w9 – The website of Swiss TV station SRG can be found here: www.srg.ch

w10 – This is the website of German TV station ARD: www.ard.de

w11 – To access the *Nano* Mediathek and watch footage online, go to the *Nano* website^{w1}, then click on 'Mediathek' in the top bar

w12 – To organise a visit to the ZDF campus in Mainz, see: www.zdf.de/ZDFde/inhalt/20/0,1872,2001332,00.html

w13 – To find out more about Girls' Day, see: www.girls-day.de and to organise an internship on Girls' Day at the ZDF, send an email to gleichstellung@zdf.de

w14 – For more information about the female mentoring network Mentorinnennetzwerk für Frauen in Naturwissenschaft und Technik, for girls and women in Hessen, see: www.mentorinnennetzwerk.de

w15 – For more information on the *Nano-Camp*, including a wealth of videos, see: www.3sat.de/nanocamp/

w16 – The website of the Helmholtz Centre for Environmental Research can be found here: www.ufz.de/index.php?en=11382

w17 – To find out more about Germany's centre of expertise for science communication, Wissenschaft im Dialog, see: www.wissenschaft-im-dialog.de/en/about-us.html

w18 – The website of the science journal *Bild der Wissenschaft* can be found here: www.bd.w.de



REVIEW

Students always assume that science means bench work, which it does initially, but there is so much more that you can do once you have a science degree. This article describes one pathway for forging a career in science journalism. Many students are fascinated by science but, like Nadia, find the reality at the bench tedious. Journalism is a varied job requiring good background knowledge in science and the ability to work to tight deadlines. This could be an ideal career for those well-disciplined students who both like and are good at writing or presenting science and have good interpersonal skills.

Shelley Goodman, UK

Teaching in Sweden: tackling creationism, making waves

Image courtesy of Per Kornhall



Conspiracies are at the heart of many a good film and book. Swedish biology teacher Per Kornhall is the author of a critical book on intelligent design and how it is taught in biology lessons in religious schools in Sweden. He talks to **Sai Pathmanathan** and **Marlene Rau** about his fascination with modern science and his views on teaching the diversity of life.

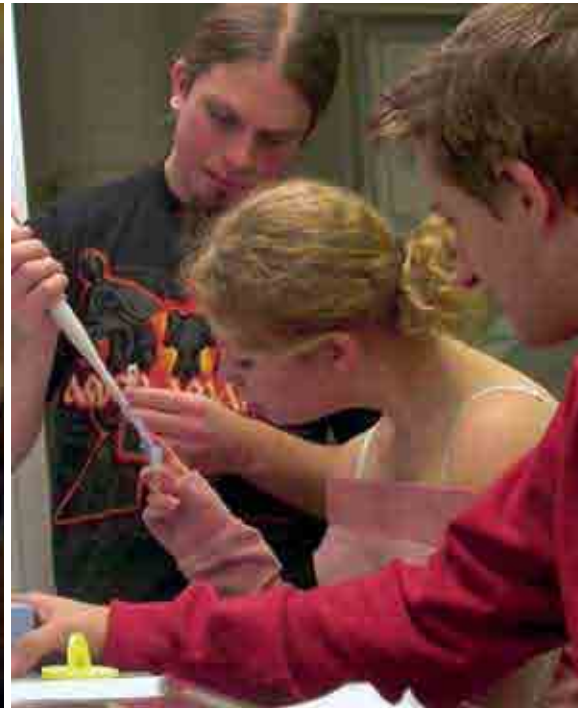
Image courtesy of Per Kornhall

Per's neighbourhood in Uppsala, taken from the Bronze Age Kung Björns hög (King Björns mound)

Image courtesy of Per Kornhall



Image courtesy of Per Kornhall



Per Kornhall is no stranger to science. Having received both a PhD in botany and a Swedish teachers' diploma, and having worked as a science teacher on and off for the past ten years (full-time for the last four), he knows exactly what he does and does not want students to be taught in science lessons – and how to get his 16- to 19-year-old students excited about scientific research. But how did someone like Per decide to enter the world of science teaching?

"I have always been amazed by science and how the scientific method gives us answers to questions we could never have tackled otherwise. It challenges the way we look at things. I think what made me want to become a teacher is a combination of my upbringing, and a very inspiring grandfather. My grandparents had their house designed for the purpose of teaching us kids, with a living room full of tools and a very long workbench. My grandfather told us everything he knew about science, from the Universe to Latin names of flowers, and explained how different

machines worked, anything from small mechanical items to gearboxes," recalls Per. "And I also had some very good teachers, especially at secondary school."

Per is head of biology at the Westerlundiska gymnasiet^{w1}, a secondary school in Enköping, Sweden. As a biology teacher, Per has a lot of freedom to structure his teaching as it suits him and his students, which is why he loves teaching in Sweden. This freedom allows him to collaborate with other teachers on interdisciplinary projects and to dig deeper into the subjects that his class are interested in.

But shouldn't the government have a say in what students should learn? "The government is, of course, interested in having some control, but I don't think this is a big problem," says Per. "Teachers like myself know that freedom in teaching comes with a great responsibility. We need to teach what is needed for higher education, and the more freedom we have to teach content in our own way, the more inspired we become."

Yet even for Per, too much of this freedom can be a curse, especially when it comes to teaching the origin of the diversity of life. For 17 years, he was a member of the Christian fundamentalist free church Livets Ord (The Word of Life) in Uppsala, and also taught biology at their school for four years. Some ten years ago, however, he started to have doubts about this church, which some people believe to be a sect. After a lot of thought, Per resigned from both the school and the church, went on to work at a communal school, and voiced his criticism – of both creationism and the Swedish school system that allows creationism to be taught in biology lessons – in a book, *Skapelsekonspirationen* (Creation conspiracy)^{w2}, that was published in April 2008.

Per's main criticism is of intelligent design (ID), a creationist theory that seems to be gaining ground in Christian schools in Sweden (for an article about the threat of creationism, read Jones, 2008). In Per's opinion, the danger lies in the fact that this is not

Image courtesy of Per Kornhall



Image courtesy of Per Kornhall



The class of Waves project students

harmless or naïve belief, but a well-organised campaign to establish a society based on fundamentalist beliefs. Since the proponents of ID have not been successful in disseminating their views through the standard scientific means of peer-reviewed publications, they now try

to get directly to media, politicians and schools. "As a teacher, I keep encountering Christian and also Muslim students who have serious doubts about evolutionary theory." In his opinion, religious schools should be forbidden if they teach anything but scientifically based facts about the origins of the diversity of life in biology lessons.

But what if a student raises the issue of creationism in a science lesson – would Per address the question? Yes, he says, but cautiously – and only once the subject of evolution has been thoroughly taught; the focus of biology lessons is, after all, to teach biology. "The teacher would need to be aware that the student might be prepared with arguments that he or she has picked up either in a fundamentalist church or via the Internet. To be able to answer the student, the teacher would need to know some of the more common arguments and how they have been refuted (often a long time ago)."

Per also cautions that some students may have been trained by mis-

sionary youth organisations to introduce debates about evolution. If a debate arises, Per stresses that while creationism can be debated, evolution is not open to debate. "Evolution is accepted by the scientific community because of overwhelming evidence. A classroom debate about evolution versus creationism would raise creationism to the same rank as evolution. There is no scientific debate between these two different ways of viewing life and acquiring information."

What about the teacher's religious beliefs? Does Per feel there is a place for more moderate religious teachers in the science classroom? "Absolutely", he replies. Religious beliefs need not be a hindrance either in the science classroom or in evolutionary research. "The problem between faith and science arises with fundamentalist beliefs – where statements of faith are used as science or in a scientific context. I recently gave a seminar together with a priest from the Swedish Lutheran Church, and we had exactly the same view on the subject – that religious texts and



Per's book

Image courtesy of Per Kornhall



Swedish ‘free schools’

BACKGROUND

Until 1991, Sweden had only about 90 ‘free schools’, besides the traditional communal primary and secondary schools. In 1992, the education system was liberalised, and since then, foundations, societies and private people can also found schools. If they do not ask for tuition fees, are open to everyone and largely comply with national curricula, they are generally acknowledged by the state and receive money from the communal government for each of their students. Many of the now almost 900 ‘free schools’ distinguish themselves by alternative educational concepts, specialising in certain subjects or offering free laptops to all students. Critics are worried, though, that among these are more than 60 religious free schools, funded by Christian or Muslim societies.

beliefs cannot be used in biology, physics or chemistry. We also both saw creationism as a problem for the church and for society.”

The science curriculum seems to be a tricky issue, not only when it comes to teaching evolution. Per tells us about two proposed reforms that have been stopped by the current government: “One was good, and the other was very bad.” In Sweden, students who want to go on to university must decide at the age of 16 between

a career in science or in humanities. Those who choose humanities must also take two basic science courses. The first tackles energy, environmental issues and the scientific method. The second, longer course consists mainly of human physiology and biology, but also covers aspects of chemistry and physics. Those who choose a career in science must take courses in physics, chemistry and biology, with physics traditionally taking up a larger part of the courses

than biology. Science teachers typically teach their science speciality (e.g. biology) to the science students, and all sciences to the non-science students.

“The first proposal was to lengthen the biology courses for the science students, meaning more time could be devoted to human physiology and genetics – and we need to spend more time on that. That was a good thing,” Per explains. “The bad thing was that for nearly all non-science students, on the other hand, the second science course would be cancelled. That would mean that future politicians, journalists and other otherwise well-educated people would have no training in physics, chemistry or human physiology in upper secondary school. And that, I think, is a dangerous route to take in our modern society.”

Per continues: “It is important that science forms part of society’s common knowledge and that our future politicians and bureaucrats have a basic understanding of the complexity and depth of science. How will science be funded if nobody knows what scientists do? Secondly, although not everybody will get involved in scientific research, it can be understood and appreciated by a much wider public. Therefore it is important that we communicate science to *everybody*, and the best place to do that is in our schools.”

A group of Per’s students at Lake Erken

One way to interest students in science is to introduce them to the ethical considerations involved. To that end, Per works together with the Nordic Committee on Bioethics^{w3}, helping to find education resources on bioethics that are suitable to be translated into all the Nordic languages. As though that wasn't enough, he also collaborates with the Swedish Centre for School Biology and Biotechnology^{w4}. The obvious problem with the Swedish system, though, is that the students who have opted *not* to study science are therefore less motivated in science lessons. Per doesn't think this is really an issue with biology, since students are naturally interested in how their bodies work. But when it comes to physics and chemistry, it's a different story: they find it boring and a repetition of what they learned earlier in school. Although most of Per's students enjoy science, he feels that those who seem disinterested are just struggling with the burden of too many other subjects: "They simply do not have any energy left – no mental space to get fascinated."

Per feels there is no point in teaching topics that students don't care about. "The students will learn it, they will write down (mainly) correct answers in their test, and then they will forget about it," explains Per. "But if you can get a student interested in your subject, you can change his or her whole life and future career." Does this mean teaching students only what is relevant to them? "I don't mean that we necessarily have to relate to everyday things," says Per. "The relevance for the student can be purely philosophical, but we need to catch their interest, in order for them to really learn something. This usually gets them motivated and wanting to know more. It is important for our students to realise that science is not static, a mere collection of facts, but a practical, hands-on, experimental endeavour that is constantly progress-

ing. I think we are sometimes stuck teaching 19th-century content when we ought to upgrade to teaching current 21st-century science to our students."

Per is forever getting involved in science projects that allow him to enthuse his students, but it is the project that won the European Physical Society's prize at the Science on Stage 2^{w5} teaching festival in Grenoble, France, that makes him really proud. He is intrigued by the fact that he, as a biology teacher, won a European prize for teaching physics. But maybe, being a biologist was actually an advantage: "It is sometimes also good to approach a subject from a different angle to see things more clearly," says Per. His idea was a simple one, and had probably been done before, but it was significant for Per, his students and those involved in science education in Sweden. It was a very successful attempt to overcome the disinterest of the non-science students in physics, by teaching them 21st-century science in a way they could relate to it.

The project, called 'Waves'^{w6}, involved teaching extremely complicated physics. "I told the students about molecular orbitals, relativity, stereochemistry, the Big Bang and quantum theory, to mention just a few," says Per. So why did he not want to tackle the basics? "Because this is the stuff that is interesting," explains Per. "Students have read about these subjects in newspapers and my goal wasn't to make them understand everything, but to give them a glimpse of the fascinating world of modern science. When they understand that equations such as $E=mc^2$ are not so complicated to understand, they gain self-confidence." Some students went home to their parents and friends, and told them that they knew exactly what Einstein meant when he came up with his famous equation.

The lessons were a mixture of theoretical and practical demonstrations using PowerPoint^{w7} presentations, incorporating images, videos and web links to illustrate the complex science.

It wasn't long before Per reaped the rewards. Prior to the project, the attendance for his class had been rather low. But it rose as students became more interested in science. "Their respect for scientists and science grew," says Per. "They found that science is not a boring subject, studied by boring people; it is a complicated and mind-blowing experience to carry out scientific research and it is done by people who know interesting stuff. And science influences students' daily lives." Students were asked to sit for a test to get a good grade on the Waves project (attendance and participation in the practical parts were enough to pass this part of the course) and all but four of 28 students turned up. Per included an evaluation to find out what the students thought. Two comments are given below:

"This project has made me understand things that I did not think it was possible for me to understand."

"I never really liked these subjects, but I am getting more and more interested. Partly because there are so many answers to some questions, partly because there are no answers to even more questions."

There are many benefits to such projects, but one of the best parts is how much fun the teacher has. "It is more fun to teach these topics," says Per. "It is very rewarding to see the faces of young men and women, when for example they suddenly understand that time-dilation calculations are real and can be used for practical purposes. Seeing their faces as science fiction turns into science reality is pure enjoyment for any teacher."

Finally, if Per had to offer all science teachers one piece of advice, what would it be? "Be happy – teach things that fascinate you."

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- Jones S (2008) Interview with Steve Jones: the threat of creationism. *Science in School* 9: 9-17.
www.scienceinschool.org/2008/issue9/stevejones
- Kornhall P (2008) *Skapelsekonspirationen*. Stockholm, Sweden: Leopard Förlag

Web references

- w1 – The Westerlundiska gymnasiet's website: www.westerlundiska.nu/
- w2 – Find out more about Per's book, *Skapelsekonspirationen*, on his website (English and Swedish): <http://perkornhall.se/> or visit the website of publisher Leopard Förlag: www.leopardforlag.se/Article/View/?articleId=124

Per's students by the River Hågaån

- w3 – For more information about the Nordic Committee on Bioethics, see: www.ncbio.org
- w4 – Organised by the Swedish Ministry of Education, the Swedish Centre for School Biology and Biotechnology aims to support and inspire teachers at all school levels. For more information (in Swedish), see: www.bioresurs.uu.se
- w5 – For more information about both the international and national Science on Stage activities, including teaching materials, see: www.science-on-stage.net
- w6 – For information on Per's prize-winning 'Waves' project, see: <http://perkornhall.se/science/index-waves.htm>
- w7 – For useful links, and examples of the PowerPoint presentations,

see Per's website: www.perkornhall.se/science/

Resources

For an interview with Lewis Wolpert about belief, science education and much more, see:

Leigh V (2007) Interview with Lewis Wolpert. *Science in School* 7: 9-11.
www.scienceinschool.org/2007/issue7/lewiswolpert

Unsure about $E=mc^2$? Why not learn how it is applied in the worlds largest particle accelerator, the LHC:

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



Ecology: media presentation CD-ROM

By Biozone

Reviewed by Sue Howarth, Institute of Education, University of Worcester, UK

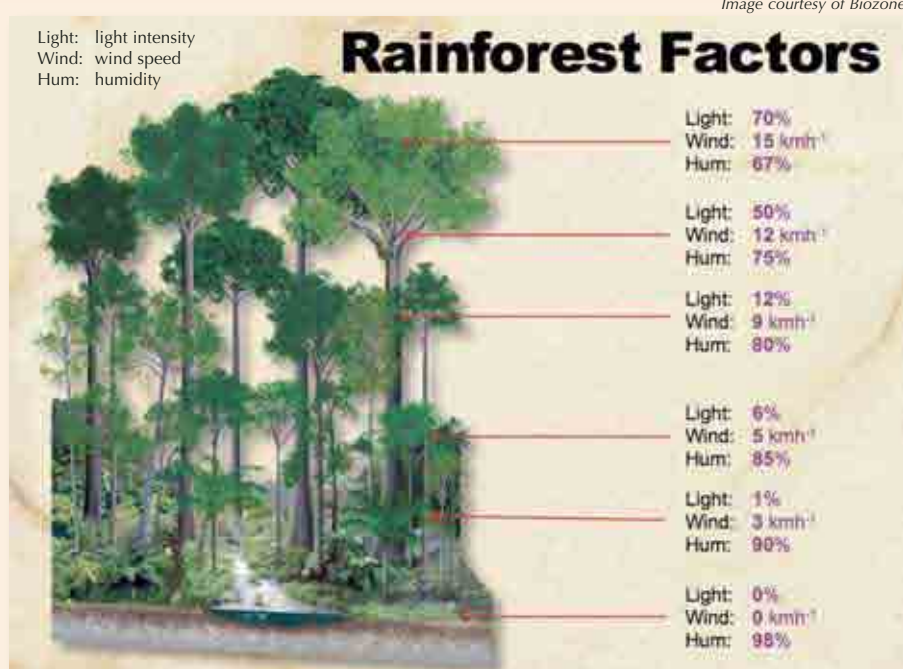
Next year, I hope to take a small group of students, aged 15-18, to Iquitos in Peru, where we will board a boat to take us up the Amazon to study the rainforest. So I was particularly interested to see that Iquitos is featured in the *Introduction to Ecosystems* series of slides on *Ecology*, a media presentation CD-ROM.

The Amazonian rainforest is just one of many ecosystems featured on this comprehensive resource. There is a bias towards Australia and New Zealand – not surprising, given that the publisher, Biozone, is a New Zealand company. However, all the sets of slides are easily edited, so any extraneous material can be removed and the excellent pictures and information tailored to fit specific courses.

The set of slides with the largest amount of material is the one addressing human impact (see full contents list on page 95). This includes eutrophication, biological oxygen demand, global warming, integrated pest management and bioaccumulation.

Each set of slides consists of a colourful and informative PowerPoint® presentation. Sometimes the slides have too much text, so a judicious pruning in advance could make them more accessible to a class.

The slide sets have been “produced to complement the student resource and activity manuals” and are recom-



mended for use as overhead transparencies (although, for this purpose, I would reduce the level of detail on many slides); with a digital projector; on school computer networks (the site licence is included); and with an interactive whiteboard (although I'm not convinced of the interactivity of most of the slides).

Ecology is a key part of all biology studies and these slide shows could be modified to fit many age groups. As they are, they are probably a little more detailed than necessary for

England's A-level requirements (ages 16-18).

There are restrictions with this CD-ROM. You may not print handouts for students, even if you modify the slides to fit your own lesson. This is a real drawback, as without notes, students will want to copy the information on the slides and thus slow down the pace of a lesson.

Overall, *Ecology* is a useful source of visual information that could help teachers to provide a sound course, and help students to appreciate some

of the concepts of ecology, as long as the theory was supplemented with practical work. I recommend this CD-ROM for anyone with a generous budget who teaches a biology course with an ecological component.

Resources

For information about all the Biozone resources, including workbooks, podcasts, RSS newsfeeds, links to other selected sites, presentation files and free samples, see: www.thebiozone.com

For information about the *Ecology* CD-ROM and other presentation media, as well as details of buying CD-ROMs in bundles (which can work out cheaper if you buy more than one), see www.thebiozone.com/media.php. Note that prices are given in US\$.

For more information about the *Ecology* CD-ROM, including details of the separate PowerPoint files, the cost of the disc for European, Australian and New Zealand customers, as well as contact details, see: www.thebiozone.com/media/ec.php

Full contents

- Introduction to ecosystems (64 slides)
- The ecological niche (69 slides)
- Populations and interactions (74 slides)
- Practical ecology (62 slides)
- Communities (66 slides)
- Biodiversity and conservation (78 slides)
- Human impact (134 slides)

Details

Publishers: Biozone

Publication date: 2005 (Version 1.0)

The CD-ROM requires a Windows or Mac computer with a CD-ROM drive. Slide shows can be run using PowerPoint®, Keynote® or QuickTime® or Adobe Acrobat® PDF. Technical support is available at support@biozone.co.nz

Ordering

Distributed by Biozone International Ltd.
PO Box 13-034, Hamilton, New Zealand

For European sales, email: sales@biozone.co.uk

Price: €189.95 (individual PowerPoint presentations can be purchased separately: e.g. *Populations and Interactions* costs about €28)



Water – Humanity’s Project: media collection for the classroom

By Siemens AG

Reviewed by Michalis Hadjimarcou, Cyprus

Water – Humanity’s Project is a CD-ROM containing a collection of about 300 pieces of media that examine water as an element of daily life as well as an important local and global issue. The collection is suitable for students and teachers of all levels.

The CD-ROM gives rapid access to contemporary, interactive lesson material. The media can be used for lesson preparation or direct application in the classroom. The selection is huge, in both the types of media and their content. It includes text files (fact sheets, worksheets, and lesson suggestions), photos, graphics, videos, animated materials and presentations. Subject categories include various aspects of water use – such as for drinking, in agriculture and industry, and in power generation – as well as topics such as water shortage and waste, and water’s future. There is something useful for every science/technology classroom (biology, chemistry, physics, geography, technology, information and communication technology and mechanics) as well as for humanities and social sciences.

The CD-ROM is relatively easy to use, thanks to its simple on-screen instructions. Navigation through the large collection of media is made easy by sort and search functions which allow quick access to specific items selected by either type or name. Another valuable tool is the specific

information available for each item in the collection. This includes the name and type of media, a brief description, the relevant subjects (e.g. sciences, physics or technology), main headings, relevant school level and subjects, and possible areas of use (e.g. information sheets, lesson preparation).

Some of the media are very simple and thus easy to incorporate into teaching. For example, the diagram showing the tetrahedral structure of the water molecule and the formation of the dipole can easily be used either in information sheets for students or for presentation by the teacher when explaining the physiochemical properties of water in a science/technology lesson.

Other items are more elaborate and will require a specifically structured lesson in order to be used. One example is the functional diagram of a sewage plant, in which all the possible stations in the plant are shown. This detailed diagram can be valuable when studying water as a waste product as it allows examination of the mechanical, biological and physiochemical treatment of water. Of course, the study of this subject is relatively complicated, as it must take into consideration several other factors including the influence that the plant has on the local environment, the willingness of the local communi-

ty to accept the plant in their area, and the usefulness of producing irrigation water in that location.

It would be possible to give the students access to the CD-ROM and have them work on projects that could be as varied in content and type as the media themselves.

Furthermore, since the media topics range from science and technology to sociology and political science, the opportunity exists for interdisciplinary teaching.

It is unlikely that any teacher would be able to use the entire media collection. Furthermore, some of the items (such as the water cycle) are likely to appear in standard textbooks. But the majority of the items are either the types of materials that most teachers would like to use but don’t have the time to prepare or look for, or material that teachers never realised could be useful in their teaching.

Details

Publisher: Siemens AG

Publication year: 2007

ISBN: 9780520202771

Ordering

The CD-Rom can be ordered free of charge by teachers. See:

www.generation21.siemens.de/generation21/international/pages/school_projects/media-collection.jsp



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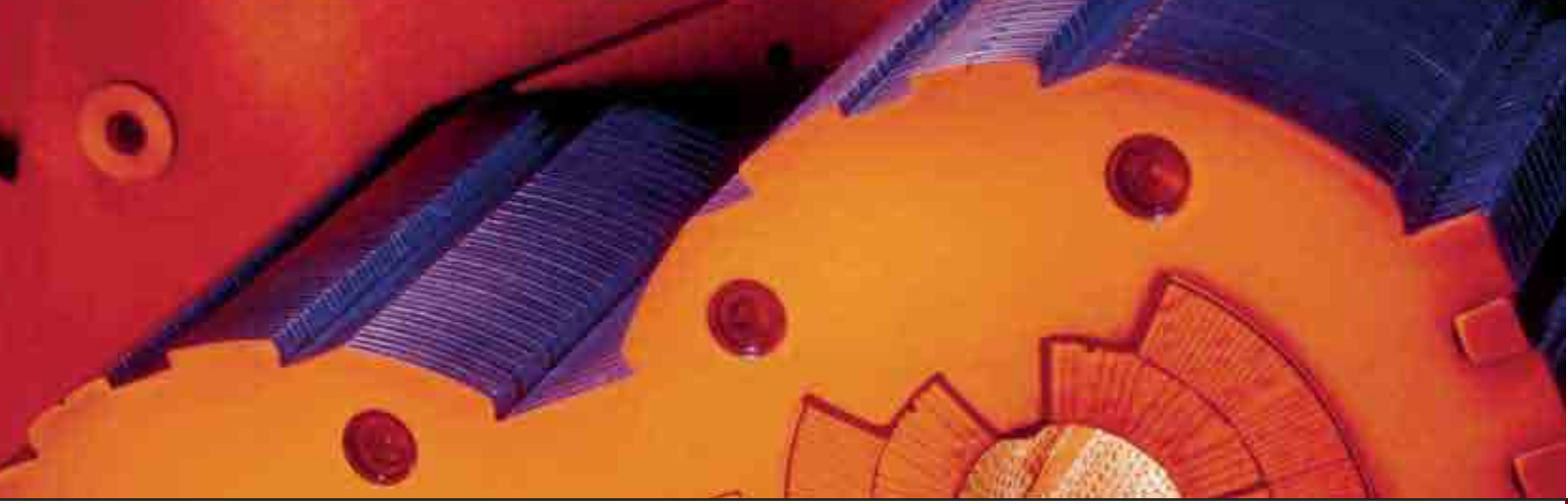
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Model of the LHC's superconducting dipole magnets
Image courtesy of CERN





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