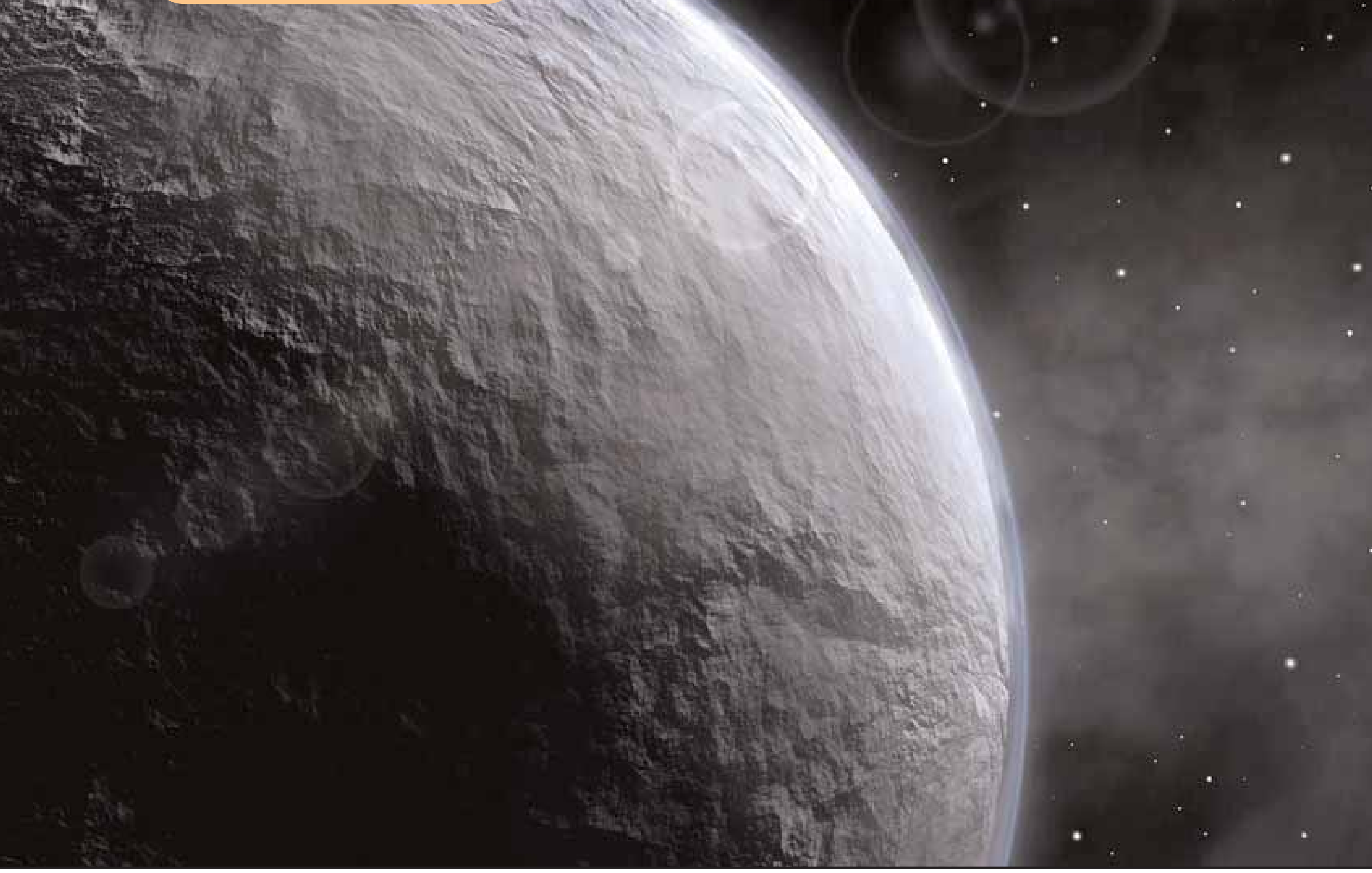
Summer 2006 Issue 2

SCIENCE in SCHOOL



In this Issue:

Exoplanets

Uffe Gråe Jørgensen describes the search for Earth-like planets around other stars.

Also:

Using insects to fight crime

Highlighting the best in science teaching and research

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Contents

Editorial 4-5

Events
Forthcoming events 6-7

Feature article
The scientist of the future 8-10

Cutting-edge science
Are there Earth-like planets around other stars? 11-16
A new tree of life 17-19

Teaching activities
Scientists at play: contraptions for developing science process skills 20-23
Modelling the DNA double helix using recycled materials 24-28
The chocolate challenge 29-33
Environmental chemistry: water testing as part of collaborative project work 34-37

Projects in science education
Promoting science and motivating students in the 21st century 38-41
The exhibition ship *MS Einstein*: a floating source of scientific knowledge 42-45
Linking university and school: addressing the challenges of science teaching in Italy 46-48

Science topics
Forensic entomology 49-53
Symmetry rules 54-58
Chocolate's chemical charm 59-61
Epigenetics 62-64

Spotlight on education
GRID: a European network of good practice in science teaching 65-67

Scientist profile
A search for the origins of the brain 68-71

Teacher profile
A zoologist at school: my pupils and other animals 72-73

Science in film
Video clip collection of European Space Agency 74-77

Reviews
Power, Sex and Suicide 78
The Science Behind Medicines 79
Success Strategies for Women in Science 80
The Physics of Superheroes 81
Real Mosquitoes Don't Eat Meat 82
Learning from Patients 83

Resources on the web
Free science journals 84

Back in the staffroom
Putting the fizz into physics 85

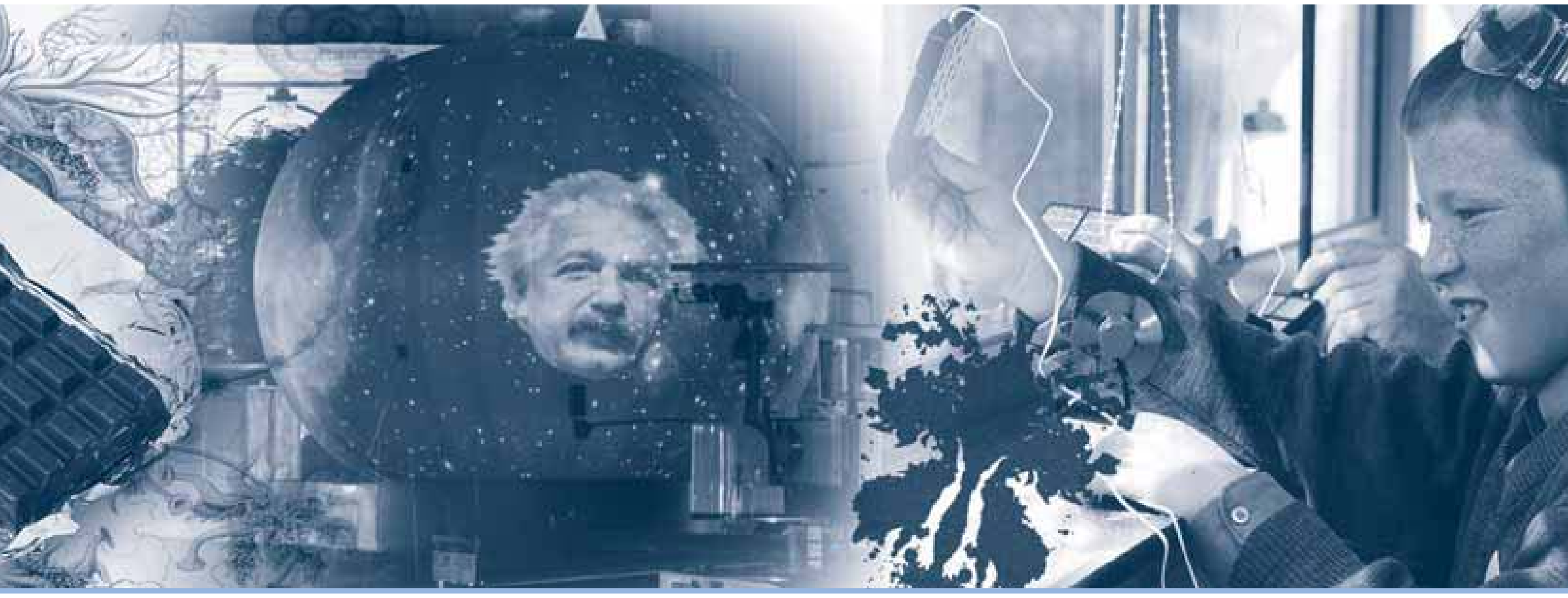
Welcome to the second issue of *Science in School*

Since the publication of the first issue, we have received a lot of enthusiastic feedback from our readers. Science teachers from across Europe particularly liked our innovative teaching ideas, accessible science coverage, interdisciplinary topics and European approach. And these are features that we intend to continue to offer.

In this issue, we have contributions from ten countries covering topics as varied as astronomy, environmental chemistry and insect biology. Exciting European projects include a floating exhibition in Germany, an Italian university-school laboratory and a UK scheme to bring young scientists into the classroom. Among my personal favourites are two articles that together address the 'theory and practice' of one of my favourite substances: chocolate.

Some of you have told us a little bit about how you have used the articles in our first issue. It seems a shame just to tell us, though, when teachers everywhere might be able to put your experience to good use. So we would like to use your work to support the teaching community across Europe. Have you perhaps turned one of our science articles into a teaching resource? Did you adapt some of our teaching materials to your own curriculum? Have you translated one of our articles for your students? Or did you use one in a completely different context, such as a language lesson or an art class? Please tell us – we are eager to spread your ideas! We may use them in the journal; otherwise, you will soon have the opportunity to join a discussion forum on our website, to exchange creative ideas and useful information.

Remember that while the print edition of *Science in School* is in English, we are adding value to the articles we publish by offering them online in many European languages. I'm pleased to be able to report that, with



the help of many people from across Europe, we already have articles available in Albanian, Czech, Dutch, French, German, Italian, Portuguese, Russian, Spanish and Swedish. Of course, we want to build on this, so if you would like to translate articles, please get in touch.

Each issue has a print run of 20,000 copies, which are being sent free of charge to European science teachers. In this, too, we have received a great deal of support: teacher organisations, scientific institutes, education ministries and others have kindly agreed to distribute print copies of *Science in School* in their own countries. If you are able to help us by distributing this free European resource further, for example, by mailing a copy with other printed material you send to teachers, that would be a great help.

Finally, we are delighted to have received many excellent contributions from readers. We hope you enjoy reading some of them in this issue – and please continue to send us articles!

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

Forthcoming events

10 May - 30 September 2006
worldwide
Plus New Writers Award – bringing mathematics to life

Plus magazine is launching the *Plus* New Writers Award to find people who can bring mathematics to life. Published online and free of charge, *Plus* is an award-winning magazine about mathematics which is aimed at the general public. Its articles by top mathematicians and science writers provide a window into the world of mathematics with all its beauty and applications, and cover fields as diverse as art, medicine, cosmology and sport.

The competition is open to new writers of any age and from any background who can explain a mathematical topic or application they think the public needs to know about. There are two categories of entrants: secondary school students and the general public. The winning entries will be read by an international audience of over 100 000 in the December issue of *Plus*, and the prize pool includes an iPod. The closing date is 30 September 2006.

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

15 May - 15 September 2006
worldwide
Have your Say: bioethics public consultation

The Nuffield Council on Bioethics, UK, has launched a consultation on the ethical dilemmas related to public health, such as the difficulties in balancing individual choice and community benefit. It is interested in the views of young people, so please encourage your students to have their say. A consultation paper provides background information and asks questions in the context of five case studies: infectious diseases, obesity, smoking, alcohol, and the supplementation of food and water. For example:

- Are there cases where the vaccination of children against the wishes of their parents could be justified?
- Would measures such as forced quarantine, which helped to control the outbreak of SARS in Asia, be acceptable in countries such as the UK?
- What are the roles and obligations of parents, schools, school-food providers and the government in tackling childhood obesity?
- Should people who smoke or drink excessively be entitled to fewer resources from the public health-care system, or should they be asked for increased contributions?
- Fortification of foodstuffs such as flour and margarine has been accepted for some time. Why does the fluoridation of water meet with such resistance?

You might decide to pick one topic for a lesson – the consultation paper includes lots of information to use with a class. Your students' views will certainly be heard, as all responses will be considered by the Nuffield Council. The deadline for responses is 15 September 2006.

More information:
www.nuffieldbioethics.org

20-25 August 2006
University of Amsterdam, the Netherlands
GIREP Conference

GIREP conferences aim to bring together physicists, physics educators and physics teachers from all levels of education to discuss issues in physics education and physics education research. The biannual conferences have developed into major events with over 300 participants from all continents except Antarctica.

The theme of this year's conference is 'modelling in physics and physics education', and guides the morning lecture sessions and some workshops. The parallel paper, poster, symposium, and workshop sessions may focus on other themes in physics education such as physics curricula, laboratory equipment, teacher education and professional development, assessment, the use of ICT in physics education, and teaching physics for engineering or medicine.

More information:
www.girep2006.nl
Contact: Ton Ellermeijer (ellermei@science.uva.nl) or Ed van den Berg (eberg@science.uva.nl)

4-9 September 2006
Braga, Portugal
3rd International Conference on Hands-on Science

The 3rd International Conference and Symposium on Hands-on Science offers those involved in science education an opportunity to exchange experience on syllabus and policy matters, social factors and the learning of science, and other issues related to science education, concentrating on the increased use of hands-on experiments in the classroom.

The contact seminar, 'Building bridges: Towards an Improved Science Education', will promote the discussion and preparation of new Comenius 1 and Comenius 2 school projects.

More information:
www.hsci.info/hsci2006/index.html
Contact: sasa.divjak@fri.uni-lj.si

8 September 2006
Universität Kassel, Germany
Englischsprachiger Biologieunterricht an deutschen Schulen (English-language biology lessons in German schools)
Biology teachers who teach in English are invited to a free workshop organised by the Verband deutscher Biologen and the Hessian Vereinigung für bilinguale Schulen. English-language teaching materials will be developed in small working groups and presented to all participants. Teachers from outside Germany are warmly welcome.
More information: www.vdbiol.de
Contact: Matthias Bohn (mbohnde@aol.com)

22-24 September 2006
Wolfsburg, Germany
'Teaching Science in Europe' conference
At the conclusion of the biennial European exchange process for developing teaching concepts and materials in science education, the publication 'Teaching Science in Europe' will be presented.
More information: www.science-on-stage.de
Contact and registration: info@science-on-stage.de

27-29 September 2006
EMBL Heidelberg, Germany
ELLS LearningLAB
The European Learning Laboratory for the Life Sciences (ELLS) is an education facility to bring secondary school teachers into the research lab for a unique hands-on encounter with state-of-the-art molecular biology techniques. ELLS also gives scientists a chance to work with teachers, helping to bridge the widening gap between research and schools. Teachers are invited to join this workshop (theme to be arranged; the working language will be English).
More information: www.embl.de/ELLS
Contact: ells@embl.de

October 2006
At-Bristol, Bristol, UK
Dynamic engineering course for gifted and talented youth
How do engineers design objects that move? How do you apply science from the natural world to solve complex problems? Students will design and build their own creatures using animation, modelling and specialist software, while learning all about the design and engineering process of dynamic modelling in this fun and hands-on five-day course. Get your students enthused about science and engineering, while gaining invaluable skills yourself as part of your own continued professional development. Places are available free to groups of four students aged 12-14 and their teachers during October half-term 2006.
More information: www.at-bristol.org.uk
Contact: edel.fletcher@at-bristol.org.uk

3-4 November 2006
EMBL Heidelberg, Germany
7th EMBL/EMBO Joint Conference 2006: Genes, Brain/Mind and Behaviour
This conference will consider the current – and future – uses of new neurological knowledge and technologies. What are the consequences when biochemical solutions to behavioural problems such as depression, addiction, or eating disorders take precedence over attempts to repair the social environment or defective interpersonal relations? How do we avert the risk of psychopharmacology being abused for neurochemical enhancement? Although new knowledge coming out of the neurosciences has an enormous potential benefit, treating or manipulating the mind also has important social, legal and bioethical implications. These are some of the main issues that will form the basis of this conference.
More information: www.embl.de/aboutus/sciencesociety/conferences/2006/scope06.html
Contact: halldor.stefansson@embl.de or andrew.moore@embo.org

Throughout 2006
Europe-wide
Marine photography competition
By sharing the enthusiasm of scientific discovery and the beauty of the sea, Marine Genomics Europe wishes to raise awareness among European citizens of the value of science and the need to protect our marine heritage. In a photography competition, underwater images will be publicly exhibited during 2006 in a travelling exhibition at aquaria, museums and schools. Schools, science museums and others are invited to host the exhibition.
More information: www.marine-genomics-europe.org
Contact: barbier@sb-roscoff.fr

Date by arrangement
Schullabor Novartis, Basel, Switzerland
Workshop 'Gentechnik Erleben' (Experience Genetic Engineering)
These workshops focus on practical laboratory work, but background information is given for all experiments. Students isolate plasmid DNA from bacterial cultures and digest it with restriction enzymes. The resulting DNA fragments are separated and visualised by gel electrophoresis. Students should already have the necessary theoretical background and be over 17 years of age. The workshops are free, conducted in German or English (on request) and have a maximum of 20 participants.
More information: www.schullabor.ch
Contact: gesche.standke@novartis.com

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

The scientist of the future

Susan Greenfield and **Martin Westwell** from the Institute for the Future of the Mind consider the needs of the future scientist.

Author,
Susan Greenfield

Think for a moment of all the scientific and technological developments in recent years, and about the prediction that new innovations will be introduced with increasing frequency: surely we should consider what the scientists of the future will need?

As developments in communication technologies make information even more accessible, scientists are in danger of drowning in a sea of irrelevant reports that range from scientific data to folklore. Future scientists will need the skills not only to transform information into knowledge, but also to select which information to consider.

In this century, the Internet is likely to continue to be one of the main sources of information for scientists. Despite the ubiquitous nature of the Internet and the general acceptance that it is important (according to 82% of pupils and 73% of people of working age), a substantial proportion of

Author,
Martin Westwell

the population (30% of 9-19 year-olds) have received no lessons on using the Internet (Dutton et al., 2005). In fact, only one-third (33%) of those children who are daily and weekly users have been taught how to judge the reliability of online information, whereas 38% trust most of the information on the Internet (Livingstone & Bober, 2005).

There seems to be a gap between the information processing abilities and skills that will be required by the scientists of the future and the education that they receive. As the world changes we need to ask ourselves an important question: what is science education for?

The first purpose of school science education should be to give the next generation of citizens who choose not to continue their formal science education the means by which to understand science and how it works. Each individual should be given the tools to appreciate how real-world science affects them and how they might form their own opinions on issues of science and technology. Some existing and planned courses help to meet this need, such as the UK's Nuffield[w1] AS qualification (ages 16-18) in 'Science for the Public Understanding', with a full A-level qualification (also for ages 16-18 but with more detail than the AS) being considered for introduction in September 2008.

But how can we teach the way that science works? Think about what happens in a class experiment to determine the boiling point of water. One thing is certain: almost no-one will achieve 100 °C unless they already know the answer and are trying to please the teacher. Skip will get 102 °C, Tania will get 105 °C, Johnny will get 99.5 °C, Mary will get 100.2 °C, Zonker will get 54 °C, while Brian will not quite manage to get a result; Smudger will boil the beaker dry and burst the thermometer. Ten minutes before the end of the experiment, the results are gathered: Skip had his thermometer in a bubble of superheated steam when he took his reading; Tania had some impurities in her water; Johnny did not allow the beaker to come fully to the boil; Mary's result showed the effect of slightly increased atmospheric pressure above sea-level; and Zonker, Brian and Smudger have not yet achieved the status of fully competent research scientists. At the end of the lesson, each child will be under the impression that their experiment has proved that water boils at exactly 100 °C, or would have done were it not for a few local difficulties that do not affect the grown-up world of science and technology, with its fully trained personnel and perfected apparatus. And yet that ten minutes renegotiation of what really happened is the important part; by reflecting upon that ten minutes, the class could learn most of what there is to know about how science works (Collins & Pinch, 1993).

The second purpose of school science education is to reach that small proportion of students who go on to higher education in science and/or to work in science and technology. For them, building a foundation of basic knowledge and an understanding of a scientific approach is important. However, in a changing world, this necessary foundation will not be sufficient.

Modern-day and future science will increasingly demand specialised proficiency from scientists, coupled with an ability to work with other scientists outside their own expertise. A natural consequence of this specialisation within interdisciplinary teams is that future scientists will have to rise to the challenge of explaining their science in ways that other scientists and non-scientists can understand. Chemists will have to engage with psychologists, molecular biologists with nanotechnologists, and neuroscientists with economists, until the edges between the disciplines are blurred. Even with the introduction of new technologies, communication and interpersonal skills will be more important than ever.

The future scientist will have to go a step further and engage with wider society if science and technology are to maintain their place at the heart of modern culture. The majority of people who did not pursue a science education will look to the minority to help them make decisions and formulate opinions. However, the enthusiastic scientist will have to take this responsibility seriously – it is not about telling people what to think.

Professor Ian Diamond, the Chair of Research Councils UK, recently said that although a survey (MORI, 2005) showed that more than 80% of adults think science makes a good contribution to society and that science will make our lives easier, we should be doing more to increase this number. The future scientist will be required to play a part in ensuring that everyone in society is adequately engaged in science. Non-scientists should feel able to contribute to scientific debates with confidence in their opinions, whether or not they agree that science makes a positive contribution to society. The integration of science with wider society and future culture is crucial for our social as well as economic development, and this integration starts at school.

In a shrinking world, science is becoming ever more global and this international community of scientists will be pivotal if we are to seriously address worldwide problems such as climate change and disease. Yet, in this globalisation of science there is a danger that we are dividing into worlds of technological 'haves' and 'have-nots'. Through initiatives such as the Science Corps[w2], the scientists of the future will be able to use their skills and abilities to apply science and technology to problems in both the developing and developed worlds.

The scientist of the future will need to be equipped to ask the right questions and to find the right answers.

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Dutton WH, di Gennaro C, Hargrave AM (2005) *The Internet in Britain: The Oxford Internet Survey (OxIS).* Oxford, UK: Oxford Internet Institute. www.oii.ox.ac.uk

Livingstone S, Bober M (2005) UK *Children Go Online: Final Report of Key Project Findings.* London, UK: UK Children Go Online. www.children-go-online.net

MORI (2005) *Science in Society: Findings from Qualitative and Quantitative Research.* London, UK: Office of Science and Technology, Department of Trade and Industry. www.mori.com/polls/2004/ost.shtml

Web references

w1 - The Nuffield Foundation 'Science for Public Understanding' website: www.scpub.org

w2 - The Science Corps: www.sciencecorps.info

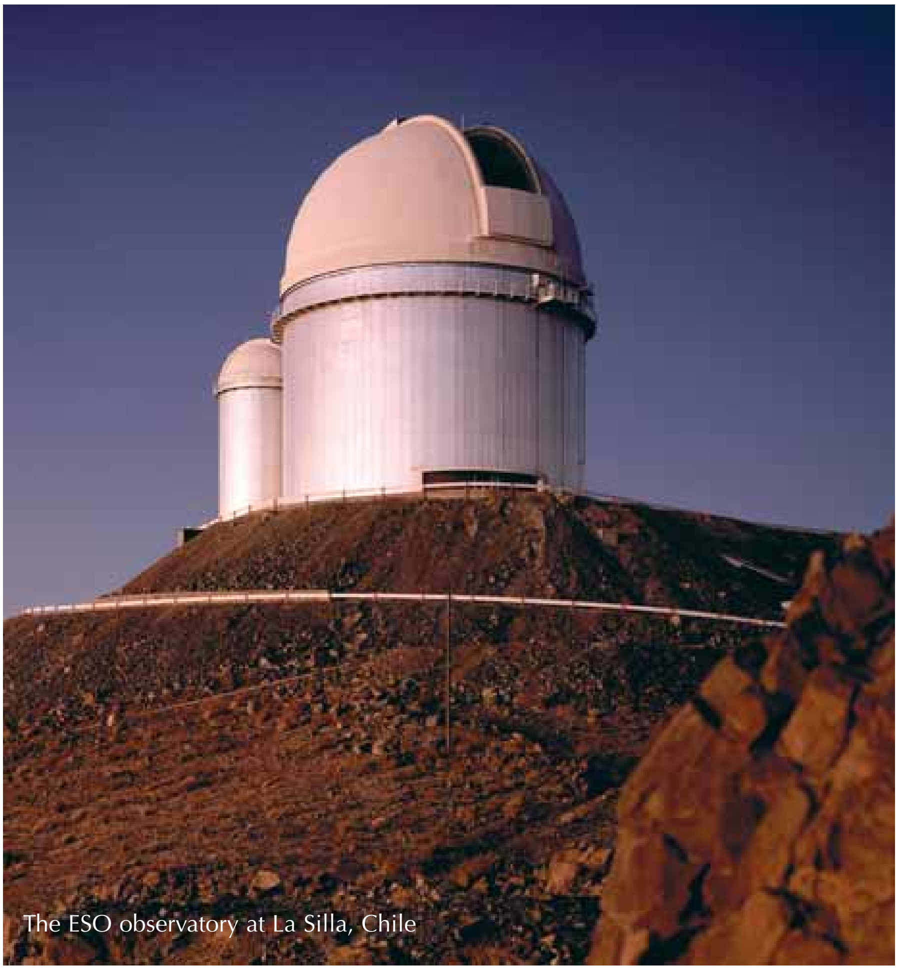
Baroness Greenfield CBE is Director of the Royal Institution of Great Britain (the first woman to hold that position) and Professor of Pharmacology at the University of Oxford, UK, where she leads a multidisciplinary team investigating neurodegenerative disorders. In addition she is Director of the Oxford Centre for the Science of the Mind, exploring the physical basis of consciousness, and of the Institute for the Future of the Mind, UK.

Her books include *The Human Brain: A Guided Tour (1997)*, *The Private Life of the Brain (2000)*, and *Tomorrow's People: How 21st Century Technology Is Changing the Way We Think and Feel* (2003). She has started four companies based on her research, made a diverse contribution to print and broadcast media, and led a Government report, *Women In Science.* She has received 28 honorary degrees, an honorary fellowship of the Royal College of Physicians (2000), a non-political life peerage (2001) as well as the Ordre National de la Legion d'Honneur (2003). In 2006 she was installed as Chancellor of Heriot-Watt University, UK, and voted Honorary Australian of the Year.

Dr Martin Westwell is Deputy Director of the Institute for the Future of the Mind at Oxford University, UK, determining how we can harness new technologies to maximise the potential of all individuals and safeguard their individuality. Martin received his degree and PhD in organic chemistry from Cambridge University and then moved to Oxford as a research fellow where he discovered neuroscience, the biotech industry and a number of science and society projects including the Café Scientifique. His awards as a science communicator include being named Scientist of the New Century in 1999 by *The Times*/Novartis .

Are there Earth-like planets around other stars?

Image courtesy of ESO



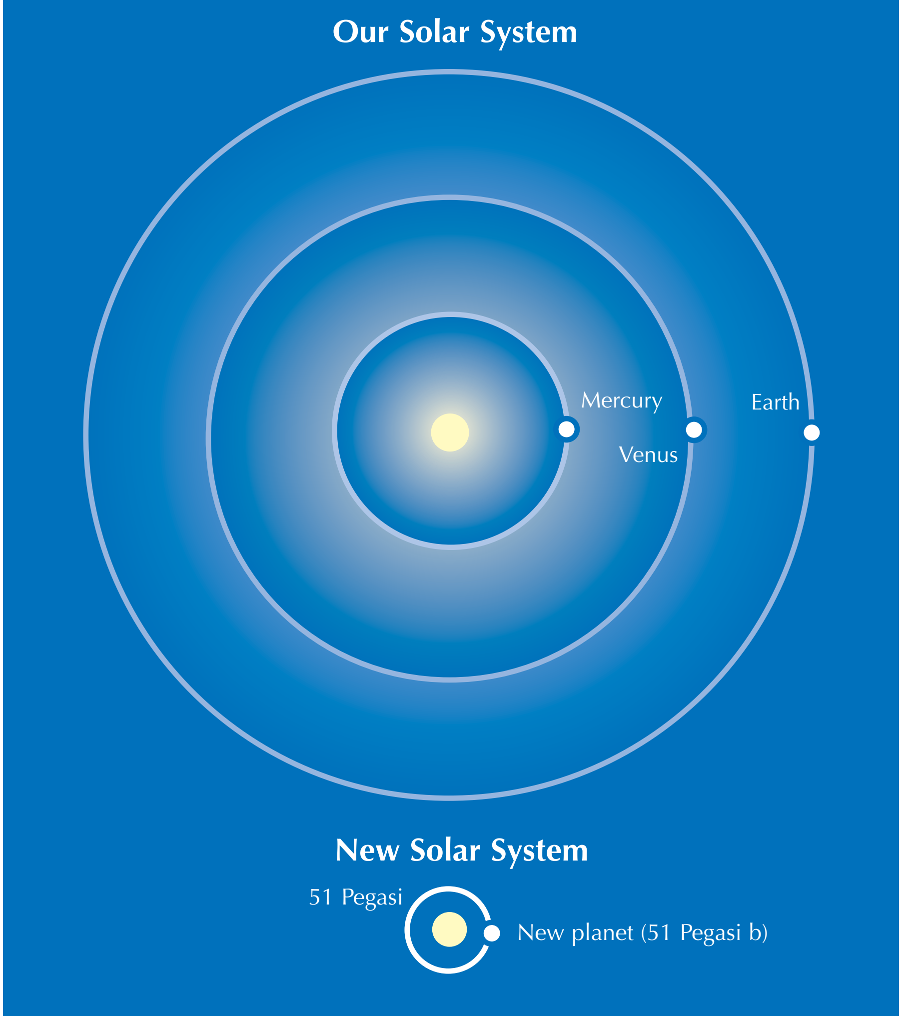
Uffe Gråe Jørgensen from the University of Copenhagen, Denmark, describes the search for Earth-like planets elsewhere in our galaxy.

There are 100 billion stars in our galaxy, the Milky Way. Many of them are quite similar to our star, the Sun. Does that mean that there are millions or billions of planets like Earth in our galaxy? Maybe even planets with life like us? Until recently, astronomers had only been able to spot planets quite unlike those in our own Solar System, but in August 2005 our group discovered the first planet outside our Solar System which might have formed and developed in the same way as Earth.

Scientists believe that our own Solar System formed from a big interstellar cloud that collapsed 4.6 billion years ago. Most of the cloud became the Sun, but because the cloud was rotating, a small fraction of it was forced into a flat disk of gas and dust around the newborn Sun. In the outer part of the disk, far away from the Sun and beyond the present-day orbit of Jupiter, it was cold enough for water to form ice crystals and snowflakes. Just like on a cold winter day, it was snowing out there – but it snowed for millions of years. Colliding snowflakes and dust grains slowly became larger clumps of solid material, a bit like dirty snowballs. Once the first clump grew larger than 15 times the

Comparison of planets

	Mercury	Earth	Jupiter	Saturn	51 Pegasi b
Mass	0.06	1.00	317.8	95.2	148.8
Diameter	0.38	1.00	11.2	9.5	ca. 10
Density (water=1)	5.4	5.5	1.3	0.7	ca. 1
Distance from star	0.39	1.00	5.20	9.54	0.52
Orbital period	88 days	1year	11.9 years	29.5 years	4.2 days
Day temperature (°C)	350	15	-150	-180	1000
Composition	iron rock	rock iron	H and He gas	H and He gas	H and He gas



Comparison of the Sun and 51 Pegasi

	Sun	51 Pegasi
Radius	1.0	1.4
Mass	1.0	0.95
Temperature (°C)	5500	5430
Age	4.6 billion years	8 billion years
Metallicity	1.0	1.2 to 1.5
Spectral type	G2 (main sequence)	G3 (main sequence)
Luminosity	1.0	1.8

A comparison of the orbits of Mercury, Venus, and Earth with the orbit of 51 Pegasi b, the first discovered exoplanet

mass of Earth, its gravity dragged in the surrounding gas. In this way, the clump transformed itself into a gigantic planet with a solid core surrounded by huge amounts of compressed gas – we call it a gas planet, even though it also has a solid core of ice with small amounts of stone and metal inside. Jupiter, which is the largest gas planet in our Solar System, contains 300 times more mass than Earth, mainly in the form of compressed hydrogen and helium gas.

In the inner part of the disk, nearer the Sun, however, it was too warm for water to form snow. Instead, water stayed in the cloud, just like it stays in the air on a warm summer day. Only the very rare dust particles made of stone and metal could form solid clumps, and therefore the inner planets, Mercury, Venus, Earth, and Mars, became 'small' stone clumps (with an iron core), just like the rocky surroundings of Earth with which we are familiar. The lack of snow in the inner part of the cloud prevented the planets in this region from ever becoming huge gas planets like Jupiter. The small amount of water and atmosphere we have today came later to Earth (in a very complicated way, which is still a subject of intense debate between scientists), but it is next to nothing compared with the huge gas masses of Jupiter and the other gas planets.

It was therefore a big surprise when the first planet discovered around another star, in 1995, was a gigantic gas planet in a tiny orbit. At first glance, the discovery of this planet, 51 Pegasi b, strongly conflicted with our understanding of how planetary systems should form, as we had learned from studying our own Solar System: large gas planets in large orbits and small, Earth-like, solid planets in smaller orbits. However, the method that had been used to find planets (see below) was sensitive to such 'strange' planets. Today, it is generally believed that these large gas planets

BACKGROUND

Recent developments on exoplanets at ESO

The discovery at La Silla of an exoplanet of five times the mass of Earth is the latest achievement in a long series of breakthroughs made with ESO's telescopes. The ESO La Silla Paranal Observatory, with its large instruments equipping the Very Large Telescope (Pierce-Price, 2006) and the various smaller telescopes, is very well equipped for the study of exoplanets, with instruments for adaptive optics imaging, high resolution spectroscopy and long-term monitoring. A list of the most recent of these achievements is given below.

2002: Discovery of a dusty and opaque disc in which planets are forming or will soon form, surrounding a young solar-type star. This disc is similar to the one in which astronomers think the Earth and other planets in the Solar System formed. For more details, see www.eso.org/outreach/press-rel/pr-2002/pr-09-02.html

2004: Confirmation of the existence of a new class of giant planet. These planets are extremely close to their host stars, orbiting them in less than two Earth days, and are therefore very hot and 'bloated'. For more details, see www.eso.org/outreach/press-rel/pr-2004/pr-11-04.html

2004: Discovery of the first possible rocky exoplanet, an object 14 times the mass of Earth . For more details, see www.eso.org/outreach/press-rel/pr-2004/pr-22-04.html

2004: First image achieved of an exoplanet, leading the way for a more direct study of exoplanets. For more details, see www.eso.org/outreach/press-rel/pr-2004/pr-23-04.html and www.eso.org/outreach/press-rel/pr-2005/pr-12-05.html

2004: Ingredients for the formation of rocky planets discovered in the innermost regions of the proto-planetary discs around three young stars. This suggests that the formation of Earth-like planets may not be so unusual. For more details, see www.eso.org/outreach/press-rel/pr-2004/pr-27-04.html

2005: Discovery of a planet of mass comparable to Neptune around a low-mass star, the most common type of star in our Galaxy. For more details, see www.eso.org/outreach/press-rel/pr-2005/pr-30-05.html

2006: Discovery of the smallest known exoplanet, with only five times the mass of Earth (this paper). For more details, see www.eso.org/outreach/press-rel/pr-2006/pr-03-06.html

2006: Detection of three Neptune-like planets, each of mass between ten and 20 times that of Earth, around a star that also possesses an asteroid belt. Of all known systems, this is the most similar to our own Solar System. For more details, see www.eso.org/outreach/press-rel/pr-2006/pr-18-06.html

2006: Observations show that some objects with several times the mass of Jupiter have a disc surrounding them and may form in a similar way to stars. It thus becomes much more difficult to define precisely what a planet is. For more details, see www.eso.org/outreach/press-rel/pr-2006/pr-19-06.html

Henri Boffin, ESO

formed in the same way as did Jupiter and Saturn, but then slowly drifted inwards, towards the star they orbit. If Jupiter had behaved like that in our Solar System, it would most likely have engulfed our small Earth into its huge interior while passing us, and there would be no Earth today. But the orbits of all the planets in our Solar System are remarkably stable. We do not know if this stability is normal for planetary systems, or if it is unique to our Solar System.

Without it, conditions in our system would most likely have changed too drastically and too often for our fragile life to have survived. For example, the stability of the outer planets caused more than a thousand billion comets to be removed from the inner Solar System shortly after Earth was formed. If they had still been around today, regular collisions with them would most likely have removed our atmosphere and evaporated the oceans, preventing life from gaining a foothold. Maybe we exist in our Solar System precisely because it is the only place in the Universe that allows life to survive and develop over biological time-scales (i.e. billions of years).

If a planet orbits a star other than the Sun, we call it an extrasolar planet, or an exoplanet. Since 1995, scientists have discovered almost 200 exoplanets. Most of them (including the first) have been discovered using the radial velocity technique, which looks for changes in the position of spectral lines from the star and is most sensitive to very big planets in very small orbits. Most of the many other techniques that are now used to search for extrasolar planets are also mainly sensitive to planets that are very different from the planets in our Solar System. Therefore we continue to find mainly 'unexpected' planets. We find large gas planets in small orbits where they cannot have formed, or small solid planets in ultra-small orbits where they cannot have formed, or extremely large and bright planets in extremely large orbits around very small stars, and so forth. But this does not necessarily mean that even Earth-like planets are rare in the Universe. We just need to look for them with other methods. The main difficulty in detecting Earth-like exoplanets around distant stars is that Earth is small (so its light is obscured by the light of the star it orbits) and at the same time in a relatively large orbit (so its star must be observed for a very long time before any periodic movement can be detected).

For some years, our group has been working on the implementation of a method called microlensing (see figure on page 16), which is particularly sensitive to planets in orbits resembling that of Earth, and those with masses as small as that of Earth. When one star passes almost directly in front of another, its gravitational field will bend the light from the background star. The front star will then act as a magnifying lens, because it causes the light from the background star to reach us from several directions at the same time, thereby making it appear brighter. If the front star is alone (i.e. there is no planet moving around it), its gravitational field will be symmetric, and the brightness of the background star will therefore first increase, as the stars approach one another, and then decrease, as the two stars slide away from one another again. In this case, the light curve is symmetric in time. If, on the other hand, the front star is orbited by a planet, the gravitational field will be asymmetric. The brightness of the background star will then decrease in a way different to how it increased: the light curve will be asymmetric. It is these asymmetries that we look for. Typically the front star will be a star somewhat smaller than the Sun (there are simply more of these in our galaxy) and the background star will be a cool, red giant star (easiest to spot because they are very bright).

At Las Campanas observatory in Chile, a Polish team called OGLE[w1] monitors about 100 million stars, and alerts the scientific community when any of them become microlensed. In a collaboration between telescopes at the European Organisation for Astronomical Research in the Southern Hemisphere (ESO) in Australia and South Africa, we have formed the PLANET[w2] group, which monitors the best of the OGLE alerts 24 hours a day. During the most critical stages, we observe a given star every few minutes. In this way, we have resolved the light curves of more than 200 microlensing events during the last three years. From the many light curves that did not show any planetary signs, we conclude that Jupiter-Saturn-like planets (i.e. large gas planets) in Jupiter-Saturn-like orbits (i.e. large orbits) are rare in our galaxy. In other words, the kinds of planets that stabilised our own Solar System over biological time-scales seem to be uncommon in the Universe – a central conclusion for estimating the odds of finding life like ours elsewhere in the galaxy.

On 9 August 2005, however, the Danish telescope at the ESO observatory at La Silla, Chile, spotted the first signs of the kind of light-curve asymmetry we had been looking for, suggesting the presence of an orbiting planet. We immediately notified our collaborators, both inside and outside

our team, and over the next six hours, four telescopes in Chile, New Zealand and Australia confirmed the nature of the deviation. After three months of intensive modelling of the light curve, we were finally convinced that we had seen the signal from the smallest exoplanet that was ever observed, and in January 2006, we announced the dis-

Image courtesy of ESO

Extrasolar planet OB05390

covery in *Nature* (Beaulieu et al., 2006).

The new planet has the name OGLE-2005-BLG-390Lb, or, in short, OB05390. It is five times the mass of Earth (i.e. it is more 'Earth-like' than Mars, which is one-tenth Earth's mass), and circles a star 22 000 light-years away, in an orbit three times the size of Earth's orbit. This makes it the only known exoplanet which, according to theories, is made of solid rock, like Earth, and orbits its star at a distance at which it could also have formed. It may be the first extrasolar system ever seen in which the planets are in stable orbits, and where conditions for life are stable over biological time-scales, as in our own Solar System.

REVIEW

This article provides up-to-date information on developments in the field of extrasolar planet discovery. It details the discovery of a new Earth-like planet orbiting a star 22 000 light-years away using a new technique called microlensing – the detection of asymmetry in the gravitational lensing of light from a distant star as it passes behind a closer star – instead of the usual search for a 'wobble' in a star's spectral lines.

The article is of interest mainly to those studying or teaching astronomy or relativity (as an application of Einstein's ideas of gravitational lensing) to update their subject knowledge or for general-interest reading. The article itself contains no pedagogical content. The clear language and interesting subject, however, mean that it could be used with comprehension questions even for lower age groups (e.g. 15-16 year-olds). The article could also be used with more advanced students as the beginning of a research topic.

Mark Robertson, UK

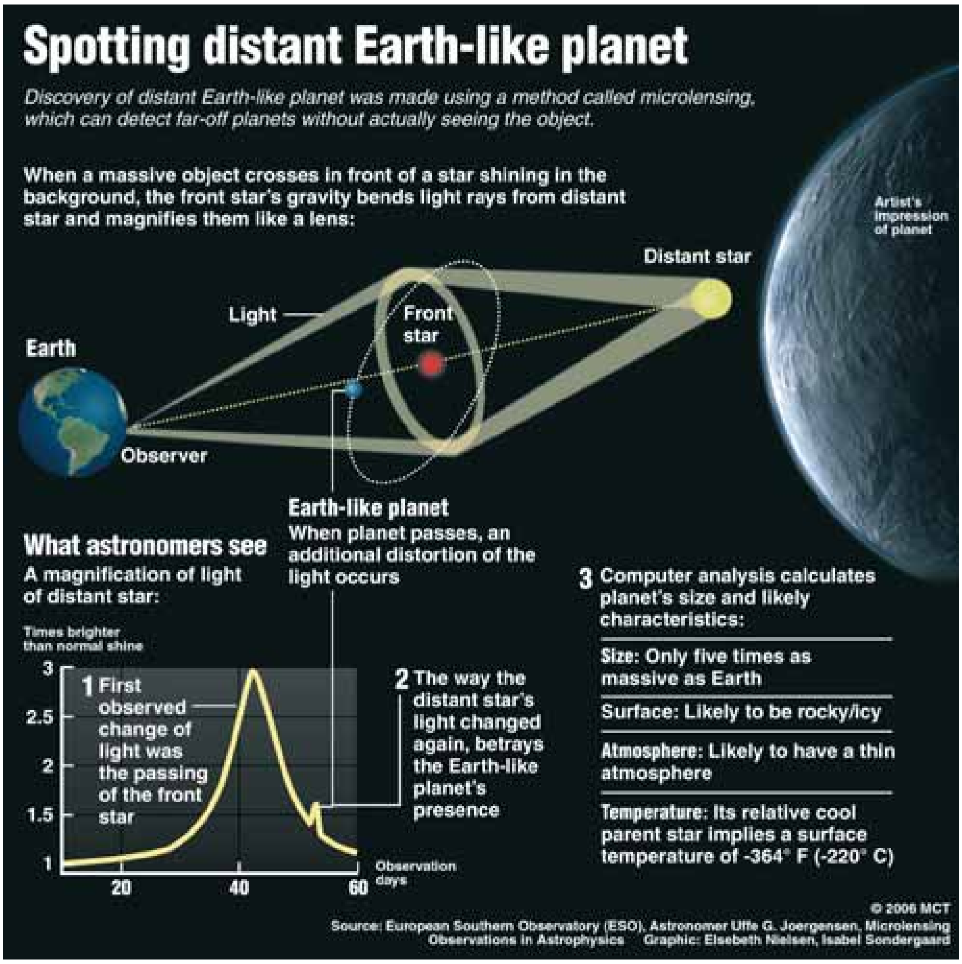


Image courtesy of Knight Ridder / Tribune Information Services

Explanation of microlensing

References

Beaulieu JP et al. (2006) Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing, *Nature* **439**: 437-440. doi: 10.1038/nature04441

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

Web references

w1 - OGLE: www.astrouw.edu.pl/~ogle

w2 - PLANET: http://planet.iap.fr

Resources

California & Carnegie Planet Search, a regularly updated site with important information about exoplanets: http://exoplanets.org

The Extrasolar Planets Encyclopaedia: http://exoplanet.eu

A recent in-depth and technical review of the subject: Marcy G et al. (2005) Observed properties of exoplanets: masses, orbits, and metallicities. *Progress of Theoretical Physics Supplement* **158**: 24-42. http://ptp.ipap.jp/link?PTPS/158/24

Further information about the research of Uffe Gråe Jørgensen and his colleagues is available here: www.nbi.ku.dk/side22730.htm

Uffe Gråe Jørgensen is Associate Professor at the Niels Bohr Institute, University of Copenhagen, Denmark

A new tree of life

From the top: Tobias Doerks, Christian von Mering, Peer Bork and Christopher Creevey

At the European Molecular Biology Laboratory in Heidelberg, Germany, Peer Bork's research group has meticulously reconstructed a new tree of life – tracing the course of evolution. **Russ Hodge** explains.

In the margins of one of Charles Darwin's notebooks is a small, twig-like drawing – unimpressive until you realise that it represents an enormous intellectual leap, a milestone in human history. It is the first modern sketch of a tree of life, representing the fact that distinct species had common ancestors. For a century, naturalists had collected facts about species, naming them and grouping them according to their similarities. Darwin suddenly understood that the similarities represented familial relationships.

Two decades later, another tree was meticulously composed by Ernst Haeckel, the great German naturalist and embryologist and a fanatical admirer of Darwin. Haeckel's chart attempts to synthesize the plant and animal kingdoms into a single genealogical record of life on Earth. He got a lot of things right, but the tree goes back only so far. Once it reached one-celled organisms, he was stuck – scientists were only beginning to glimpse the amazing variety of such species alive on Earth; they certainly didn't know enough to make a convincing phylogeny stretching back before the divergence of plants and animals.

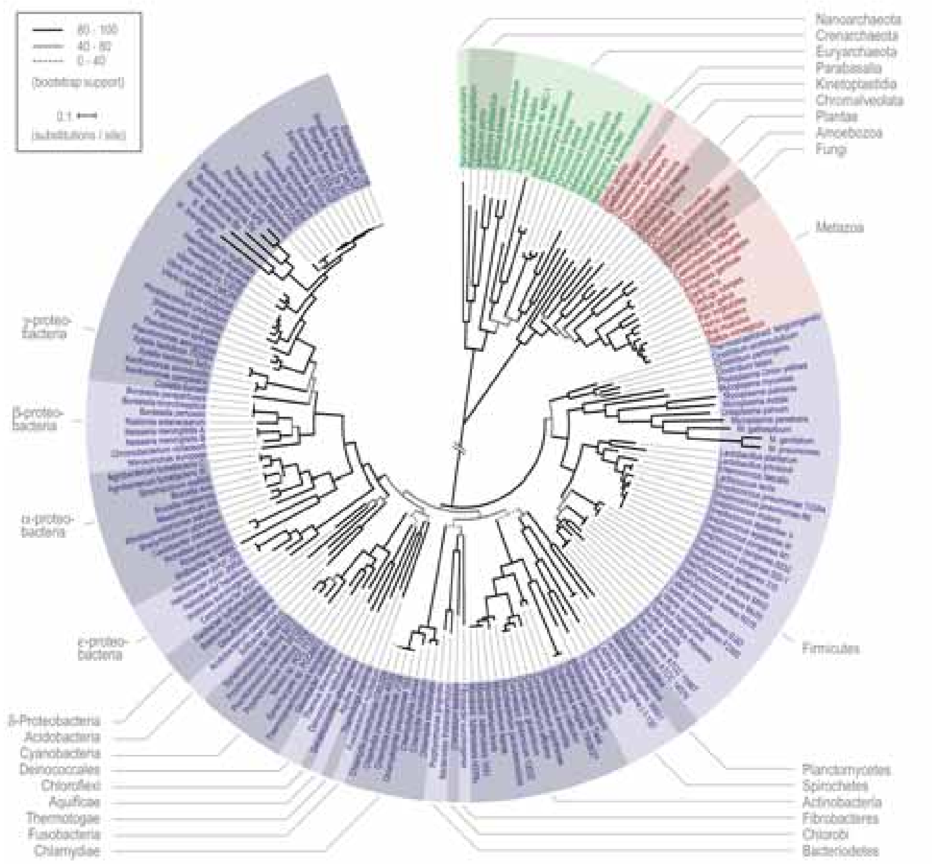
Since then, scientists have filled in branches and twigs, climbed down the trunk, and pushed deeply into the roots, drawing on the written record of evolution that is preserved in DNA. Still, questions remain, particularly with regard to the early history of life on Earth. Peer Bork's group at the European Molecular Biology Laboratory in Heidelberg, Germany, has now finished the highest-resolution tree of evolution that has yet been made. It may never be final – millions of species surely remain to be found, and those we know will continue to evolve. But it fills in many of the gaps, and will help scientists sort out fragmentary clues of the existence of new organisms. It also sheds light on the very early history of life on Earth.

★★★

Early in Earth's history, there existed an organism that would give rise to all the species known today. In 1994, Christos Ouzounis and Nikos Kyrpides gave this shadowy creature a name: LUCA, for the last universal common ancestor. Studies of DNA sequences taken from plants, fungi, animals, bacteria, and another form of one-celled organism called Archaea proved that it must have existed. But until recently, scientists could say very little else about it.

"Two things have changed," Peer says. "First is the immense amount of information we have from DNA sequencing – over 350 organisms have been completely sequenced, spread across the entire spectrum of life. This gives us a huge amount of data that can be compared to make a good tree and also to answer some questions about LUCA. Certain key genes can be found in all of them, and the chemical 'spelling' of these genes permits us to group them into families and historical relationships."

It also allows researchers to reconstruct hypothetical ancestors. A fundamental principle of evolution, called the principle of common descent, states that if two organisms share features, it is almost always



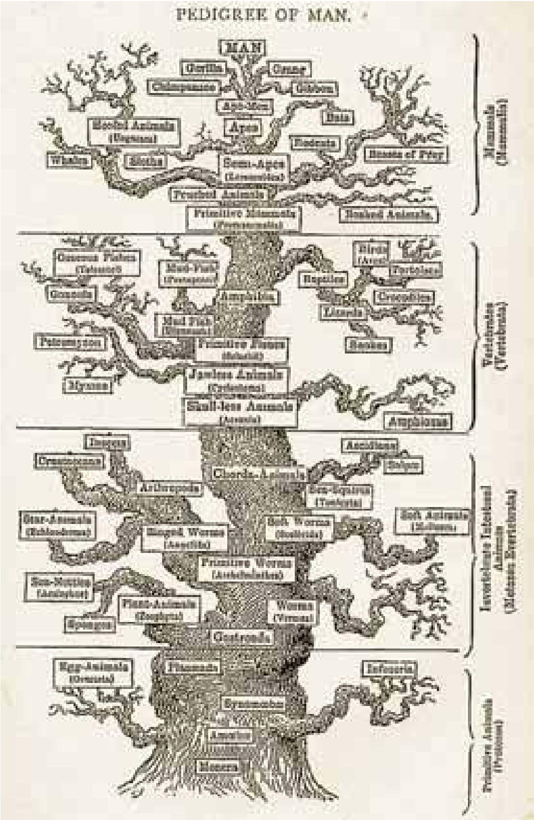
The new tree of life includes all three domains of life: Archaea, Bacteria and Eukaryota. There are so many species that the tree has to be drawn in a circle

because they inherited the characteristics from a common ancestor. So by comparing existing species, scientists can obtain a picture of more ancient forms of life.

"Over the past few decades, scientists have realised there is an important exception to this rule," Peer says. "Bacteria can swap genes with each other, and sometimes they can even steal a gene from a plant or an animal. Once that has happened, they pass the gene on to their descendents. Such genes have a completely different profile to genes inherited the normal way. It's like finding a branch from a tree that grows crosswise and fuses into another branch."

Peer says that attempts have been made to find such genes and eliminate them when building trees from DNA sequence data. But no one knew how often such events, called horizontal gene transfer (HGT), happened, or had developed a convincing method for finding them. "For a while, it was almost as if the amount of data was increasing the problem rather than solving it," Peer says. "There were big debates, and the numbers of classifications were growing rather than reaching a consensus." Part of the problem lay in the fact that the work could only be done by computer in a highly automated way, due to the incredible amount of genomic data that had to be sifted through.

Francesca Ciccarelli, a postdoc in Peer's group, decided to tackle the problem of the tree anew and find a solution to the problem of the HGTs. She started by combing the complete genomes of 191 species for unique orthologues – genes in different species that had evolved from a common ancestral gene. The task was difficult because it couldn't be completely automated. Francesca found 36



Haeckel's tree of life, from *The Evolution of Man* (1879)

cases, five of which seemed to have been shuffled around through HGTs and were thus discarded.

Eliminating these from the analysis, the scientists could now build a complete tree by combining information from 31 genes. Peer was worried that some HGTs might have still have slipped in – a single mistake could spoil the quality of the tree. So the scientists put the computer to work doing some heavy lifting. The 31 genes were randomly divided into four groups. Trees were systematically drawn over and over again, for all of the genes in each group, with the exception of a single gene that was eliminated in each round. Then the results were compared. If the branches of the trees changed from pass to pass, an HGT was likely to be involved, and the gene was submitted to two more tests. In the end, the scientists found seven more candidates for HGTs, which they eliminated from their analysis.

The remaining information was combined into a super-tree which was compared once again to trees based on individual genes in three different ways. "Any one of these methods on its own might have left a tree with some mistakes," Peer says, "but by combining them, we're confident that we have an extremely accurate picture of the evolutionary history of these molecules and the species."

The results clear up some old controversies, for example, a debate about the very early evolution of animals. Some trees in the past proposed that the vertebrates (which include humans) split off from another branch which would remain united for a while before splitting into separate branches leading to worms and insects. The new version groups things differently: vertebrate and insect ancestors split off from the worms together, and diverge from each other later.

The higher resolution of the tree is also important, Peer says, because of metagenomic studies which are underway to sequence all the genes found in environments such as farm soil or ocean water. His group has participated in several such projects. "Most sequencing approaches start with a given organism and work through its whole genome systematically," he says. "Metagenomics is sequencing a place – like a global positioning system coordinate. In many cases we recover fragmentary traces of thousands of genes, and have no idea what organism they come from. Often these molecules represent creatures that have never been seen before." The breadth and detail of the new tree will allow scientists to make much better guesses about where such fragments fit in and what types of living beings they belong to.

Has the living world been fairly split up into major branches, limbs, and twigs, or have we overemphasized the prominence of our own lineage? A close look at the new tree shows that the latter seems to be the case. The eukaryotes, which include yeast, plants and animals such as ourselves, are so visibly different from one another that scientists have pushed them apart from each other on the tree. Genetically speaking, however, the species are often much more closely related than many single-celled forms of life.

"Smaller genomes evolve faster," Peer says. "There isn't a single organism that has been sequenced that is both evolving fast and has a large genome. It suggests that some of the simplest species around have ended up that way because they have pruned things down. Evolution isn't always about acquiring complexity."

The study also gives the scientists a closer look at LUCA. "One very big question has been what the earliest bacteria were like when they split off from the Archaea. Bacteria are grouped into two classes, called Gram-positive and Gram-negative, based on features of their membranes. The new tree reveals that Gram-positive bacteria evolved first. And if you look at their repertoire of genes, they seem to be suited to a very hot environment. The first Archaea were discovered in hot ocean vents, and most of the species alive today are thermophilic. It strongly suggests that LUCA was, too."

This article appears in the annual report of the European Molecular Biology Laboratory, a collection of articles on topics from the most current science. The rest of the report can be seen at: www.embl.org/aboutus/news/publications/report.html

Scientists at play: contraptions for developing science process skills

In the second of two articles on developing the processes of enquiry, hypothesis and testing, **Alfredo Tifi**, **Natale Natale** and **Antonietta Lombardi** describe how to build and apply some of the low-cost equipment they have developed.

To recap, science process skills are fundamental to science, allowing everyone to conduct investigations and reach conclusions. We are convinced that there is a serious educational gap in this area, both in bringing these skills into the classroom and in training teachers to do this. To facilitate the introduction of science-inquiry principles in school, we developed a set of lab activities for use in primary and secondary schools. In the first of two articles (Tifi et al., 2006), we discussed the development of these activities and described games involving 'transformer machines'. Below, we describe contraptions – physical black boxes to inspire exploration, hypothesis and testing.

Contraptions

The principle behind contraptions is similar to that of the operating machines described in our first article, but these are physical black-box machines that have at least two external movable parts that act as input and output. The parts may be coloured threads, rotating knobs or stems, penetrating bars or tilting levers. The two are coupled through an inner mechanism of gears, pulleys and belts, wheels or Technic Lego®. Alternatively, common objects may be used, such as the rollers found in corrector pens.

Lego gear wheels

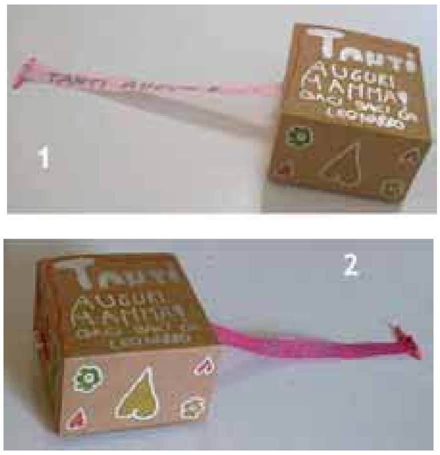
Corrector pen roller

The students explore the contraptions and do experiments, manipulating one of the external parts (input) and observing causal behaviour (output) on other external parts.

The students can only infer the inner mechanism by developing models and comparing the predictions from the models with what happens with the actual machine.

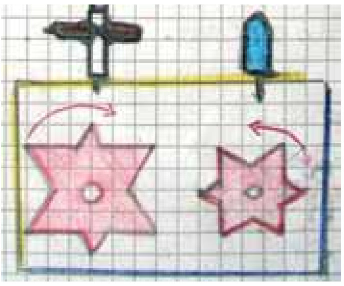
Gear and pulley machines can have two or more wheels of the same or different diameters. They can be coupled using a single thread, or a continuous belt, creating a wide assortment of hidden mechanisms.


Investigating gears


A gadget for mother

See page 23 for a construction plan of the tape contraption.

With a simple reel wound with two coloured threads in opposite directions, all hidden inside a card box, you can make a machine in which pulling a red thread causes a white thread on the opposite side to be drawn inside. If the threads are wound in opposite directions on two coaxial bobbins of very different diameters, pulling both threads causes the box itself to move vertically, whereas pulling just one thread causes the other thread to be drawn into the box at a different rate. See page 22 for a construction plan of the thread-lifting contraption.



These investigations were the most popular among grade 4-5 children (ages 10-12): ideas within 'research groups' (3-4 pupils) were discussed and the children enthusiastically searched for effective models, using ribbons, wheels, pencil-made axis, and paper strips[w1].

Not only did the students closely observe the machine behaviour and record the factual evidence, as well as conjecturing, improving, debating and defending their models; they also had a strong creative need to make their own prototypes of the models. One group used the principle of the thread machine to build pretty gadgets for their mothers, in which different words of affection were displayed on the same fabric band, depending on the side from which the band was pulled.

The manipulative aspect of these tangible machines encourages representative and kinaesthetic thinking, both of which are crucial for scientific insight and speculation. Furthermore, the children feel comfortable with these investigations, because they are at the same level, tackling a completely new job with classmates of equal abilities. This is in sharp contrast to the low self-esteem that children often have in content-based curricular subjects. It is not uncommon to find children who cope successfully and participate actively in these modelling and creative activities, despite low scores in traditional schoolwork.


Modelling gears

Materials

Attaching the thread

Assembling the contraption

Construction plan for the thread-lifting contraption

Materials

- Cardboard box
- Two 50-70 cm pieces of strong, coloured thread
- Two pieces of compact foam polystyrene cut to fit the opposite walls of the box, both with a hole in the centre
- A plastic tube (e.g. from a pen) and an axis to be inserted inside the plastic tube (this latter is as long as the opposite sides of the box and permits the external tube to slide and to rotate freely; the tube is shorter then the internal axis so that it is free to rotate once it is mounted in the box)
- A spool that can be fixed on the tube with the larger diameter
- One or two discs adaptable to the rotating tube, to control the rolling-up of the thread
- Two nuts.

Method

1. Open a paperclip and heat it over a flame; use this hot point to make a hole in the plastic spool where you want to fix the thread and where the thread will be rolled up. Pass the thread through this hole and fix it with a big knot.
2. Attach another piece of thread, tying it tightly near the centre of the tube.
3. Insert the spool almost onto the centre of the tube, and then fix the knot with a drop of quick-drying glue (above centre). The two threads must be rolled up as far as possible near the centre of the tube.
4. Insert the counter-disc on the opposite side of the big spool (this is optional). If the spool groove is not deep enough, use another disc to separate the two threads and prevent them from tangling. Fix all pieces over the tube with quick-drying glue.
5. Cut 50-70 cm of each thread; make two narrow holes at the centre of two opposite sides of the box at a right angle to the rotating axis direction, then pass the threads through the two holes. Only one thread must be completely rolled around its seat. Tie two nuts to the free end of the threads.
6. Insert the axis inside the tube and mount the rotating axis over the two facing styrofoam rectangles, standing outside of the box.
7. Insert the mechanism into the box, pulling out the threads to leave them free to go out and in. Close the box and seal it only when you are sure it works well; then give it to the children!

Operating

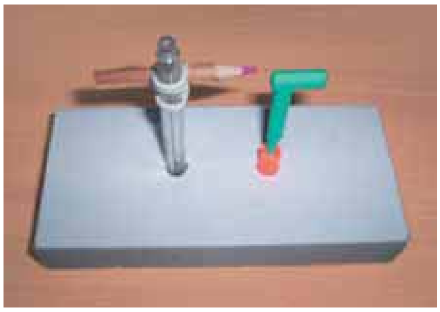
When both threads are pulled, the box moves upwards and towards the thread that is rolled around the smaller pulley. Relaxing the pulling force allows the box to drop under gravity. The rates of disappearance and emergence of the two threads are proportional to the diameter of the pulley to which they are fixed.

It is advisable to start playing with a similar machine where the big pulley is absent and the two threads are rolled on the same reel. The children will devise a simpler model; then it will be easier for them to jump to the two-wheel model.

The contraption in operation

Materials

Reattach the tape to the wheel



The finished tape contraption

Construction plan for the tape contraption

1. Open an old recording tape cassette.
2. Unblock one end of the tape, cut out most of the tape, leaving 20-25 cm, and fix the free end to the wheel again (above centre)
3. Enclose the tape cassette in a box, fixing it with adhesive tape.
4. Make two small holes in the box, corresponding to the two wheels on the cassette. Cover the gears to make them invisible from outside and then close the box.
5. Model two suitable pens, adapting them to the gears behind the holes.

This contraption is very puzzling for children and should be introduced after the simpler gear and pulleys contraptions. The tape contraption can be complicated further by changing one of the two wheels for a bigger one.

Investigating gears

REVIEW

This article deals with science process learning in school, and I recommend it for teachers both in primary and secondary schools. These are practical descriptions of how to construct the black boxes with hidden contents. There are good examples of different boxes that can be used with different ages of students according to their ability. Pictures showing the boxes and experiments are provided to help the teacher make the black boxes.

Sølve Marie Tegner Stenmark, Norway

References

Tifi A, Natale N & Lombardi A (2006) Scientists at play: teaching science process skills. *Science in School* **1**: 37-40. www.scienceinschool.org /2006/issue1/play/

Web references

w1 - www.scienzainrete.it/unita_ didattiche/marchingegno.htm

Resources

The American Association for the Advancement of Science stresses that key science concepts need to be given in the context of an authentic understanding of how scientists go about their work to reach conclusions. For an example, see: www.project2061.org/publications /bsl/online/ch1/ch1.htm

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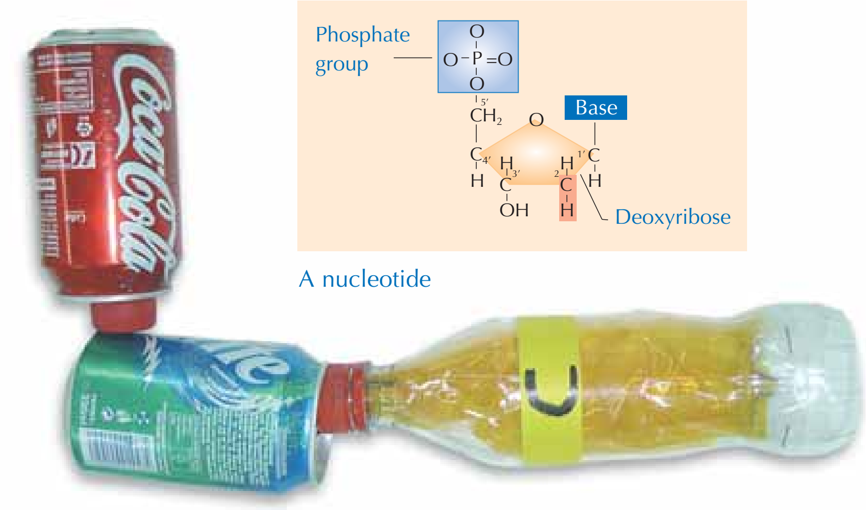
Modelling the DNA double helix using recycled materials

Dionisios Karounias, Evanthia Papanikolaou and **Athanasios Psarreas**, from Greece, describe their innovative model of the DNA double helix – using empty bottles and cans!

This project to construct a 3D model of a DNA molecule, using everyday materials, stimulated the students' interest, encouraged teamwork, dexterity and the investigation of the properties of materials, and allowed the students to express their own opinions and solve problems. More specifically, students learned the basic structural elements of DNA and their 3D molecular organisation.

Molecular structure of DNA

The basic unit of DNA is the nucleotide, consisting of a phosphate group, a sugar molecule (deoxyribose) and one of four nucleobases (also known as bases): adenine (A), thymine (T), guanine (G) or cytosine (C). The DNA molecule consists of successive nucleotides arranged in a double helix – a spiral ladder – the sides of which are formed from sugar and phosphate groups, with each step consisting of a pair of bases. The base pairs are formed from complementary nucleotides: adenine pairs with thymine, while guanine pairs with cytosine.



A nucleotide

The model

Each of the three constituents of the nucleotide were represented with 3D objects (see Table 1) which were connected to form a double helix with ten steps (base pairs). See below.

Table 1: DNA molecular components and the corresponding model materials

DNA molecule	Model
Phosphate group	Coca Cola® can
Deoxyribose molecule	Sprite® can
Base	Plastic bottle

Materials

Recycled materials

Our choice of materials reflected their abundance in the school recycling bins.

- 20 aluminium Coca Cola® cans
- 20 aluminium Sprite® cans
- 20 plastic Coca Cola bottles (500 ml)
- 60 red caps from Coca Cola bottles
- 10 plastic Fanta® bottles (500 ml)
- 20 orange caps from Fanta bottles
- a thin piece of paper or plastic, approximately 1 m long.

Additional materials

- 6 m thin rope
- 20 plastic drinking straws
- 20 nuts and thin double-threaded bolts
- 4 sheets of coloured confectionery cellophane (blue, green, red and yellow).

Tools

- Scalpel or sharp knife for cutting the plastic bottles
- Thick nail for the making holes in plastic and aluminium
- Small pliers
- Stapler
- Two pieces of thin telephone cable, about 40 cm long, for passing the rope through the straws.

Method

First, each of the three nucleotide constituents (deoxyribose, phosphate and base) are modelled, reflecting the geometry of the molecule as far as possible. Next, the components are assembled to form nucleotides and the DNA helix is constructed.

Puncture the aluminium cans and the bottle caps with the same nail. Heating the nail will enable the caps to be more easily pierced. Choose a suitable thickness of nail to enable the plastic drinking straws to pass through the holes and fit firmly, creating a stable link between the structural elements.

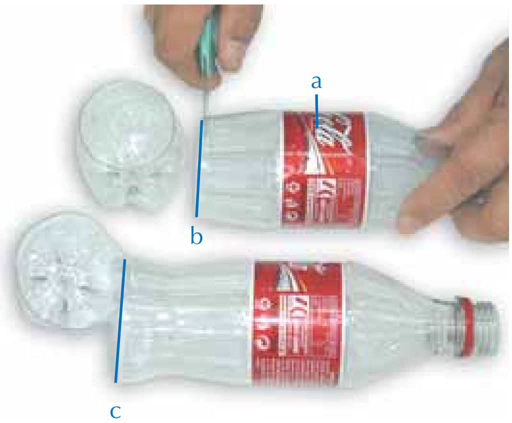
Deoxyribose

Deoxyribose is modelled with a Sprite can with three red bottle caps attached, representing the carbon atoms at the 1′, 3′ and 5′ positions (above right). An orange bottle cap at position 3′ represents the hydroxide that will be connected to the next nucleotide.

1. Puncture the can in positions 1′, 3′ and 5′, as shown above .
2. Puncture four bottle caps (three red and one orange) in the centre.
3. Using a nut and bolt, attach a red cap firmly in position 1′ so that a bottle can be screwed on.
4. Firmly attach two caps, one red and one orange, to one end of a straw (first the red, then the orange).
5. Pass the straw through the can, using holes 3′ and 5′.
6. Fix the can to the straw, threading another red cap to the side of the can in position 5′. The final result can be seen above right.

Phosphate group

Using the same nail, puncture the centre of the Coca Cola can base, which represents the phosphate group. Thread the straw attached to the Sprite can (deoxyribose) through the Coca Cola can (phosphate group), with the top of the Coca Cola can closest to the Sprite can. The phosphate group is now attached to the deoxyribose in position 5′ (see page 26, left).



The straw connects the two cans, and also makes it easy to pass the thin rope through both cans, connecting the nucleotides into a molecule chain (see below). For this reason, it is important not to bend the straw.
To maintain the correct scale between the molecule and the model, the distance from the base of the Coca Cola can to the orange cap should be 23 cm.

Complementary base pairs

Next, plastic bottles representing the bases are modelled so that they can only be connected to their complementary base (adenine to thymine, and guanine to cytosine).

To construct two complementary base pairs, cut two Fanta bottles and three Coca Cola bottles in cross-section, using the scalpel and scissors. Take care!

1. Remove the base of two Coca Cola bottles (incision c above centre)
2. From the third Coca Cola bottle, remove
   a) the neck, cutting 10 cm below the mouth (incision a) and
   b) the lower part of the bottle, cutting 4 cm above the base (incision b).

Using scissors, make five to six incisions, 2 cm long, in the neck and the base of the third Coca Cola bottle. These can then open to allow other bottles in (see above right).

Using these building blocks and the coloured cellophane, the structural elements that represent the bases can be created (see page 27).

Thymine (T)

Place green cellophane in a Coca Cola bottle without a base.

Adenine (A)

To the base of a Fanta bottle, attach the neck of another Coca Cola bottle. Place blue cellophane inside both parts.

Thymine (T), represented by the colour green, is connected by two hydrogen bonds to adenine (A), represented by the colour blue. To model this, push the blue neck firmly into the green bottle without the base.

Guanine (G)

Place red cellophane in a Fanta bottle.

Cytosine (C)

Place yellow cellophane in a Coca Cola bottle without a base. Firmly attach the base of another Coca Cola bottle, upside down.

Guanine (G), represented by the colour red, is connected by three hydrogen bonds to cytosine (C), represented by the colour yellow. To model this, open the base of the yellow bottle (cytosine) along the incisions to allow the base of the red bottle (guanine) to enter and lock firmly.

For symmetry and the scale of the model, the two pairs of linked complementary bases should be 42 cm long. Each coloured bottle is screwed into the bottle cap (carbon) at position 1′ of a deoxyribose molecule, forming four different nucleotides (see page 28).

This representation of the hydrogen bonds enables the easy connection and detachment of complementary bases. This, in turn, facilitates not only the separation of the DNA strands but also the change in position of bases for teaching purposes.

Constructing the DNA molecule

Having constructed 20 nucleotides, we can build a double helix with 10 steps – two strands of 10 nucleotides each. Because the distance from the end of the Coca Cola can (phosphate group) to the orange cap (hydroxide linked with the next phosphate group) is 23 cm, the strand of 10 nucleotides will be 2.3 m long.

Attach the telephone cable to approximately 3 m of the thin rope and use the stiff cable to pass the rope through the straws of the nucleotides to form two strands of molecules, which are hung vertically 2 m high and 65 cm apart. The two strands of the DNA molecule are read in the direction 5′ to 3′ and are anti-parallel. In the model, the direction in which we read the word Coca Cola coincides

with the direction 5′ to 3′. Thus, in one of the strands, the words Coca Cola can be read from top to bottom and in the other strand, from bottom to top. Our model DNA strands are thus also anti-parallel.

We must also make sure that the bases on one strand are complementary to those on the opposite strand. Adenine should be opposite thymine and cytosine opposite guanine.

If these criteria have been met, tie a paper roll at the end of each strand so that a thin bar can be passed through the roll and used to twist the linked strands clockwise, 360 degrees (see page 28, bottom right).

Scale

The model represents a DNA molecule at a scale of 320 000 000:1, that is, 320 million times bigger than it really is. If we tried to represent an entire human DNA molecule with our model, we would need a double helix 640 000 km long, capable of wrapping around Earth's equator 16 times.

Using the model in class

The model was constructed and used in three phases over one to two weeks.

Phase 1: Constructing the model

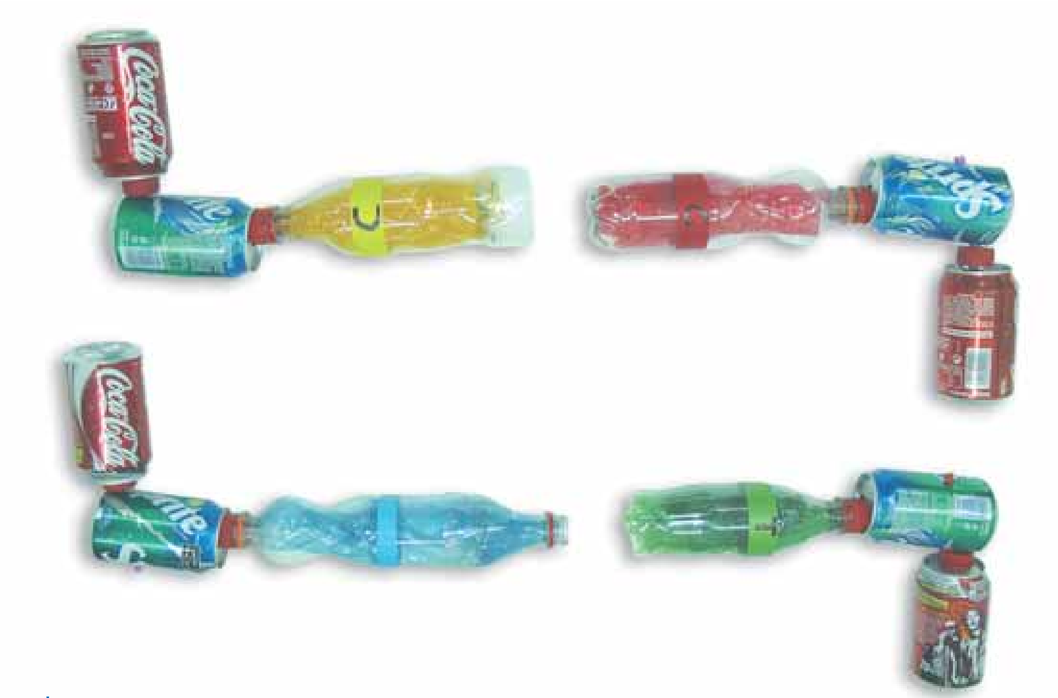
Students aged 14 followed the construction directions with interest and were involved in resolving practical problems.

Phase 2: Representing a DNA molecule

In the appropriate unit of their biology course, students aged 15 were given a worksheet where they recognised and matched the prepared structural materials of the model with those of the DNA molecule as illustrated in their textbook. They composed and twisted the double chain of the model. They asked a lot of questions and had an intense and interesting discussion.

Table 2: Sizes and proportions of a DNA molecule and the model

	DNA molecule	Model
Diameter	2 nm	0.65 m
Helix step	3.4 nm	1.1 m
Helix length	7.14 nm	2.30 m
Helix length: diameter	3.57	3.53
Helix step: diameter	1.7	1.7



Phase 3: Copying a DNA molecule

In their free time and as a theatre game, the same 15-year-old students pretended to be suitable enzymes and, with the help of the model, performed the following steps:

1. Splitting hydrogen bonds between the complementary bases, from the top of the molecule until the sixth base (bottle) pair on the model (enzyme: DNA helicase).
2. Separating the two strands.
3. Beginning to create daughter strands complementary to the parental strand (DNA polymerase).
4. Splitting the rest of the hydrogen bonds.
5. Creating daughter strands complementary to the parental strand (DNA polymerase).
6. Checking for possible errors and correcting them if necessary.

REVIEW

Students learn much more quickly and easily when they are actively involved in the lesson. Teaching the structure of DNA is made much easier if a 3D representation of the molecule is used. Jigsaw puzzle-type activities give a 2D picture, but it is difficult to visualise the shape of the molecule. This ingenious project describes how a scale model of DNA can be made using cans and bottles. It would be easy to collect the materials required to make this model, as students could recycle cans and bottles.

It may be a good idea for a technician or teacher to do some of the preparation work; this would decrease the amount of time needed in the lesson as well as addressing safety considerations with the use of a hot nail to puncture the bottle tops and a sharp implement to cut the plastic bottles. Alternatively, the model could be made in a design-technology class and then used in biology lessons. Group work could be designed so that teams race each other to prepare a DNA model. The model could be used as a teaching tool to demonstrate DNA replication, either in mitosis or in the polymerase chain reaction. The fact that the model is to scale will help the students appreciate the spatial relationship of the components of the DNA molecule. I feel that students will enjoy learning about DNA using this idea, which means that the lesson will be both understood and remembered.

Shelley Goodman, UK

The chocolate challenge

John Schollar from the National Centre for Biotechnology Education at the University of Reading, UK, finds an excuse for eating one of his favourite foods – chocolate.

Every country in Europe seems to have its own favourite chocolate, and the characteristics of the best-selling brands vary greatly. Thus, milk chocolate with a caramel note dominates the English market while the French prefer darker chocolate with a greater content of cocoa solids. How can different brands of chocolate be objectively compared, and how can quantitative data be obtained from such comparisons? Here are some simple yet effective comparative procedures that are widely used in the food industry. Typically, they are used for quality control, to assess changes in the product (for example, as a result of changes in raw materials or production methods), to monitor shelf life and to assist in the development of new products. The methods yield data suitable for statistical analysis and can be used for chocolate or for other food products such as fruit juice or biscuits.

Preparing the chocolate

For this exercise, you will need a minimum of three different products. The maximum number of brands you can compare will be determined largely by the time you have available, but in practice it is difficult to compare more than six products. We usually find that four different types of chocolate, carefully selected to give a range of characteristics, are ideal for a classroom activity.

To avoid bias, the chocolate should be presented to the students without identifying the brand. Identify each of the products with a three-digit code picked at random so that there is no number bias.

Manufacturers' names are often moulded into chocolate bars, so you may wish to remove the name to preserve the anonymity of each type of chocolate. This can be done in two ways. We have a laboratory heating block set to 40 °C, which we cover with a clean sheet of aluminium foil. We place the each chocolate bar face down on the foil for a few seconds until the manufacturer's name has been melted away. If you do not have a heating block, remove the name with a spoon or knife that has been warmed in boiling water; this takes a little time, but it is effective as most chocolate melts at about 37 °C.

Unfortunately the shapes of chocolate bars often provide a clue about the identity of the brand, so removing the name may not be a fool-proof means of ensuring that the tasters are not biased.

Once the names have been removed, cut chocolate into pieces that are suitable for tasting - we usually provide students with pieces about 10 mm square.

For each working group, put samples of each type of chocolate into separate clean plastic bags, labelled with the appropriate identification code. Provide one sample for each student (we usually ask students to work in groups of four).

Materials and equipment needed by each person

- Three or four different brands of chocolate, cut into small squares about 10 mm x 10 mm (one sample of each type)
- A clean paper plate on which to place the chocolate samples
- A glass of water for cleaning the palette after tasting each sample
- Photocopied sheets (pages 31-33) on which to record the results
- A ruler marked in millimetres
- Coloured pencils (a different colour for each type of chocolate)

Procedure

1. Taste each chocolate sample in turn, and as you do so, use the sensory testing chart to record the characteristics of each brand of chocolate. Use a different coloured pencil for each chocolate sample. Take a sip of water after tasting each sample to refresh your palette.

2. Measure the distances between the beginning of each line and the coloured marks you have made on the lines. Convert the positions marked for each characteristic for each chocolate sample into percentage values, and record these values in the personal summary table. Note that each line on the first chart is 100 mm long, so that the positions marked on the line are easily converted into percentages.
3. Collate the results for your group in the group summary table. Note that it may be easier if you divide the work and one person collects all the data for one chocolate type.
4. Calculate the group mean for each characteristic. If desired, you may also collect the data for the entire class.
5. In the chart on page 33, plot a sensory profile (zero at the centre, 100% at the extremity) for each chocolate brand. Each brand of chocolate will have a sensory profile represented by a different shape. If you use coloured pencils for this, all the data can be shown on one chart.
6. If time allows, the data for the entire class can be collated and compared. Your personal perception of each chocolate's characteristics can be compared with group or class results.
7. Finally, discover the identity of each of the different brands of chocolate you have tasted. Look at the ingredients such as milk and cocoa solids listed on the wrappers for each of the chocolate samples. Try to relate the results you have obtained to information on chocolate wrapper and any advertising claims made for each brand.

Safety

For reasons of hygiene, wear disposable plastic gloves while you are preparing the chocolate. The samples must be prepared in a kitchen or room suitable for food preparation, not a laboratory. The chocolate should not be tasted in a laboratory.

IMPORTANT! Teachers should be aware that some students may have food allergies (e.g., to nuts) and will therefore be unable to carry out this work.

Preparation and timing

The activity takes about 60 minutes. The chocolate samples should be prepared in advance.

Resources

Further information about chocolate manufacture, including practical investigations suitable for the school laboratory are given in:

Beckett ST (2004) *The Science of Chocolate.* London, UK: Royal Society of Chemistry

Additional information is provided in Chapter 12 of:

McGee H (2004) *McGee on Food and Cooking: an Encyclopedia of Kitchen Science, History and Culture*. London, UK: Hodder and Stoughton Ltd

A useful compendium of chocolate facts and figures is provided in:

Ayral D (2001) *A Passion for Chocolate*. London, UK: Cassell & Co

Sensory testing chart

For each chocolate sample, mark a point on the line showing where you think the relative strength of each attribute lies. Use a different coloured pencil for each chocolate sample, or write the chocolate's code above the mark.

	NONE	A LOT
Aroma COCOA		
Aroma MILK		
Flavour SWEET		
Flavour BITTER		
Flavour COCOA		
Texture MELTING		

Personal summary table

Each line on the sensory testing chart is 100 mm long. By measuring the distances from the left-hand edge to your marks, turn your assessment for each chocolate and characteristic into a percentage, where 1 mm = 1%. Record your assessment of each chocolate sample in the chart below.

	CHOCOLATE SAMPLE CODE			
	273	475	620	948
Aroma COCOA				
Aroma MILK				
Flavour SWEET				
Flavour BITTER				
Flavour COCOA				
Texture MELTING				

Group summary table

Collate the results for your group in the table below and calculate the group mean for each characteristic. You will need a separate copy of this table for each chocolate sample.

CHOCOLATE SAMPLE CODE:

	GROUP MEMBER NAMES				Group mean
Aroma COCOA					
Aroma MILK					
Flavour SWEET					
Flavour BITTER					
Flavour COCOA					
Texture MELTING					

Class summary table

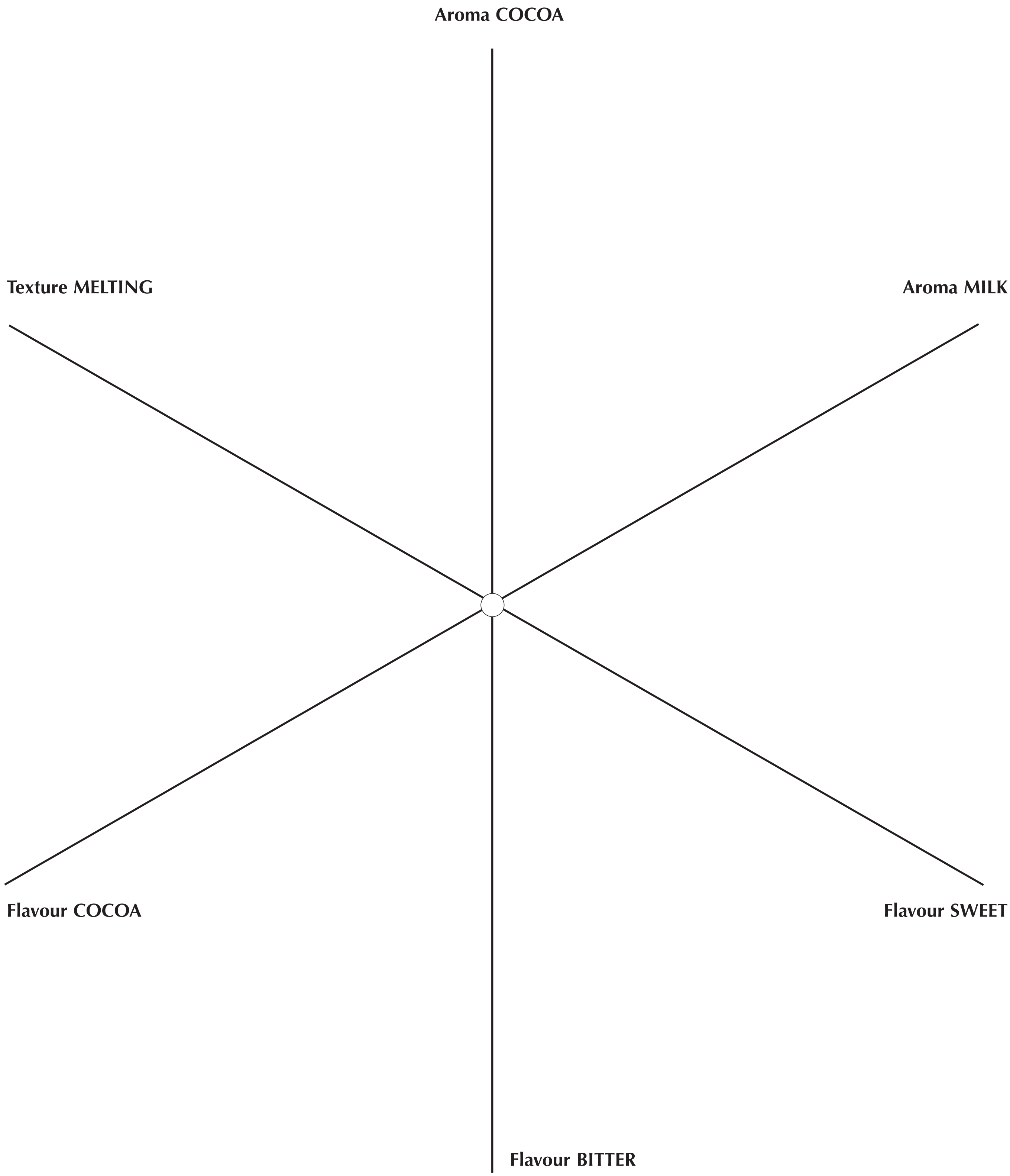
OPTIONAL: Collate the results for your class in the table below and calculate the class mean for each characteristic. You will need a separate copy of this table for each chocolate sample.

CHOCOLATE SAMPLE CODE:

	GROUP NUMBER										Group mean
	1	2	3	4	5	6	7	8	9	10	
Aroma COCOA											
Aroma MILK											
Flavour SWEET											
Flavour BITTER											
Flavour COCOA											
Texture MELTING											

Sensory profile

On the chart below, plot a sensory profile (zero at the centre, 100% at the extremity) for each chocolate sample. Each sample will have a sensory profile represented by a different shape. If you use coloured pencils for this, all the data can be shown on one chart.



Environmental chemistry: water testing as part of collaborative project work

Wetlands are key habitats for a vast range of wildlife. **Richard Harwood** and **Chris Starr**, from Aiglon College, Switzerland, describe a school project to measure water quality in a local wetlands region.

Environmental issues centred on water are among the key concerns in our modern world; the global problem of disappearing wetland regions is particularly significant. Wetland regions are key habitats in the preservation of a vast range of wildlife species, and the health of such regions is an important indicator of the health of the 'blue planet'. The past 50 years have seen the earth's wetlands reduced by around 50%.

Concern over wetland regions provides part of the background to a series of cross-curricular studies that we have carried out at Aiglon College, an international school based in western Switzerland. The collaboration between our geography and chemistry departments in carrying out these studies was also seen as important, emphasizing the interaction between the skills and methods involved in the two subjects. The studies were carried out by students in their final two years of secondary school.

Aiglon's location close to the eastern end of Lake Geneva allows us ready access to a small, but highly significant, wetland region at the delta of the Rhone where it flows into the lake. This region of Switzerland is experiencing rapid urbanisation and the development of services for the tourist industry, which are putting increasing pressure on the few remaining natural habitats of the Rhone plain. The delta wetlands area, known as Les Grangettes, is rich in wildlife, featuring a great diversity of reptiles, amphibians, invertebrates and birds. Around 265 bird species have been identified in the reserve, including many migratory waterbirds. Since 1990, the area has been recognized as a wetland of international importance under the Ramsar Convention, but it is still threatened by the encroachment of human activities and modifications of the natural environment, whether intentional or unintentional.

Collecting a sample from a canal

The scope of the studies

Our studies of this region included a range of approaches involving land use surveys, an analysis of the impact of tourism, biodiversity data collection and the assessment of water quality. To carry out a thorough study of water quality, it was important to strategically choose the points in the area to collect water samples. Water samples were taken from some 24 different sites in the Les Grangettes region, covering a range of different locations – canals, drainage ditches, lake frontage and stagnant pools.

We tested water for a range of parameters, such as:

Reed beds in the Okavango Delta – one of Earth's most unique wetlands

The team minibus serves as a base as we move around the 24 sites

Testing the water samples – in both the field and the lab. A range of equipment was used, from pH strips to datalogging sensors

- pH
- dissolved oxygen
- nitrate ion concentration
- phosphate ion concentration
- turbidity

Some of these tests were carried out immediately in the field, but these were also followed up with more sophisticated testing back in the lab.

The type of testing that we carried out varied from simple test strip methods for pH and nitrate ion concentration to electronic sensing (for dissolved oxygen and turbidity, for example), reflectometric reading of test strip colours (for nitrate and phosphate ion concentration), and the use of specific ion electrodes (for nitrate ion concentration). The electronic sensors were linked to data-logging instruments and electronic calculators. The use of this range of methods not only served to check the reliability of the methods but also introduced the students to the different levels of sensitivity available for measuring these factors.

A major focus was to assess whether fertilisers were leaching from

BACKGROUND

Statistical analyses

The purpose of the statistical tests used is described below. Details of how the tests are performed can be found in Lenon & Cleves (2001).

Spearman's Rank Correlation Coefficient

This technique is used to summarise the strength and direction of any correlation between two variables, such as nitrate [NO_3-] content of water and distance from arable land. The correlation coefficient (numerical index of correlation) varies from +1 (a perfect positive correlation) to -1 (a perfect negative correlation). A value of 0 indicates no correlation between the two sets of variables. The greater the sample size and number of measurements, the more significant the correlation is likely to be. Its significance can be tested by using a test of significance, such as the t-test.

Remember, this coefficient does not necessarily prove a causal relationship between the variables. However, it may suggest that it is worthwhile conducting further research to uncover the processes which may have led to the correlation.

Mann-Whitney U-Test

This is a test of statistical significance, used to establish whether the differences between two sets of data are really significant or could have occurred by chance. For example, here we are trying to establish whether there is a significant difference between the nitrate [NO_3-] content in water bodies originating inside the nature reserve, where strict controls on the use of fertilisers exist, and that of water originating outside the reserve, which is likely to have been more affected by arable land uses.

Remember, if we find that there is a high probability that the relationship between the data sets could have occurred by chance, it may indicate that there is no significant difference between the data sets. However, it could also reflect the fact that our sample size was too small to produce a significant result.

A statistically significant difference between data sets is obviously a starting point for further investigation into the processes which may have led to these differences.

surrounding agricultural land into the protected area. Such leaching would result in eutrophication and its consequent impacts on the ecology of this environmentally sensitive area. There are strict local restrictions on farmers in the immediate area and we were able to link our data with that from the Grangettes Foundation, the organisation responsible for the management of wildlife conservation in the protected area.

The analysis of the data from these tests is of crucial importance in increasing the usefulness of the study. Applying valid statistical methods to the analysis of the results is important in establishing their meaning. One aspect of our studies that has produced revealing results on statistical analysis was the testing of nitrate levels. The choice of the most appropriate statistical test is key here, and, as with the use of practical techniques of differing sensitivity, this gives students a useful insight into research techniques.

Statistical analysis of nitrate ion results

Our aim was to see if there was any relationship between nitrate concentrations and agricultural activity at different sites. We first conducted a straightforward rank correlation test (Spearman's, see box) using all of the data. The test was used to see if there was any correlation between the distance from the nearest arable land and the nitrate content of the water sample. The results showed no apparent correlation.

This led us to consider the different nature of the sample sites more closely. Lakefront sites, part of the large body of water that is Lake Geneva, were likely to have very low nitrate levels through dilution when compared with, say, drainage ditches. Lakefront samples were therefore discounted and the other sites were then examined more closely. A pattern did emerge when the origins of the water in the channels and ponds within the reserve were analysed. The water in some sites had its origin within the boundaries of the reserve, while other channels flow in, bringing water that has drained land outside the reserve boundaries. When the results were interpreted with this added information, it appeared that all the sites that had measurable nitrate ion concentrations contained water originating from outside the reserve (see table). On the other hand, water bodies and channels originating within the boundary of Les Grangettes showed no measurable concentrations of nitrate.

The reliability of this apparent difference was tested using the Mann-Whitney U-test (see box). The results of the Mann-Whitney test indicated a less than 5% probability that the differences observed between the two types of site could have occurred by chance. There was more than a 95% probability that the difference observed between our samples originating within and outside the reserve reflected a wider pattern.

Concluding remarks

The discovery of a statistically significant difference between the two types of site was important for two reasons. It was supported by our subsequent finding, in an interview with the Director of the Grangette Foundation, that there are very strict regulations on the use of fertilisers by arable farmers within the reserve, whereas such restrictions do not apply to farmers outside the reserve. The local farmers seem to abide by these regulations. Secondly, the students' reactions to successful data collection and analysis were encouraging; it gave us and them much pleasure to apply skills from different subject areas to real-life situations.

A number of students took part in different aspects of these studies, and the methods and results formed the basis of successful examination projects for students taking chemistry and/or geography courses.

Water analysis techniques can be applied to a variety of local situations and there are useful websites and Internet-based projects that can be accessed to give further dimensions to local studies. Two such sites are those of the GLOBE Program[w1] and the Global Water Sampling Project [w2].

Table: Nitrate content at different types of site within the Grangettes Reserve

Site number [water from sources inside Les Grangettes]	Nitrate content [mg/dm^3]	Site number [water flowing in from outside sources]	Nitrate content [mg/dm^3]
5	0	2	0
6	0	4	0
11	0	9	8
12	0	10	9
18	0	13	11
19	0	14	9
20	0	17	0
23	9	24	6
Total number of sites	7	Total number of sites	9

References

Lenon B & Cleves P (2001) *Fieldwork Techniques and Projects in Geography*. London, UK: HarperCollins

Web references

w1 - GLOBE Program: www.globe.gov

w2 - Global Water Sampling Project: www.k12science.org/curriculum/waterproj/index.shtml

Resources

AquaData, a school project using five different methods to measure water quality (German): www.bionet.schule.de/aquadata/

Information about measuring river quality, including results for your local (UK) area, can be found on the UK Environment Agency website: www.environment-agency.gov.uk/yourenv/eff/1190084/water/213902/river_qual/?lang=_e

The *Water Quality Standards* Handbook from the US Environment Protection Agency: www.epa.gov/waterscience/standards/handbook/

REVIEW

This article is an example of good practice for secondary school teachers interested in a scientific approach to environmental education. It is interdisciplinary, involving chemistry, earth sciences, statistics, and a heuristic methodology; focuses on a real situation; and demonstrates the transferability of the situation and the methods used in the study.

The style is plain and clear, so the material can easily be used in lower grades in secondary schools with only minor simplifications.

The web references will enable interested teachers to find further information and guidance to plan similar experiments in their own countries.

Giulia Realdon, Italy

Promoting science and motivating students in the 21st century

Marilyn Brodie from the Centre for Science Education, UK, describes two projects to involve the scientific research community in schools and raise enthusiasm for science among students.

When science is taught out of context and seems irrelevant to their lives, many students lose interest. And if a student's own motivation is disregarded, even the most careful preparation on the part of the teacher will be wasted. It is crucial, therefore, to highlight the importance of science and its relevance to students' lives. Students also need more positive and realistic demonstrations of the scope and limitations of science and scientists. Both of these challenges can be addressed by mobilising the scientific and engineering research community.

Some underpinning research

The UK has a long tradition of educating and training scientists, engineers and mathematicians who have contributed greatly to the economic stability of the nation. However, even though more young people are entering higher education, fewer students are choosing mathematics, physics and chemistry (HESA, 2005), resulting in a skills shortage. The key to reversing this trend is to inspire and enthuse young people in science and engineering throughout their school education. Mathematics and the physical sciences, however, lack positive role models and effective careers advice for aspiring students (Roberts, 2002; Rasekoala, 2001). A survey of 50 schools across the UK showed that although most students enjoyed learning science at school, few wanted to study science after school (Bevins et al., 2005). Physics in particular was seen as complex and difficult.

"[Physics] is too hard. There are too many laws and stuff. It doesn't really matter anyway. I will never need that type of stuff when I start work. You only need to know it if you want to do physics as a job."

13-year-old student

Students recognised that access to practising scientists and engineers would increase their interest and enthusiasm, as well as provide valuable information on careers and studies. They also felt that an expert in the classroom would help to put the subject into context and make classroom activities more exciting.

Researcher with students at the Royal Institution, London

"When we're doing things like gases, if an expert is in school to help us they could show us why we use gases and how they use them in their jobs – that would make [the concept] really interesting."

14-year-old student

"It would be good to ask them questions about their jobs and find out what they do, how they do it and how they learned to do it – how much they get paid."

13-year-old student

Students also suggested that school visits by professionals and to their workplaces would help them to learn about and understand specific professions.

BACKGROUND

The Centre for Science Education (http://extra.shu.ac.uk/cse) is one of the UK's foremost groups in science education research and development, and is the largest academic group in the field in Europe. Its wide portfolio includes continuing professional development, the creation of motivating and innovative intervention schemes, and curriculum development in both print and digital media.

The Centre for Science Education is committed to reversing the trend away from science careers and qualifications by inspiring and capturing the imagination of young people in science through the development of 'creativity-rich' resources and activities.

"It would be good to visit a university to see what they do. It would be exciting."

12-year-old student

Both the Researchers in Residence project and the Express Yourself conferences expose students to practising scientists and engineers, developing the students' images of scientists and engineers, as well as of the fields of science and engineering.

Researchers in Residence

Researchers in Residence is a project to bring some of the most creative research talents in the UK into secondary schools. The chosen researchers are fiercely passionate about their subject and their enthusiasm can ignite a fresh interest for science among young people.

PhD students and post-doctoral researchers in science, technology, engineering and mathematics volunteer to spend four to five days in secondary schools. They may give classroom support or presentations, arrange visits or attend field trips. After the initial placement, many researchers continue their involvement with the schools (Brodie & Hudson, 1995).

Among the reasons given by researchers for their involvement are the opportunities to: act as a positive role model (~40% are female); demystify research; improve the image of scientists; and pass on enthusiasm for science, technology, engineering and mathematics. Furthermore, the researchers may benefit by improving their communication skills, investigating the world of education and teaching, enhancing their CV – or simply by taking a break from their normal routine.

"Working with school children and knowing that there is a lot of upcoming talent"

"I think the programme is a welcome return to the 'real world' and helps put research in perspective. You have a different view of your thesis topic once you have had to explain it to young people and relate it to the subjects studied and skills learned at secondary school."

Two PhD students

The project is funded by the Research Councils UK and the Wellcome Trust, and managed by the Centre for Science Education (see box). Since it began in 1995, the Researchers in Residence project has recruited, trained and placed around 3500 researchers in over 2000 schools, working with about 2000 teachers and 300 000 students.

Express Yourself conferences

Celebrating science and the achievements of school students not only helps to promote science but also can be highly motivating for the students involved.

The Express Yourself conferences are linked to the Researchers in Residence project. Hosted by research scientists, these conferences give school students a forum in which to present the findings of their own science investigations. The conferences are run similarly to real research conferences, with opportunities for students to:

- Communicate and share their ideas with other students, teachers and researchers
- Present research papers in seminars chaired by researchers in residence
- Present and host displays of their investigations
- Participate in other activities, such as discussing their work with experienced researchers, attending keynote lectures and demonstrations, and participating in practical workshops.

Summary

Science teachers and the scientific community have an important role in promoting science and raising its profile with young people, particularly

REVIEW

Many countries in Europe struggle to overcome the falling interest in university science studies. This article describes two innovative projects to provide students with a positive and realistic image of science. Bringing researchers into secondary schools motivates students by providing them with role models and a genuine picture of research. For example, communicating ideas and results at conferences is an essential part of scientific research – but one that is habitually overlooked when explaining to students what research actually involves.

The initiatives presented in this article are useful for science teachers who want to enhance their students' motivation for science, either by inviting researchers to visit their schools or by organising student science conferences. Both projects provide science teachers with ideas that can be incorporated into classroom activities and in schools.

Organising such events is time-consuming, but unquestionably worthwhile. Cooperation across science subjects might give an even more complete image of scientific research. Ask researchers at your local university to participate in these projects – they too will benefit.

Roeland van der Rijst, the Netherlands

Researchers in residence working with school students

by increasing student participation, motivation and success. This can be encouraged by mobilising professional scientists and engineers to support school science and by celebrating students' achievements in science.

References

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Brodie M, Hudson T (1995) Pupil Researcher Initiative: Researchers in Residence. *Education in Science* **165**: 18-19

HESA (2005) *Qualifications Obtained by, and Examination Results of, Higher Education Students at Higher Education Institutions in the United Kingdom for the Academic Year 2003/04.* SFR PR82. Cheltenham, UK: Higher Education Statistics Agency

Rasekoala E (2001) *African-Caribbean Representation in Science & Technology (ACRISAT).* London, UK: National Endowment for Science, Technology and the Arts

Roberts G (2002) *SET for Success: The Supply of People with Science, Technology, Engineering and Mathematical Skills.* London, UK: Her Majesty's Stationery Office

Resources

Research Councils UK is a strategic partnership of seven UK research councils championing science, engineering and technology: www.rcuk.ac.uk

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

Researchers in Residence: http://extra.shu.ac.uk/cse/site/projects/cse/rinr

Express Yourself conferences: http://extra.shu.ac.uk/cse/site/projects/cse/pri

BACKGROUND

Help is at hand

If you are interested in setting up a similar scheme in your own country and would like advice, the Researchers in Residence team would be happy to help. Contact Marilyn Brodie (M.M.Brodie@shu.ac.uk).

The exhibition ship *MS Einstein*: a floating source of scientific knowledge

Imagine a barge carrying not coal or other heavy cargo, but something much more precious – inspiration! **Beate Langholf** from Wissenschaft im Dialog, Germany, describes a science exhibition that travels the rivers of Germany with a different theme each year.

"The most important thing is to never stop questioning." That was the advice given to a young student by Albert Einstein in 1955. It was therefore an appropriate motto to adopt for the exhibition aboard the *MS Einstein* – Wissenschaft im Dialog's exhibition ship. Beginning on 9 May 2005, the ship travelled through Germany, stopping at 36 different cities along the way. It finally ended its tour in Basel, Switzerland, on 19 September.

The 105-metre barge had already been underway with its unusual cargo for a number of years. It was not, you see, carrying a load of containers or coal but rather a much more sensitive freight: a science exhibition designed for a wide audience, including children and young adults. The exhibition theme is chosen each year to coincide with the current science year proclaimed by the German Ministry of Education. In 2002, the University of Bremen created the *Geoship*. Subsequently, the *MS Chemie* (chemistry, 2003), the *MS Technik* (technology, 2004) and the *MS Einstein* (2005) were floated by Wissenschaft im Dialog[w1]. The goal of this initiative by German science organisations is to draw attention to current scientific research as well as to encourage a lively dialogue between the world of science and the general public.

Two weeks before the planned start of the exhibition, captain Albrecht Scheubner brought the *MS Jenny* (the ship's name for much of the year) to the appointed harbour in Bremen. The exhibition, which had been planned over the preceding

MS Einstein in Berlin by day

MS Einstein in Berlin by night

months, was then rapidly set up on board. Crewed by young scientists, the exhibition was free to visit.

"How fast does time pass?", "Is there really nothing faster than the speed of light?", "Why will I age faster on earth than I will in a rocket travelling through space?" Answers to these questions and many more were to be found on the *MS Einstein*.

Nine themed zones in the bowels of the exhibition ship explained the Nobel prize-winner's theories in such a way that even non-physicists could understand them. The zones covered the photoelectric effect, the general and special theories of relativity, mass-energy equivalence, stimulated emission as well as cosmology. Along the side of the ship, a time-line reflected aspects of Einstein's personal life. Finally, Einstein's failed search for a unified theory of everything was demonstrated symbolically through the use of a giant three-dimensional and (almost!) unsolvable wooden puzzle.

These are only a few examples of the numerous interactive stations at the exhibition. The purpose of the hands-on exhibits was, of course, to handle and examine them. Curiosity drove a school group to press around the table in the 'Einstein and me' room. And that was exactly the point of this room – to awaken curiosity and stimulate the appetite of both

BACKGROUND

Help is at hand

If you are interested in setting up a similar exhibition in your own country and would like advice, the Wissenschaft im Dialog team would be happy to help.

Contact Beate Langholf (beate.langholf@w-i-d.de).

Trying to solve the nearly unsolvable puzzle

children and adults for exploration and investigation. The students cooperated to try to find solutions to the tricky puzzles on display; for example, try to join nine points (arranged in rows of 3 x 3) with four straight lines. Everyone wanted to try their own luck and numerous attempts failed. With a helpful hint from one of the exhibition's organisers, however, the students finally succeeded and the resulting euphoria accompanied them to the next table and the next challenge.

The exhibition on the *MS Einstein* was designed for students in grade 9 (age 15) and above. Younger children were nonetheless able to stay busy and have fun with the numerous playful components of the exhibition.

Many teachers had never seen their students so engaged. For the teachers, the visit to the exhibition ship complemented their natural-sciences lessons. The exhibition demonstrated the uses of scientific theories in everyday life, as well as showing research being done in colleges and research centres. The students were thereby able to take a close look at the practical and daily relevance of scientific work. Classroom knowledge and schoolwork could be seen in relation to a bigger picture.

Some students, of course, refuse to be enthused by anything. Nonetheless, there is almost never any trouble on the exhibition ship: the continuous refinement of the interactive concepts has gradually succeeded in ridding the exhibition of vandalism. The mixture of interactivity, suspense and concentration has been key.

Among those planning the exhibition ship were representatives from the participating science organisations such as the Fraunhofer Gesellschaft, Helmholtz Gemeinschaft, Leibniz Gesellschaft and the Max Planck Gesellschaft. Together with the exhibition agency, they ensured that the proposed exhibits were suitable for exhibiting and developed some hands-on exhibits specially. The overall goal of the exhibition was to make up-to-date research findings readily accessible to a broad audience.

The fact that the exhibition was on a barge meant that many people attended who would not normally visit a scientific exhibition. The unusual location and the fact that it was free also drew many chance visitors. People who only wanted to take a look often ended up spending many hours in the floating science centre and showed up again the next day with friends or family in tow. The exhibition organisers heard almost nothing but positive feedback.

Young scientists in teams of four 'pilots' were responsible for answering visitors' questions and supervising the exhibition. Many have been so thrilled by the work that they come back year after year. These students from the most diverse fields of study

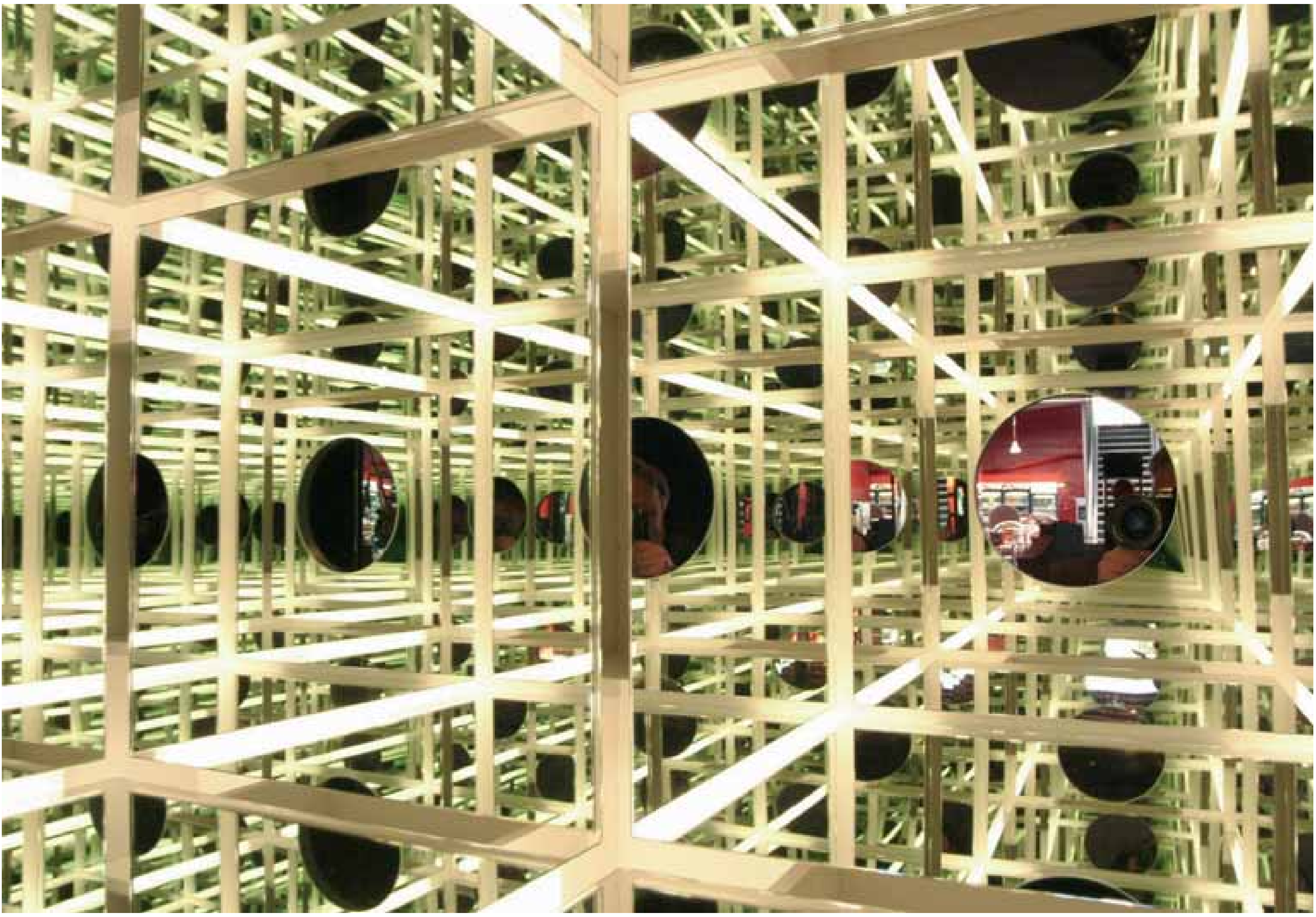
REVIEW

Welcome aboard a scientific cruise on German rivers!

An exhibition ship has been travelling through many cities on German rivers each summer with a scientific exhibition. The idea is that what is researched and discovered in laboratories and universities is of interest to all of us because science and research significantly influence the living conditions and culture of our society.

The boat (which was originally called *MS Jenny* but which changes its name each year according to the theme of the exhibition) is open to school classes and all visitors from May to September. This year's name is *MS Wissenschaft – Sport and Computer Science*. Read this article and go on board!

Sølve Marie Tegnér Stenmark, Norway



View into infinity

were able to gain a familiarity with communication and conveying scientific subject matter to others. And they were also willing to accept that, at the end of the day, they might be handed a vacuum cleaner or a screwdriver to ensure that everything was shipshape, ready for the next day.

After about four months and 100 000 visitors, the exhibition was dismantled: the attendants and organisers went home, the exhibits were returned to their institutions, and the *MS Jenny* went back to carrying her normal freight. But the planning continues: the *MS Wissenschaft – Sport and Computer Science* will use sporting themes in 2006 to answer questions like “how does computer science function?”, “what can it do?” and “where can it be found at work?”[w2]

Relativistic cycling

So, once again, the slogan will be: science ahoy!

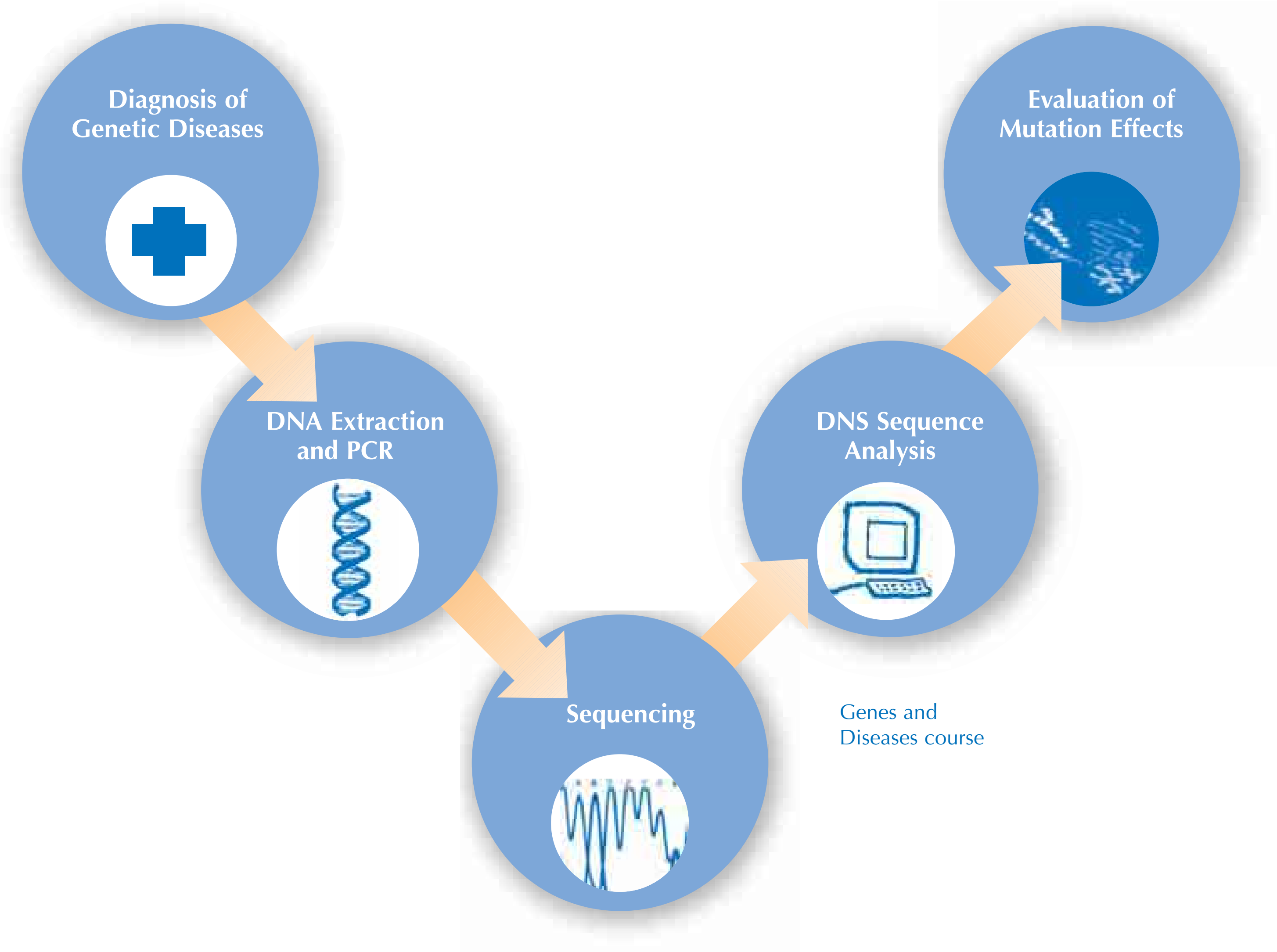
Web references

w1 – Wissenschaft im Dialog is committed to ensuring a constant dialogue between scientists and as many people and social groups as possible: www.wissenschaft-im-dialog.de/english/wid.php4

w2 – Details of the *MS Wissenschaft*’s trip in 2006, including a timetable (German): www.ms-wissenschaft.de

Linking university and school: addressing the challenges of science teaching in Italy

Mariolina Tenchini, Director of Cus-Mi-Bio in Milan, Italy, introduces a university initiative to motivate science teachers and provide both them and their students with hands-on experience of cutting-edge science.



Genes and Diseases course

Science teaching in Europe provides many rewards, but also many challenges. Some of these are familiar to teachers in all countries: keeping up with developments in science, for example, or dealing with difficult children. Other problems depend to an extent on where you are teaching: which country, which region or which type of school.

In Italy, unlike in some other European countries, science teachers are expected to cover the full range of sciences from geology to molecular biology, from stoichiometry to astrophysics. Although this offers the opportunity to teach some fascinating interdisciplinary topics (e.g. Farusi, 2006), it makes it very difficult for teachers to feel confident about their own knowledge.

Of course, colleagues in the region may have the necessary expertise and be willing to help, but the opportunities to exchange opinions, discuss problems and offer advice are not always available.

The vast majority of Italian schools have little if any money to invest in laboratory equipment. In schools that have laboratories, the equipment is often outdated and unsafe, reagents are inappropriately stored and waste disposal is problematic.

Responding to the need for teachers to receive training in the latest scientific developments, swap advice, and use modern and well-equipped laboratories, the University of Milan, in cooperation with the Education Office of Lombardy, has developed a centre for science education in secondary schools: Cus-Mi-Bio. Since 2004, Cus-Mi-Bio, the Centro Università di Milano Scuola per la Diffusione delle Bioscienze, has offered teachers an innovative and stimulating opportunity to combine instruction in theoretical developments in biology with hands-on laboratory work.

Cus-Mi-Bio organises activities for both high-school students and high-school teachers. The two are closely linked, with teachers helping to develop the courses for the students.

Courses for teachers and high-school students

Courses for teachers at Cus-Mi-Bio are intended not only to update their scientific knowledge but also to motivate teachers by getting them personally involved in the process of improving science education in high schools. The topics covered so far include recent advances in molecular genetics, such as genetic engineering, forensic science, the Human Genome Project, regulation of gene expression, and bioinformatics. The teachers learn about modern scientific developments and work in well-equipped university laboratories, and they are provided with materials and ideas to use in their own schools. Most of the courses are in Italian but some, in collaboration with the European Learning Laboratory for the Life Sciences[w1], have been in English. Courses conducted over the last few years include 'Recent advances in molecular genetics', 'From organisms to genes: what zebrafish can tell us', 'Genes and diseases', e-learning activities, and 'Bioteach: tools and tips for biology teachers'.

A key feature is that some of the attendees not only benefit themselves but also work together to develop resources for all teachers, which are published on the Cus-Mi-Bio website[w2]. Together with university scientists, about 50 high-school teachers, in collaborative groups of ten, prepare new materials or tools to be used in school. The school teachers, therefore, have a dual role: they not only learn new information, but also use their expertise and experience to ensure that the materials developed are appropriate and interesting for their students.

Once the materials have been prepared, the teachers in the collaborative groups test them in their schools and provide feedback. Then the next step begins: bringing the high-school students into the University of Milan. Students attend courses in groups of 20-25, accompanied by their teacher. The course, 'Try the BioLab', consists of various laboratory activities devised by the collaborative groups. Each student has his or her own working space and gains hands-on experience of working in a laboratory. The accompanying teachers should first attend a course for teachers on the same activities, so that they can prepare their students for the course, with the help of handbooks prepared by the collaborative groups.

The courses are run by 'lead' teachers employed by the Education Office; these are high-school teachers who have worked in one of the groups to develop the materials. Additionally, research students from the university work as tutors, explaining the equipment to small groups of five or six school students. The involvement of these young scientists is very impor-

BACKGROUND

Search for European partners

Cus-Mi-Bio aims to establish a network of European universities working to improve science education for high-school students. If you are interested in setting up a similar centre in your own country and would like advice, the Cus-Mi-Bio team would be happy to help. Contact anna.cartisano@istruzione.it or cinisa@tiscali.it.

BACKGROUND

A personal slant

After nearly 30 years of teaching science, we still enjoyed it: students are often very stimulating and we both love the subjects we teach. The chance to join the Cus-Mi-Bio team was a new and exciting challenge. It was a chance to do something we believed in: to help enthuse our colleagues and provide them with the materials to teach inspiring lessons in modern science.

Very important is the friendly atmosphere at Cus-Mi-Bio, where teachers can get to know each other. We are now a real landmark for teachers who want advice, information, or a place to study or exchange experiences. The enthusiastic response shows that high-school teachers needed something like this. The two different worlds of university and school are slowly drawing closer, thanks to the support of some university professors. Working at the interface is not always easy, but it is always interesting.

Anna Cartisano and Cinzia Grazioli, high-school teachers working at Cus-Mi-Bio

Cinzia Grazioli

tant, as they act as role models for the students and are able to give careers advice.

The courses are popular with both teachers and their students; many teachers return several times with different classes. Now in its second year, Cus-Mi-Bio has increased the numbers of students attending from 1000 in the first year to 4000.

Although many of the people attending the Cus-Mi-Bio courses are from around Milan, participants are welcome from all over Italy. Attendees receive handbooks including protocols of the experiments and a CD of information. Teachers unable to attend the courses can still download materials from the Cus-Mi-Bio website.

Other activities

Cus-Mi-Bio also enables Italian high-school teachers to attend national or international meetings, where they can swap ideas with teachers from other backgrounds. In 2005, for example, one group of teachers attended a summer course in Sweden, while another presented activities developed together with Cus-Mi-Bio at a meeting in Germany.

In addition to the 'Try the BioLab' courses, which are open to all high-school students, Cus-Mi-Bio also offers a work-experience programme for a few selected students. The students, who spend a week working alongside scientists in the laboratory, all declared it to be a fantastic experience.

References

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

Web references

w1 - The European Learning Laboratory for the Life Sciences (ELLS): www.embl.de/ELLS

w2 - Cus-Mi-Bio: www.cusmibio.unimi.it

Forensic entomology

Are you a biologist with a mission? Do you want to fight crime with science? **Martin Hall** and **Amoret Brandt** from The Natural History Museum in London, UK, introduce the fascinating (and smelly) field of forensic entomology.

Forensic entomology is the study of insects and other arthropods in a legal context. The applications are wide-ranging, but the most frequent is to determine the minimum time since death (minimum post-mortem interval, or PMI) in suspicious death investigations. This is done by identifying the age of the insects present on a human corpse, which can provide a relatively precise estimate in circumstances where pathologists may only be able to give a broad approximation. The fundamental assumption is that the body has not been dead for longer than it took the insects to arrive at the corpse and develop. Thus, the age of the oldest insects on the body determines the minimum PMI.

Female (left) and male (right) adults of the common bluebottle blowfly, *Calliphora vicina* (Diptera: Calliphoridae)

Two examples of this are:

1. A body discovered in the summer in southern England had suffered extensive burns, making the pathologist's interpretation of the conventional post-mortem changes in the body very difficult. Ageing the blowfly larvae on the body indicated that the first fly eggs had been laid on the body six days before. Witnesses subsequently testified that the fatal fire was observed on the night before the estimated day of egg-laying.
2. A body discovered in late winter in northern England was well preserved because of the cold temperatures, and pathological evidence

Life cycle of a calliphorid fly (clockwise from bottom left): adults, eggs, first instar larvae, second instar larvae, third instar larvae, puparia containing pupae

suggested that the person had died two to three weeks before. In contrast, insect evidence suggested that the person had died more than two months before the body was discovered. This was consistent with other evidence and was accepted by the coroner's court.

The insects of greatest value to forensic entomology are blowflies (family Calliphoridae), because they are usually the first insects to colonise a body after death, often within hours. Because of this, the age of the oldest blowflies gives the most accurate evidence of the PMI. Many other species of fly, beetle, wasp and moth are also associated with cadavers, resulting in a succession of insects arriving at the body, but as they tend to arrive after the blowflies, they are less useful in establishing a PMI.

Blowfly infestations of human bodies are a natural outcome of the flies' role in the environment as primary decomposers. The ubiquity of fly larvae on carrion is clear to anyone who comes across the dead body of a hedgehog or rabbit while walking in the country. The larval infestations might look gruesome, but they are a vital component of the natural recycling of organic matter and, on human bodies, they can provide vital clues to the timing and cause of death.

Adult blowflies are well adapted to sensing and locating the sources of odours of decay, so cadavers are quickly found. Eggs are usually laid in the natural orifices (e.g. eyes, nose, mouth, ears) or other dark and moist places, such as the folds of clothes or just under the body. Eggs hatch into first instar larvae that grow rapidly, moulting twice to pass through second and third instars until they finish feeding. Depending on the species, they pupate on the body or move away to find a suitable site. They may move many metres before burrowing into the soil or under objects such as rocks and logs or, if indoors, under carpets and furniture. The larva then contracts and the cuticle hardens and darkens to form the barrel-shaped puparium, within which the pupa metamorphoses into an adult fly. When the fly emerges, the empty puparial case is left behind as long-lasting evidence of the insect's development.

The rate of development of all insects is directly dependent on the ambient conditions, particularly temperature. Between upper and lower thresholds, which vary between species, the higher the temperature, the faster the insects will develop; the lower the temperature, the slower they will develop (see graph below).

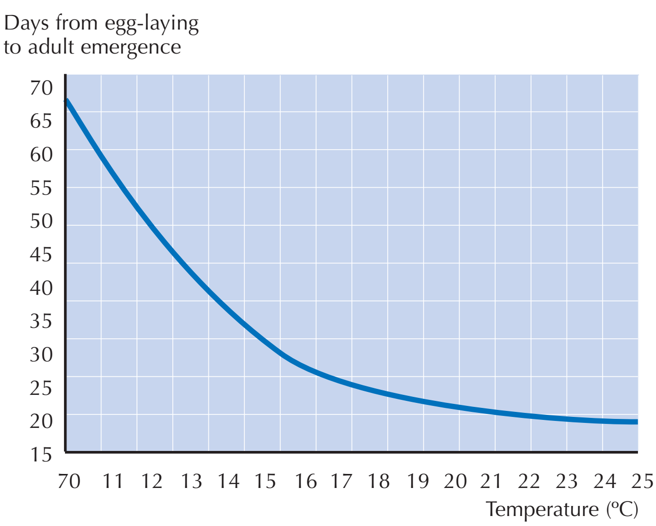
If the ambient temperatures during the period of development are known, then, in theory, the minimum PMI can be determined.

However, there are many complicating factors that affect the rate of development of larvae on a body:

- Temperature (which can depend on geographical location, indoor or outdoor exposure, sun or shade, time of day and season)
- Heat generated by the maggot mass
- Food source (tissue type, e.g. liver, heart, lungs)
- Contaminants and toxins (external and internal)
- Burial or other obstructions (e.g. plastic sheets, water) that hinder access and egg-laying by adult insects.

All of the above need to be considered when estimating a PMI, yet for many of them, little information is available. For example, the elevated temperature due to the maggot mass can be readily appreciated by any angler reaching into a bowl of bait maggots, but quantifying its effect on larval development still requires detailed study, for example using novel thermal imaging techniques (see box).

The degree to which a forensic entomologist is involved in a case can

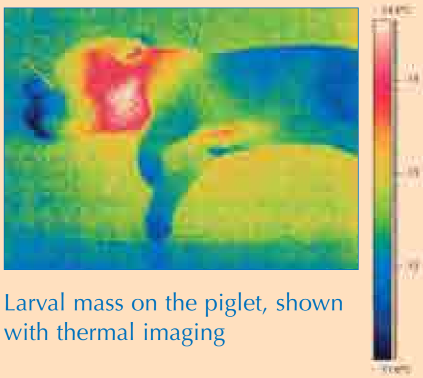


Graph showing the rate of development of the immature stages of blowflies with temperature, based on published data for the bluebottle blowfly *Calliphora vicina* (Diptera: Calliphoridae)

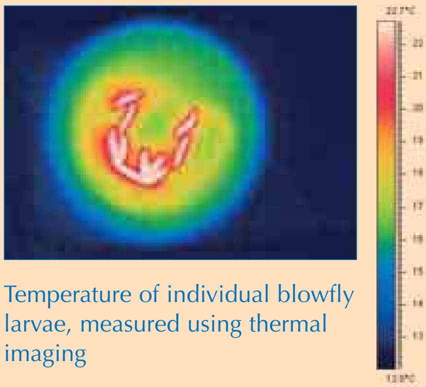
BACKGROUND

Thermal imaging

Still-born piglet



Larval mass on the piglet, shown with thermal imaging



Temperature of individual blowfly larvae, measured using thermal imaging

Scientists at The Natural History Museum, London, UK, are just beginning to explore the thermal dynamics of larval masses using infrared photography. The temperature of individual blowfly larvae can be measured (bottom right). The still-born piglet (above) appears untouched by insects in a normal photograph, but thermal imaging indicates an active larval mass in the throat and chest regions (top right) that causes an increase in temperature where the larvae are feeding.

vary. The entomologist may attend the crime scene personally to collect the insect specimens from the body or its surroundings. This is ideal, because he or she can use knowledge of insect biology and behaviour to make sure that as many specimens as possible are collected and to help interpret the results. Alternatively, the entomologist may collect insect specimens during the post-mortem examination as well as viewing photos of the crime scene or visiting the scene after the body has been removed. Finally, the specimens may be collected by the police, for example, ideally after telephone consultation with the entomologist. Photographs of the scene and the post-mortem examination will then be shown to the entomologist.

When investigating a suspicious death, the main questions which need to be answered by the forensic entomologist are:

Which species of blowfly are present on the body? The collected specimens must be correctly identified, so that all of the relevant information on physiology, behaviour and ecology of that

Author, Martin Hall

insect species can be used. This question is answered by taxonomy, one of the most neglected of the natural sci-

Third instar blowfly larvae feeding on a human body, many head down, in a maggot mass at a temperature approximately 15 ºC above ambient

Searching soil samples from a gravesite for insect specimens. The initial search at the scene is made on a plastic sheet, before bagging the samples for further analysis in the laboratory. Note the use of full protective clothing

ences but the foundation for all others.

Which are the oldest specimens of blowfly? They may still be feeding on the body; they may have left the body to pupate elsewhere; or they may have already emerged as adults and left behind their empty puparial cases.

How old are the oldest specimens? Estimating age involves detailed morphological study of the insects under a binocular microscope, to determine their stage of development and to compare that with data from standard databases relating developmental stage to age at different temperatures (see next question).

What were the ambient temperatures at the scene while the flies were developing on the body? An electronic temperature

BACKGROUND

Interview with a forensic entomologist

After a zoology degree and a masters in taxonomy and biodiversity, Amoret worked on various groups of insects, such as hoverflies and wasps, and spent three years rewriting *The Handbook of British Fleas*. In search of more applied work, leading to a career in entomology, she then moved into forensics. She is studying part-time for a PhD at King's College London, as well as doing casework in forensic entomology at The Natural History Museum.

Author, Amoret Brandt

"I think the most interesting thing about the job is the variety and uncertainty of it. You never know when the phone's going to ring. Every case is different, and I guess one of the hardest things is never quite knowing what you're going to be confronted with.

Casework constantly raises new questions, and makes you realise how little we know, even about the most common of insects. For instance, a couple of years ago, we were asked to visit a crime scene to search for puparial cases. The problem was that the crime was two years old, and no research has been done on how long empty puparial cases remain intact in the soil. So I started a study where I buried a large number of empty puparial cases and over a period of three years I dig them up. The results should be able to tell us the rate at which the puparial cases degrade over time, at least over a three-year period. So the next time we're faced with an 'old' crime, we'll be better able to help.

Probably the most fascinating thing I've done is to work at the Anthropological Research Facility (or Body Farm[w1], as it is also known) at the University of Tennessee in Knoxville, USA. This is the only place in the world where the decomposition of humans can be studied, so it's an amazing opportunity to study the succession of insects on humans, rather than pigs, which is what we usually use.

There's no obvious route to getting into forensic entomology, but I believe that being an entomologist first, and then branching into forensics, is the right way to do it. You need the training and skills of an entomologist to understand the ecology and behaviour of the insects you're dealing with."

data logger is placed at the crime scene for seven to ten days and the readings are compared with data from the meteorological station over the same period. This comparison and the data from the meteorological station for the time before the discovery of the body can then be used to estimate the temperatures during that period at the scene of the crime. This determines the temperature at which the larvae developed.

Forensic entomology is a relatively young science, so there are many areas which need further investigation. DNA studies are currently being carried out to determine genetic differences between fly species and also between populations of the same species, which could help to determine whether a body has been moved after the initial infestation. Extracting and analysing the gut from larvae which have been feeding on a body may help determine whether drugs were present in the body, suggesting a suicide or overdose. Gunshot residue in the larval gut would indicate a shooting when physical evidence no longer exists. It is even possible that human DNA could be extracted from larvae, showing the previous presence of a body, even when that body has been removed, leaving the larvae behind.

The most common species of blowfly can be found all year round, but the effect of cold on the different life stages of blowflies has been poorly studied. A greater understanding of this subject would be valuable, as the slow rate of development in cold periods allows useful PMI estimates to be made much longer after death than is possible in summer. Further research would help to improve the accuracy and robustness of case reconstructions based on forensic entomology.

Web references

w1 - The Body Farm: http://web.utk.edu/~anthrop/index.htm

Resources

Readers interested in forensic entomology are encouraged to consult the following publications and websites for further information:

Byrd JH, Castner JL (eds; 2000) *Forensic Entomology: the Utility of Arthropods in Legal Investigations.* Boca Raton, FL, USA: CRC Press

Catts EP, Haskell NH (eds; 1990) *Entomology and Death: a Procedural Guide.* Clemson, SC, USA: Forensic Entomology Associates

Erzinçlioglu Z (2000) *Maggots, Murder, and Men: Memories and Reflections of a Forensic Entomologist.* Colchester, UK: Harley Books

Goff ML (2000) *A Fly for the Prosecution: How Insect Evidence Helps Solve Crimes.* Cambridge, MA, USA: Harvard University Press

Greenberg B, Kunich JC (2002) *Entomology and the Law: Flies as Forensic Indicators.* Cambridge, UK: Cambridge University Press

Smith KGV (1986) *A Manual of Forensic Entomology.* Ithaca, NY, USA: Cornell University Press

American Board of Forensic Entomology: www.research.missouri.edu/entomology/

European Association for Forensic Entomology: http://new.eafe.org

Forensic Entomology: www.forensic-entomology.com

North American Forensic Entomology Association: www.nafea.net

CLASSROOM ACTIVITY

Editor's comment

Why not take up Paula Starbäck's challenge: can you devise a way to teach forensic entomology in school? Email your suggestions to editor@scienceinschool.org and we'll publish the best ideas.

REVIEW

This article is engaging and fascinating for all teachers, as it deals with the inevitable decay after death. It gives an interesting insight into the area of forensic science, which is quite popular today, as shown by many television series on the subject.

The language and the content of the article are easily understood. The biological (entomological) forensic approach is particularly fascinating, as the most common view of this topic is biochemical or medical. This article shows that you have to work in an interdisciplinary way to solve crimes. Sherlock Holmes is indeed dead – instead the scientist, police officer and legal team are all necessary. Maybe this will inspire teachers to work across disciplines more often?

Unfortunately, any classroom activity with meat and blowflies would be too disgusting and smelly, but if a creative person could come up with a good idea to reduce the bad smell, it would be a very fascinating task for students.

Paula Starbäck, Sweden

Symmetry rules

Everyone knows what symmetry is. In this article, though, **Mario Livio** from the Space Telescope Science Institute, Baltimore, USA, explains how not only shapes, but also laws of nature, can be symmetrical.

This inkblot is obviously symmetrical...

Everybody will recognize the inkblot above right as being symmetrical, but few know that the figure below is also considered symmetrical in the precise mathematical sense. So, what is symmetry, really? And why has this concept become so pivotal that many scientists believe it to be the basis of the laws of nature?

...but so is this!

When things that could have changed, don't

Symmetry represents immunity to possible alterations – those stubborn cores of shapes, phrases, laws, or mathematical expressions that remain unchanged under certain transformations. Consider, for instance, the phrase "Madam, I'm Adam", which is symmetrical when read back to front, letter by letter. That is, the sentence remains the same when read backwards. The title of the documentary, *A Man, a Plan, a Canal, Panama,* has the same property. Phrases with this type of symmetry are known as palindromes, and palindromes play an important role in the structure of the male-defining Y chromosome. Until 2003, genome biologists believed that, due to the fact that the Y chromosome lacks a partner (with which it could swap genes), its genetic cargo was about to dwindle away through damaging mutations. To their surprise, however, the researchers who sequenced the Y chromosome discovered that it fights destruction with palindromes. About 6 million (out of 50 million) of the chromosome's DNA letters form palindromic sequences. These 'mirror' copies provide backups in the case of damaging mutations, and allow the chromosome, in some sense, to have sex with itself – strands can swap position.

For two-dimensional figures and shapes, like those drawn on a piece of paper, there are precisely four types of 'rigid' symmetry (when stretching and distortions are not allowed), known as: reflection, rotation, translation, and glide reflection.

We encounter symmetry under reflection all around us – this is the familiar bilateral symmetry that characterises animals. Draw a line down the middle of a picture of a butterfly (see below). Now flip it over, while keeping the central line in place. The resulting perfect overlap indicates that the butterfly remains unchanged under reflection about its central line. Many letters of the alphabet also have this property. If you hold a sheet of paper up to a mirror, with the phrase 'MAX IT WITH MATH' written vertically, it looks the same.

Symmetry under rotation is also very prevalent in nature. A snowflake (see below) rotated through 60, 120, 180, 240, 300, or 360 degrees about an axis through its centre (perpendicular to its plane) leads to an indistinguishable configuration. A circle rotated through any angle about a central, perpendicular axis will remain unaltered.

Symmetry under translation is the type of immunity to change that is encountered in recurring, repeating motifs, such as the one at the bottom of page 54. Translation means a displacement or shift, by a certain distance, along a particular line. Many classical friezes, wallpaper designs, rows of windows in high-rise apartment buildings, and even centipedes, exhibit this type of symmetry.

Finally, the footprints generated by a left-right-left-right walk are symmetrical under glide reflection (see right). The transformation in this case consists of a translation (or glide), followed by a reflection in a line parallel to the direction of the displacement (the dotted line).

All of the symmetries discussed so far are symmetries of shape and form – ones that we can actually see with our own eyes. The symmetries underlying the fundamental laws of nature are in some sense closely related to these, but instead of focusing on form or figure they address a different question: what transformations can be performed on the world around us that would leave unchanged the laws describing all observed phenomena?

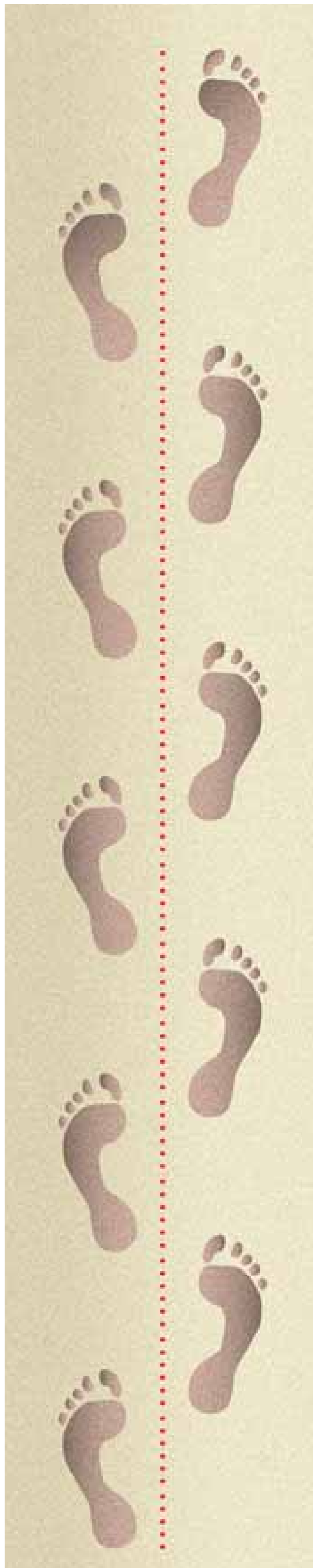
A butterfly's bilateral symmetry

A snowflake is symmetrical under rotation

Symmetry rules

The 'laws of nature' collectively describe a body of rules that are supposed to explain literally everything we observe in the universe. That such a grand set of rules even exists was inconceivable before the 17th century. Only through the works of scientific giants such as Galileo Galilei (1564-1642), René Descartes (1596-1650), and in particular, Isaac Newton (1642-1727), did it become clear that a mere handful of laws could explain a wide range of phenomena. Suddenly, things as diverse as the falling of

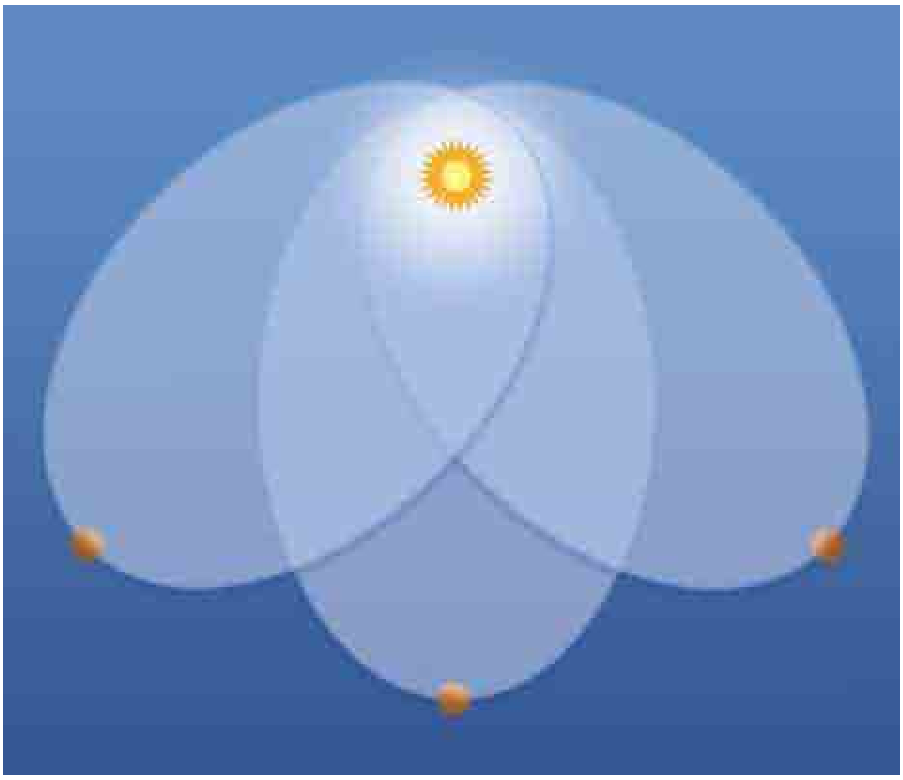
Footprints are preserved by glide reflection



apples, tides on the beach, and the motion of the planets all fell under the umbrella of Newton's law of gravitation.

Similarly, building on the impressive experimental results of Michael Faraday (1791-1867), the Scottish physicist James Clerk Maxwell (1831-1879) was able to explain all the classical electric, magnetic, and light phenomena with just four equations! Think about this for a moment – the entire world of electromagnetism in four equations.

The laws of nature were found to obey some of the same symmetries we have already encountered, as well as a few other, more esoteric, ones. To begin with, the laws are symmetrical under translation. The manifestation of this property is simple: whether you perform an experiment in New York or Los Angeles, at the other edge of the Milky Way or in a galaxy a billion light-years from here, you will be able to describe the results using the same laws. How do we know this to be true? Because observations of galaxies all across the universe show not only that the law of gravity is the same there as here, but also that hydrogen atoms at the edge of the observable universe obey precisely the same laws of electromagnetism and quantum mechanics as they obey here on Earth.



Newton's law of gravity may be symmetrical under rotation, but this doesn't mean the orbits are

The laws of nature are also symmetrical with respect to rotation – the laws look precisely the same whether we measure directions with respect to north or the nearest coffee shop – physics has no preferred direction in space.

If it were not for this remarkable symmetry of the laws under translation and rotation, there would be no hope of ever understanding different parts of the cosmos. Furthermore, even here on Earth, if the laws were not symmetrical, experiments would have to be repeated in every laboratory across the globe.

A word of caution is needed to distinguish between symmetries of shapes and symmetries of laws. The ancient Greeks thought that the orbits of the planets around the sun were symmetrical with respect to rotation: circular. In fact, it is not the shape of the orbit, but Newton's law of gravity that is symmetrical under rotation. This means that the orbits can be (and indeed are!) elliptical, but that the orbits can have any orientation in space (see left).

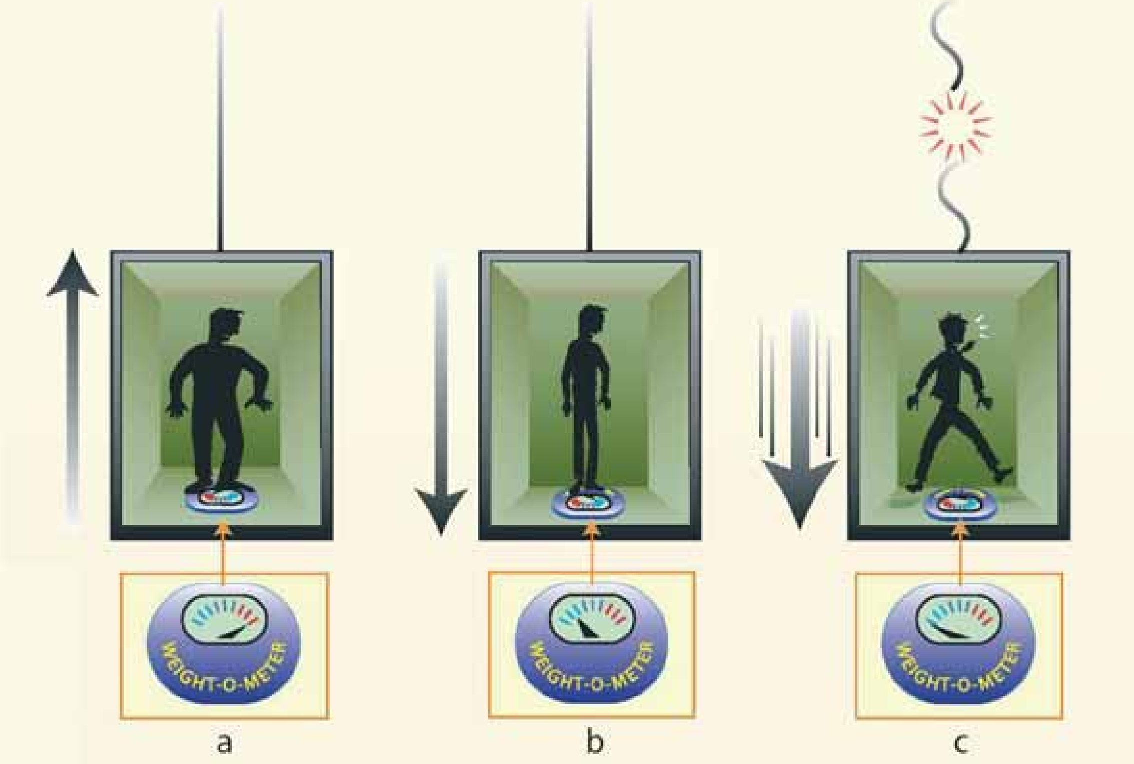
In my opening paragraph, I made a statement stronger than merely saying that the laws obey certain symmetries; I said that symmetry may be the source of laws. What does this mean?

The source of natural laws

Imagine that you have never heard of snowflakes before, and someone asks you to guess the shape of one. Clearly, this is an impossible task. For all you know, the snowflake may look like a teapot, like the letter S, or like Bugs Bunny.

Even if you are given the shape of one ray of the snowflake (below, a) and are told that this is part of its total shape, this is not much help. The snowflake could still look, for example, like the configuration below, b. If

Trying to reconstruct a snowflake



Weight control, elevator style – gaining weight when the elevator accelerates upward (a), losing weight when it accelerates downward (b) and achieving weightlessness when it free-falls (c)

you are told, on the other hand, that the snowflake is symmetrical under rotations through 60 degrees about its centre, this information can be used very effectively. The symmetry immediately limits the possible configurations to six-cornered, twelve-cornered, eighteen-cornered, and so on, snowflakes. Assuming, based on experience, that nature would opt for the simplest, most economical solution, a six-cornered snowflake (page 56, c) would be a very reasonable guess. In other words, the requirement of the symmetry of the shape has guided us in the right direction.

In the same way, the requirement that the laws of nature would be symmetrical under certain transformations not only dictates the form of these laws, but also, in some cases, necessitates the existence of forces or of yet undiscovered elementary particles. Let me explain, using two interesting examples.

One of Einstein's main goals in his explanation of general relativity was to formulate a theory in which the laws of nature would look precisely the same to all observers. That is, the laws had to be symmetrical under any change in our point of view in space and time (in physics, this is known as 'general covariance'). An observer sitting on the back of a giant turtle should deduce the same laws as an observer on a merry-go-round or in an accelerating rocket. Indeed, if the laws are to be universal, why should they depend on whether the observer is accelerating?

Although Einstein's symmetry requirement was certainly reasonable, it was by no means trivial. After all, a million whiplash injuries per year in the United States alone demonstrate that we feel acceleration. Every time an aeroplane hits an air pocket, we feel our stomachs leap into our throats – there appears to be an unmistakable distinction between uniform and accelerating motion. So how can the laws of nature be the same for accelerating observers, when these observers appear to experience additional forces?

Consider the following situation. If you stand on bathroom scales inside an elevator that is accelerating upward, your feet exert a greater pressure on the scales – the scales will register a higher weight (above, a). The same would happen, however, if gravity somehow became stronger in a static elevator. An elevator accelerating downward would feel just like weaker gravity (above, b). If the elevator's cable snapped, you and the scales would free-fall in unison, and the scales would register zero weight (above, c). Free-fall is therefore equivalent to someone miraculously switching gravity off. This led Einstein in 1907 to a ground-breaking conclusion: the force of gravity and the force resulting from acceleration are in fact one and the same. This powerful unification has been dubbed the 'equivalence principle', implying that acceleration and gravity are really two facets of the same force – they are equivalent.

In a lecture delivered in Kyoto in 1922, Einstein described that moment of epiphany he had in 1907: "I was sitting in the patent office in Bern when all of a sudden a thought occurred to me: if a person falls freely, he won't feel his own weight. I was startled. This simple thought made a deep impression on me. It impelled me toward a theory of gravitation."

The equivalence principle is really a statement of a pervasive symmetry; the laws of nature – as expressed by Einstein's equations of general relativity – are the same in all systems, including accelerating ones. So why are there apparent differences between what is observed on a merry-go-round and in a laboratory at rest? General relativity provides a surprising answer. They are differences only in the environment, not in the laws themselves. Similarly, the directions of up and down only appear to be different on Earth because of the Earth's gravity. The laws of nature themselves have no preferred direction (they are symmetrical under rotation); they do not distinguish between up and down. Observers on a merry-go-round, according to general relativity, feel the centrifugal force that is equivalent to gravity. The conclusion is truly electrifying: the symmetry of the laws under any change in the space-time co-ordinates necessitates the existence of gravity! This explains why symmetry is the source of forces. The requirement of symmetry leaves nature no choice: gravity must exist.

Dr. Mario Livio is a Senior Astrophysicist at the Space Telescope Science Institute (STScI; Baltimore, MD, USA), the institute which conducts the scientific programme of the Hubble Space Telescope.

His interests span a broad range of topics in astrophysics, from cosmology to the emergence of intelligent life. He has done much fundamental work on the topic of accretion of mass onto black holes, neutron stars, and white dwarfs, as well as on the formation of black holes and the possibility to extract energy from them. During the past few years, his research has focused on supernova explosions and their use in cosmology to determine the nature of the 'dark energy' that pushes the universe to accelerate, and on extrasolar planets. His latest popular book, *The Equation that Couldn't be Solved*, discusses symmetry.

This article was first published in a longer form in Plus, *a free online magazine which aims to introduce readers to the beauty and applications of mathematics. The original article can be read here:* www.plus.maths.org/issue38/features/livio/index.html

REVIEW

Dr. Mario Livio, a Senior Astrophysicist at the Space Telescope Science Institute, gives a very interesting account of the symmetry of the laws of nature. For figures and shapes drawn on a piece of paper, there are four types of symmetries: reflection, rotation, translation, and glide reflection. How can these be applied to the laws of nature? Are the laws of nature symmetrical? And which transformations can be performed on them so that the laws remain unchanged?

Although not directly connected with curriculum material for school science, this article will surely interest all science teachers who would like to improve their understanding of the laws that govern the universe. Mathematics teachers would find this article of particular interest.

Elton Micallef, Malta

Chocolate's chemical charm

Dhara Thakerar, a second-year student of natural sciences at Cambridge University, UK, elucidates the science of chocolate.

The use of chocolate by humans dates as far back as the Pre-classic period (900 BC to AD 250). Using high-performance liquid chromatography, scientists have discovered cocoa residues in Mayan ceramic pots used in food preparation, dated around 600 BC (Hurst et al., 2002). Numerous Mayan murals and ceramics are inscribed with hieroglyphs depicting chocolate poured for rulers and gods. Perhaps this is not surprising, considering that the Latin name for the cacao tree, *Theobromacacao*, means 'food of the gods'.

When chocolate was introduced to Europe in the 16th century by the Spanish conquistadors, a sweetened version became a luxury item throughout the continent. In 1847, the first commercial chocolate bars were invented in England by Joseph Storrs Fry, with the Cadbury brothers following soon after.

Ever since, chocolate has been absorbed into the fabric of daily life; however, few are familiar with the ways in which it affects our body. The media's message about chocolate remains confusing, as reports alter-

BACKGROUND

Editor's comment

Now that you've grasped the theory of chocolate, it's time for the practical work! See our chocolate-tasting activity on page 29.

nate between scrutinising chocolate for health risks and praising it for hidden health benefits. So, is the mantra of 'eating just a piece a day' more detrimental than beneficial?

The pleasurable feelings that chocolate induces can be explained by its physical properties. Professor John Harwood and his colleagues at Cardiff University believe that the high stearate content of cocoa butter, a key ingredient in chocolate, is responsible for its melting behaviour and stability. Cocoa butter contains between 30% and 37% stearate in its lipid content. As a result, it is solid at room temperature, but when consumed, its fat content absorbs heat from the mouth and melts at body temperature, producing the 'melt in the mouth' effect.

Chocolate has long been suspected of having aphrodisiac properties: the Aztecs thought it invigorated men and made women uninhibited. Consistent with this, the chemical tryptophan is found in chocolate. This is used in the brain to make serotonin, the neurotransmitter that can produce feelings of ecstasy. However, tryptophan is present in chocolate in only small quantities, fuelling debate as to whether it causes the elevated production of serotonin.

Phenylethylalanine, which promotes feelings of attraction, excitement, giddiness and apprehension, has also been isolated in chocolate, but again, its low concentration may be insufficient to produce the effects typically associated with this compound.

Theobromine – a weak stimulant found in chocolate – in concert with other chemicals such as caffeine, may be responsible for the characteristic 'buzz' experienced when eating chocolate. Scientists at the Neurosciences Institute in San Diego suggest that chocolate contains pharmacologically active substances that produce a cannabis-like effect on the brain, such as anandamide: a cannabinoid neurotransmitter (Di Tomaso et al., 1996). Chocolate also contains N-oleoylethanolamine and N-linoleoylethanolamine, which inhibit the breakdown of anandamide, and thus may prolong its effects. In addition, elevated levels of the neurotransmitter can intensify the sensory properties of chocolate (texture and smell), thought to be essential in inducing cravings.

The high fat content of most chocolate – Cadbury's Dairy Milk alone contains 30 g of fat per 100 g – means that excesses can contribute to obesity, which carries with it a range of health risks, including heart disease and diabetes. Nevertheless, not all accusations levelled at chocolate can be justified. The often-touted link between chocolate and acne has been intensively studied for three decades. In a 1969 study at the University of Pennsylvania School of Medicine, 65 subjects with moderate acne ate either chocolate bars containing ten times the amount of chocolate found in a typical bar or identical bars containing no chocolate. Test subjects who consumed the excessive amount of chocolate for four weeks did not show signs of increased acne (Fulton et al., 1969).

Additionally, chocolate has not been proven to contribute to cavities or tooth decay. Cocoa butter may in fact coat teeth and help protect them by preventing plaque formation.

Although the sugar in chocolate contributes to cavities, it does so no more than the sugar in other sweet foods. However, by altering blood flow to the brain and releasing norepinephrine, some chemicals in chocolate can cause migraines.

Perhaps the best compromise is to snack in moderation, particularly on dark chocolate. Not only does it contain more cocoa and proportionally less sugar and fat than milk chocolate, but it is also full of antioxidants called flavonoids. In fact, dark chocolate has been reported to contain more flavonoids than other antioxidant-rich foodstuffs, such as red wine. Flavonoids reportedly prevent cancers, protect blood vessels, promote cardiac health, and counteract mild hypertension (high blood pressure).

Milk chocolate may not offer the same benefits. In one study, patients on separate days ate 100 g of dark chocolate,100 g of dark chocolate with a small glass (200 ml) of whole milk, or 200 g of milk chocolate (Serafini et al., 2003). One hour later, those who ate dark chocolate alone had the highest concentration of antioxidants in their blood, suggesting that the milk in milk chocolate may interfere with the absorption of antioxidants.

Science can explain a number of features that contribute to the lasting popularity of chocolate, although how some of its post-consumption effects occur is still debatable. Although it is unlikely to ever be marketed as a health product, eating the darker varieties and snacking in moderation could prove beneficial. But one thing is certain: from both scientific and sensory perspectives, there is nothing quite like chocolate.

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Resources

For more information on the science of chocolate, see the BBC's Hot Topics website: www.bbc.co.uk/science/hottopics/chocolate

Professor John Harwood's research is described here: www.cf.ac.uk/biosi/research/molecular/staff/harwood.html

This article was first published in BlueSci, *a science magazine based at Cambridge University: www.bluesci.org*

REVIEW

Mmm...chocolate! Everybody loves it. And it is potentially good for you; that is, of course, if it is dark and in small quantities. This is what the short but highly interesting and enlightening article by Dhara Thakerar suggests, citing scientific evidence to support her case.

Although the details of the chemical substances in chocolate might be beyond the secondary school level, their effects on the body and health can be easily understood and appreciated. This article can thus be directly used in any science class to inform students about the advantages and disadvantages of eating chocolate. Furthermore, biology and chemistry teachers might find the article suitable for a discussion on how a single type of food can be either beneficial or harmful depending on how, by whom and for what purposes it is used. In fact, a debate could be carried out with groups of students acting as proponents or opponents of the habit of eating chocolate.

Finally, if the theoretical treatment of the subject is considered insufficient and needs practical investigation, all the teacher has to do is to take a box of dark chocolate into the classroom...

Michalis Hadjimarcou, Cyprus

Image created by Nicolas Bouvier; courtesy of Genevieve Almouzni, Curie Institute, Paris, France

Epigenetics

We tend to think of our genetic information as being encoded in DNA – in our genes. **Brona McVittie** from Epigenome NoE, UK, describes why this is only part of the story.

How epigenetics shapes life

" … it is tempting to wonder if this twisted sugar string of purine and pyrimidine base beads is, in fact, God."

James Watson

More than 50 years have passed since James Watson and Francis Crick first published the 3D structure of the DNA double helix. With Darwinian evolutionary theory now so widespread, the discovery that DNA encodes hereditary characteristics has proven popular. When Crick passed away in 2004, broad media coverage signified how much these concepts are accepted beyond the scientific community. However, we are coming to realise that gene-centric theories of evolution are limited in their scope. The genetic blueprint, like a complex musical score, remains lifeless without an orchestra of cells (players) and epigenotypes (instruments) to express it.

Science is now uncovering what plays our genetic score, and it appears that this performance can change dramatically between generations without any alteration to the DNA sequence. The field of epigenetics seeks to determine how genome function is affected by mechanisms that regulate the way genes are processed. Epigenetic factors include both spatial patterns, such as the arrangement of DNA around histone proteins (chromatin), and biochemical tagging.

There are hundreds of different kinds of cells in our bodies. Although each one derives from the same starting point, the features of a neuron are very different from those of a liver cell.

With some 30 000 genes in the human genome, the importance of silence, as in any orchestral performance, must not be underestimated. As cells develop, their fate is governed by the selective silencing of genes. This process is subject to epigenetic factors. Patterns of DNA methylation, the addition of a methyl group, play a role in all sorts of phenomena in which genes are switched on or off, from the splash of purple on a petunia petal to the growth of cancerous tumours.

Failure to silence genes can produce a hazardous cacophony. Abnormal DNA methylation patterns can alter the spatial arrangement of chromatin. This, in turn, affects which genes are silenced after cell division. Hypermethylation can inhibit the work done by protective tumour suppressor genes and DNA repair genes. Such epimutations have been observed in a wide range of cancers. These epigenetic insights are offering new therapeutic avenues for exploration.

Epigenetics also provides a means by which genetic material can

The twins aged 29: Jason (left) and Gavin on the beach

The twins aged 7: Jason (left) and Gavin with their mother and grandmother

respond to changing environmental conditions. Although plants do not have a nervous system or a brain, their cells have the ability to memorise seasonal changes. In some biennial species, this ability is linked to their capacity to flower in the spring, when warmer ambient temperatures are detected. Research has shown how exposure to cold during winter triggers structural changes in chromatin that silence the flowering genes in mouse-ear cress. These genes are reactivated in spring when longer days and warmth are more conducive to reproduction.

The environment can also prompt epigenetic changes that affect future generations. Recent laboratory studies on inbred mice demonstrated how changes to their diet might influence their offspring. Their fur can be brown, yellow or mottled depending on how the *agouti* gene is methylated during embryonic growth. When pregnant mothers were fed methyl-rich supplements such as folic acid and vitamin B12, their young developed mainly brown fur. Most of the babies born to the control mice (not given the supplements) had yellow fur.

Just as the conductor of an orchestra controls the dynamics of a symphonic performance, epigenetic factors govern the interpretation of DNA within each living cell. Understanding these factors could revolutionise evolutionary and developmental biology, and thus affect practices from medicine to agriculture. To answer Watson, "The genetic alphabet is more akin to the word of God, and its translation to His hand."

Twin profiles

"At times in their lives they have definitely striven to be perceived as a unit and at other times seem to want people to acknowledge their differences and respect them as individuals," says Jim of his friends Gavin and Jason. Gavin and Jason are identical twins. One is literally a clone of the other.

Their similarities cannot be disputed, but when I first met them, I found them to be quite different people. Had I met them a few years earlier, I doubt I would have been able to tell them apart.

Monozygotic (identical) twins occur with an incidence of 1 in every 250 births worldwide. For reasons yet unknown, a fertilised egg cell clones itself and gives rise to separate embryos. Each will begin and end life with the same genetic make-up, but as they grow and develop they will experience differences in their environment, some of which might alter their appearance and behaviour.

Gavin and Jason have exactly the same DNA. If one committed a crime and unwittingly left samples for forensic analysis, it would be impossible to determine the culprit from DNA fingerprint analysis. However, closer inspection of their molecules may reveal significant differences. Although the two share the same genes, recent evidence suggests that some genes might be active in one twin but not the other. They might be identical genetically but not epigenetically.

Such differences are discernable at the molecular level in the way that their chromosomes are arranged within the nucleus of each cell. Twisted around tiny protein (histone) balls, the same DNA string can have different consequences for a cell. Both balls and string assume complex 3D structures depending on their biochemical flavour. A variety of small molecules can affect the nuclear infrastructure by adhering to DNA and its associated histone proteins. Such flavours are influenced by the environment, most notably our diet.

Biochemical fine-tuning of the genome determines which genes are switched on, so twins are not necessarily destined to share the same fate. Recent research (Fraga et al., 2005) on around 80 different sets of monozygotic twins has revealed that their DNA is marked in different ways by a tiny molecule called methyl. So it's not really true to say that they are identical. What's more, these differences were much more pronounced in older than in younger twins.

This is new fodder for the age-old debate over how much the environment influences our fate relative to our genes. Although the similarities between identical twins are more striking than the differences, their inequalities could offer new avenues for disease research. For example, although Gavin and Jason are both at risk for type II diabetes, Jason was recently admitted to hospital with a pancreatic infection and had to inject himself with insulin for some time afterwards. The doctors were unable to make a more specific diagnosis. Had they been equipped with better diagnostic tools, such as those offered by new advances in epigenetic research, they might have been able to profile the twins to ascertain what was wrong with Jason.

References

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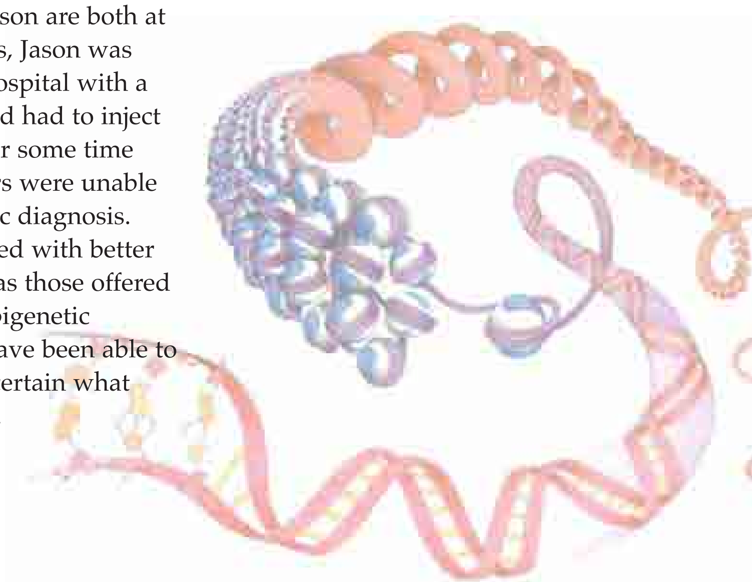
Resources

Further information about epigenetics is available on the multilingual Epigenome NoE website: www.epigenome.eu



REVIEW

Traditionally, identical twins are considered identical in all aspects of their make-up, right down to the way in which their DNA functions. The debate over nature versus nurture has persisted for many years, with many studies looking at identical twins who have been separated at birth and raised in different environments to see how they differ. At last there appears to be concrete evidence that nurture or environmental pressures influence how DNA is methylated or silenced in the genome, leading to minute changes in gene expression. These epigenetic changes, affecting the arrangement of DNA around histone proteins and its biochemical tagging, can be influenced by something as simple as diet or, in plants, by seasonal changes. The discovery of this phenomenon means that identical twins could, for example, react differently to the same medicine. Investigating how genome function is affected by gene silencing is thus an emerging and important field.

Although the control of gene expression in terms of the *'lac'* operon is included in some syllabuses, DNA methylation as a mode of gene control is not considered within the UK A-level biology syllabus. It is mentioned in text-books in the context of bacterial DNA being methylated to prevent its own restriction endonucleases from cutting endogenous DNA. The idea of silencing genes by methylation could be introduced into genetics lessons as 'how identical are identical twins?' Most students should be aware of the nature versus nurture debate in the upbringing of twins, but this can now be extended. It may also be possible to introduce the concept of DNA methylation inactivating one of the X chromosome in females.

Shelley Goodman, UK

GRID: a European network of good practice in science teaching

Sibylle Moebius introduces a project, GRID, to identify and promote innovative science education in Europe.

Sir Harry Kroto at a workshop for primary school children in Waterford, Ireland

The GRID project, GRowing Interest in the Development of teaching science, aims to create a network of decision-makers and schools to exchange good practices in European science teaching. The primary objective is to identify, analyse and promote primary- and secondary-school initiatives to make science teaching attractive. The ultimate aim is to disseminate the best practices thus identified via a website[w1].

The first stage of the GRID project was to analyse European education policies with a direct impact on schools. This was done by reviewing policy reports, recommendations and institutional plans published by ministries, regional and local education authorities, and educational institutions. This report is currently being finalised and will be available on the GRID website.

Children enjoying Science Week at the Waterford Institute of Technology, Ireland

Via the GRID website, a major survey has been launched to identify and analyse existing school initiatives to increase the attractiveness of science. If you are a science teacher in a primary, lower or upper secondary school who is involved in an isolated classroom-based initiative, or who is running a major local, county, regional, national or even international project, we encourage you to participate in the survey.

In each of the partner countries, the six to 12 best projects will be selected as case studies. The purpose of the case studies is to maximise the impact of existing projects and encourage their spread across Europe. The case studies will include video clips and interviews with the teachers involved.

Subsequently, workshops will be organised in each partner country, in which teachers can share their experiences and offer advice to others interested in setting up similar science education projects.

CALMAST chemistry display at the Young Scientist and Technology Exhibition, Ireland

Pupils investigating solar power

The first results

The GRID survey of innovative science education projects in Europe has already identified some particularly inspiring projects.

Physics is Cool (Belgium)

The University of Antwerp has developed a project for secondary schools called 'Physics is Cool'[w2]. Some 40 kits contain all the materials needed to carry out a wide range of experiments with 14-17 year-old students. A teacher's guide and a CD are also included. The experiments are intended to provoke discussion and improve scientific communication between students, to make them aware of the causes of everyday phenomena, and to confront them with experiments which are rather easy to do but sometimes difficult to explain.

The Ada Lovelace Project: mentoring for women in science and technology (Germany)

Female university students in science, engineering and mathematics act as mentors to schoolgirls as part of the Ada Lovelace Project[w3]. The mentors are trained in communication and moderation methods, with supervision by pedagogy or psychology staff. They visit schools and discuss reasons to study science, engineering and mathematics, offer advice on overcoming obstacles, and inform the school students about university life. As a second step, the mentors invite girls to participate in university courses and laboratory work.

Life Learning Center (Italy)

The main goal of the Life Learning Center[w4] is to provide teachers and school students with hands-on laboratory experience of the life sciences at university. They learn about modern molecular biology, genetics and biotechnology, and use advanced laboratory equipment with the support and supervision of university tutors.

Chemistry at Work (UK)

Chemistry at Work[w5] events demonstrate to school students the importance of chemistry in everyday life and work, with particular emphasis on what is happening in their local area. The events offer a positive image of the chemical sciences and present them as exciting, interesting and financially beneficial activities that are worth considering as the basis of a career.

Updates on the GRID project

The GRID newsletter, available on the GRID website or by email, is aimed at project partners, science teachers, decision-makers, contributors and all others involved and interested in the project. It documents the project and its activities and events, and provides partners and contributors with practical information. To

Eoin Gill at the CALMAST stand at the Young Scientist Exhibition, Ireland (left)

Primary school pupils at the Young Scientist Exhibition, Ireland (right)

subscribe to this free newsletter, send an email to Sibylle Moebius (smoebius@amitie.it) with your name, surname, profession, country and email address.

Acknowledgements

The GRID project is funded within the framework of the European Community Socrates Programme, coordinated by the Pôle Universitaire Européen de Nancy-Metz, France, and carried out by a European multidisciplinary consortium.

Web references

w1 – GRID website: www.amitie.it/grid
w2 – Physics is Cool: http://webhost.ua.ac.be/focus/Koffers/english.htm
w3 – The Ada Lovelace Project: www.uni-koblenz.de/~alp/projekt_en.htm
w4 – Life Learning Center: www.golinellifondazione.org/eng/
w5 – Chemistry at Work: www.rsc.org/Education/chemwork/

All images courtesy of GRID partner Sheila Donegan, CALMAST, Waterford Institute of Technology, Ireland

Chamber of Challenges at the Waterford Institute of Technology, Ireland

A search for the origins of the brain

Detlev Arendt, a molecular biologist at the European Molecular Biology Laboratory, Heidelberg, Germany, describes to **Russ Hodge** how his cutting-edge research is following in the footsteps of a 19th-century scientist.

Detlev Arendt

Through the glass windows of his tiny office, you can see four or five members of Detlev Arendt's research team pipetting, scribbling in their lab notebooks, and preparing experiments. Detlev ventures out into the lab every day, but he feels most at home at his desk, surrounded by stacks of books and journal articles.

"By nature I'm more of an armchair scientist," he says. "I could easily spend my whole day reading and writing. But the best science comes from a marriage of theory and lab work. You can have great ideas, but when you produce data, things often turn out differently than you imagined, and the end result is more beautiful."

Even Charles Darwin, fresh off the ship *HMS Beagle*, had to put in his time at the microscope; he was told that a "serious biologist" had to have studied one organism exhaustively and contributed original work on it. As a result, he dedicated himself for a decade to a creature which, until then, had received little attention: the barnacle.

The armchair approach has been unusually successful for Detlev, starting during his third year of biology studies at university. He says he was a "typical undergraduate", not terribly concerned about a career. He chose biology because in school he had been attracted to the most complicated topics he could find, and biology was certainly complicated enough.

Detlev had also considered working in ecology. He had been introduced to the field during an 18-month period of civil service that young German men can choose instead of military service, when he had given guided tours of the North German seashore. "It's a fascinating habitat," he says. "The tide runs out, and you can walk for kilometres and kilometres among the mud flats, finding millions of worms, mussels and snails that you don't see anywhere else." But when it came to deciding which subject to concentrate on at university, Detlev felt that ecology didn't offer enough, and he chose biology instead.

When it came time to write his thesis, he went to the library to read. Two topics that interested him tremendously were evolution and development: how animals' bodies grow from single egg cells. At the time, these two fields had started to come together on the molecular level, following in the footsteps of a 19th-century German scientist named Ernst Haeckel.

"Haeckel put forward the idea that as an individual animal body forms, it goes through phases that resemble the history of its evolution as a species. So human embryos start off as single cells, then go through stages that first resemble very simple multicellular animals, then worms, fish and mammals, before they finally take on a form that is uniquely human."

A century later, scientists began to understand that tissues and body structures arise when young cells activate new sets of genes, changing their shapes and interactions, building tissues and organs. Molecular developmental biology and genetics were coming together in a new research field called evolution and development – or 'evo-devo'.

In the early 1990s, as Detlev sat in the library, this new field was in its infancy. One amazing study revealed that a particular family of genes had been conserved through nearly a billion years of evolution in all sorts of organisms. Called the homeobox (HOX) genes, they lay down the basic head-to-tail organisation of the body plans of widely diverse animals. HOX genes are arranged next to each other on a chromosome, like a string of words making up a sentence. As cells in the early embryos of animals divide, HOX genes are activated one after another, in the order in which they appear on the chromosome. The result is the step-by-step formation of the head and lower segments of the bodies of worms, flies and humans.

Were other body parts built using ancient blueprints like the HOX genes? "People went looking for patterns," Detlev says. "For example, they had discovered molecules that formed the ventral and dorsal – upper and lower – sides of flies. Then they began looking for relatives of these genes in mammals. They found most of the crucial ones, and there was literature about how mutations in these genes affected the body plans of mammals. But at first there didn't seem to be a strong parallel between insects and vertebrates."

Detlev read paper after paper in search of similarities between mice and flies. As he stared at two papers lying side-by-side on his desk, one about insects and the other about mice, a pattern suddenly leapt out at him.

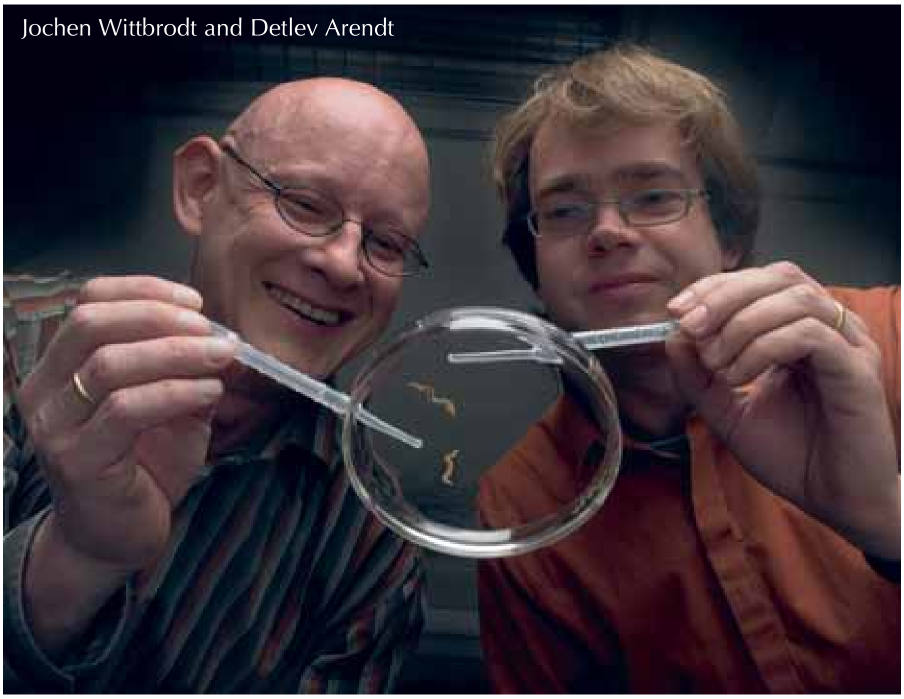
"Maybe there was a simple genetic programme to determine these sides after all," he says. "All you had to do was make one assumption – that the genes that formed the ventral side of insects were forming our dorsal side, and vice versa. In other words, at some point in evolution, vertebrates had flipped over."

University of Freiburg, Katharina Nübler-Jung. She encouraged him to send a letter to one of the most important scientific journals in the world – *Nature.*

The result was something almost unheard of – *Nature* printed a scientific communication from an undergraduate student. Scientists everywhere peered more deeply into Detlev's hypothesis, even seeing patterns in their own data that they had missed. He began to receive invitations to conferences all over the globe. Not only was it exciting to be invited to so many places – it also gave him a thesis topic.

★★★

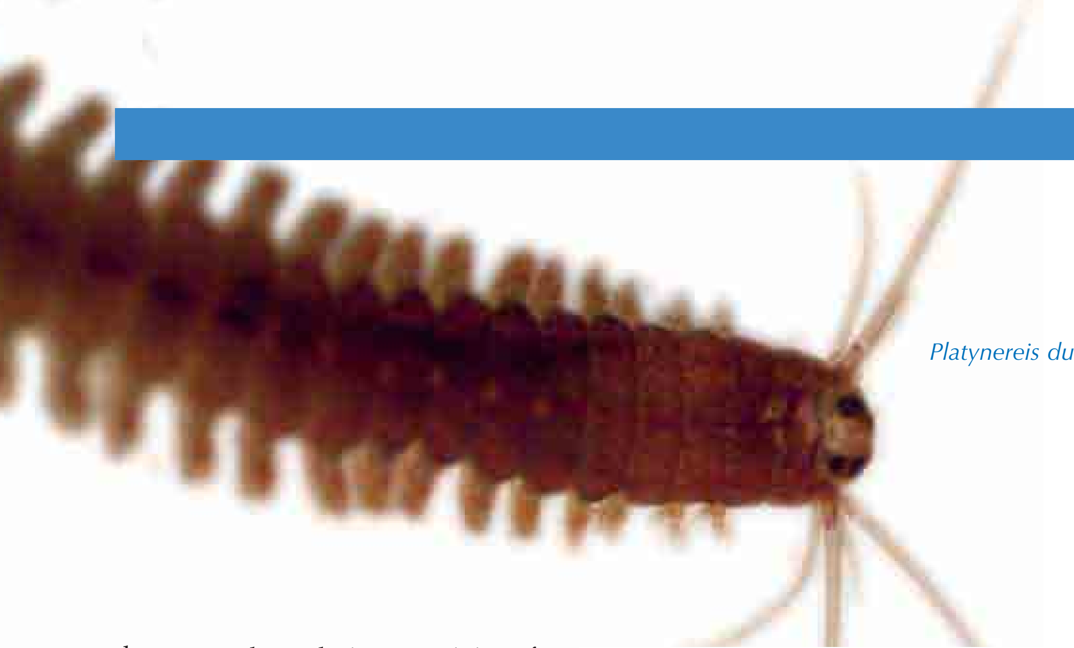
Detlev walks me from his office, through the lab, then down the hallway to another room. Here are aquaria full of his favorite organism: a small marine worm called *Platynereis*


Jochen Wittbrodt and Detlev Arendt

Detlev raced through all the literature he could find on genes that guided these developmental processes. Everything he found suggested that he was right. So he checked the results with one of his teachers at the

dumerlii. Detlev brought the animal to EMBL when he began doing postdoctoral work in the lab of Jochen Wittbrodt.

Detlev was working on a fascinating question: he wanted to discover



Platynereis dumerlii

the very early evolutionary origins of the brain. This was an excellent match with Jochen's work, he says, because Jochen was interested in studying the origins of the eye. And if you go back far enough in evolution, it's really the same question.

To explain this, he takes down a round dish containing some worms swimming energetically. This simple creature holds important clues to the origins of our own brain. "All living animals with brains and eyes – from insects to humans – descend from one ancestor; *Platynereis* descends from it as well," he says. "That ancestor had a symmetrical body plan from head to tail: the right and left half mirrored each other. Before it evolved, there were other forms of life that didn't have this symmetry, like sponges."

Some features of this worm resemble that ancestor more than today's insects and vertebrates, making it something like a "living fossil". The *Platynereis* brain is like a blueprint for what insect and vertebrate brains have in common, and thus for the brain of their common ancestor. By studying its development, Detlev hopes to discover how the first brains arose.

★ ★ ★

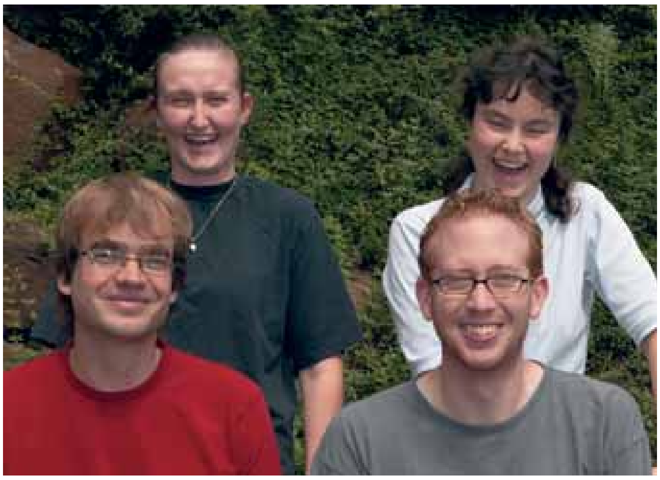
Where does the brain come from? The question can mean two different things, Detlev says. The first is how our species' brain evolved. The second is how an individual's brain grows from a single cell. Very recently, following in the footsteps of Ernst Haeckel, scientists like Detlev have begun to connect these two stories.

The 49[th] plate from Ernst Haeckel's *Kunstformen der Natur* (1904), showing various sea anemones classified as Actiniae

A fertilised egg divides over and over, differentiating into specialised types of cells like blood, muscle and neurons, which form all of our tissues and organs within the space of nine months. This happens because our genetic code contains instructions for producing tens of thousands of different molecules, like a huge recipe book. Although every cell in our bodies contains a copy of the entire book, each type draws on only a subset of the recipes, producing a unique cocktail of molecules that determines its shape and behaviour. Modern technology allows scientists to analyse that protein cocktail, yielding a "molecular fingerprint" that identifies the type of cell. This permits them to discover cells that are just on the verge of becoming the first nerves and parts of the brain, long before there are any recognizable organs.

Detlev is convinced that the molecular fingerprint can also be used to find related cells among different species. Over nearly a billion years, he believes, evolution has held onto the basic recipe for creating the major cell types and organs. Similar cell types in different animals will share the most important ingredients of the cocktail because they were inherited from a common ancestor. So if you can find those cells in insects, fish and mammals, and then pin down a common recipe, you most likely have the original cocktail for building brains. The patterns can be tested by checking them against what happens in *Platynereis.*

It's a new method that changes the way biologists are learning about evolution, and Detlev thinks it has solved a great debate about one of Darwin's evolutionary riddles: how many times nature "invented" the eye. Even after the closest scrutiny of cells from different species under the electron microscope, scientists came to many different conclusions – estimates ranged from two to 40 different acts of "evolutionary invention" for eyes.



Detlev's research group: Heidi Snyman, Kristin Tessmar, Patrick Steinmetz and Detlev (clockwise from top left)

The fingerprinting method has permitted Detlev, Jochen and many enthusiastic PhD students to clear up some of the confusion. "I'd be lost without my students," Detlev laughs. Starting with the key genes involved in making light-sensitive cells in insects, they checked for related molecules in the genomes of mammals and fish. Then they began scanning early larvae of *Platynereis*, probing for cells that used these genes. A pattern emerged: in all of these different species, the same recipe was being used to make two fundamentally distinct types of photoreceptor cells. So even though the eyes of today's insects and vertebrates look very different- even down to the architecture of the cells that compose them – they can be traced back to these two types of light-sensitive cells.

The 98th plate from Ernst Haeckel's *Kunstformen der Natur* (1904), depicting organisms classified as Discomedusae

The project has also given the scientists a detailed view of how evolution can generate different organs from the same basic cell types. Photoreceptor cells are used to create many different structures; different branches of life seemed to have spun off the cell in different ways. But they are all somehow related to the eye and its connections to the brain.

The work with Jochen has now given Detlev – "and my enthusiastic students" – the tools they need to tackle the question of brain evolution. Doing so will require a healthy mix of ideas and data. That's nothing new in the science of evolution. Evidence that species could change had been known for a long time; it took a young man about Detlev's age to step back from the data, retreat to his armchair, and weave it all together into a coherent theory. So it shouldn't come as a surprise that taking care of Charles Darwin's unfinished business, from 150 years ago, will require a similar approach.

A zoologist at school: my pupils and other animals

Silvia Boi, a science teacher from Italy, explains how her fascination with science led her to study ant behaviour, worm reproduction and the human genome – and how she now tries to awaken that fascination in her pupils, using somewhat unusual techniques.

From the field to the laboratory

"Science is fun!" I thought, aged seven, when I first read Konrad Lorenz's *King Solomon's Ring*. "I want to be a scientist when I grow up!" I didn't change my mind during my time at school, and so, many years later, I found myself as a biology student at the University of Milan, with the impossible mission of writing a thesis on a mathematical model to describe the formation of armies in slave-maker ants.

After a couple of months filming ants in a national park in northern Italy, sleeping in a tent and walking hours every day to reach the ant nest, I spent countless hours analysing my data in front of the computer screen. Then, in the summer of 1996, I received my biology degree and, thinking that nothing could be better than being paid to have fun, I happily started a PhD in invertebrate biology.

My new research was on sperm in small annelid worms called *Tubifex tubifex*, commonly found in polluted and smelly streams. I spent most of my time playing with immunocytochemical techniques, fluorescence and confocal microscopes, and getting excited about pictures of worm sperm. But my first passion, the ants, had not been forgotten, and in 1998, I took a break from my PhD to spend six months at the University of Bath developing a mathematical model of activity patterns in ant nests.

As often happens, the project turned out to be quite complex and the available time was very short, but I was lucky to find a good research group to work with, and I learned a very important thing: the collaborative nature of science. Discussing ideas and distributing work according to individuals' different abilities is indeed the basis of research.

In 2000, I earned my PhD on annelid reproduction and, after another year working on the same subject, my curiosity led me towards molecular biology and the study of the human genome. But (in every good story, there is a 'but'), after many stimulating years of research, travel and meeting people, I wanted to spend more time with my family. Furthermore, it was clearly going to be very difficult to find a permanent position in academia: it was time to move on.

In the same period, I became interested in the public perception of science. I first thought about teaching science at school, because I would be able to enjoy science together with my pupils. Although I would miss research, the curiosity and wonder of young people would add a new zest to science. I was lucky enough to be awarded a permanent position as a science teacher and, almost before I knew what had happened, I found myself standing for the first time in front of a classroom of 15-year-olds in an Istituto Professionale, a vocational Italian high school.

Into the classroom

"Science is fun," I thought, as I smiled confidently at the pupils. But I wasn't smiling a few minutes later as, during the usual first-day interview, I

asked the pupils to introduce themselves and their opinions of science. "Science is boring," they replied. "Science is difficult," and, more dangerous than any other criticism, "science is useless"! In less than half an hour, I was involved in a discussion about why they should learn some science even though their professional curriculum did not specifically require any scientific knowledge.

The second day was better. I began to lecture and, as the pupils were quite prepared to deal with boredom, they happily occupied themselves while I tried to communicate the exceptionality of living systems.

One surprise for the scientist moving to teaching is the amount of bureaucracy: forms to fill in for every pupil and for the whole class, evaluating their knowledge, behaviour and needs; tests and questionnaires for the pupils, all written in incomprehensible jargon. Schools often seem to be more concerned with bureaucracy than with how much their pupils learn. Sometimes, even the pupils seem to be interested in the teacher only as a marking machine: "What's my mark for this answer?"

Where to start? How to convince students that science is useful, accessible and fun? The school where I work, like many in Italy, has no science lab, and for safety reasons, no experiments may be performed in the classrooms.

There are no microscopes, no globes, no stellar maps, no anatomical models or tables. The only resources available are a computer lab, a TV and a projector. The first idea I had was to use simple models to explain things. I showed my students an atom made out of little coloured balls of Plasticine®. I represented a cell with a box of different components (a battery representing mitochondria, an instruction manual representing the DNA in a plastic bag to represent the nuclear membrane and so on...). And I let them act out the Big Bang.

Then I tried to talk less and let the pupils try to solve a problem. For example, I gave them a balloon and asked them to identify the position of a point drawn on it, hoping they would draw a system of lines similar to the latitude and longitude. I also tried to make the tests more fun, as when I asked an astonished class of teenagers to pretend to be the digestive or circulatory apparatus. After the initial shock, they accommodated themselves to the demands of an absolutely mad teacher and made costumes to play the part of the liver or the heart.

Does this work? Honestly, I have no idea. The pupils learn some science, some of them even learn quite a lot, but I cannot say whether these techniques are better than traditional lectures. What I know for sure is that we all enjoy the science classes! That's a first step, and an important one. I'm still new to this, but you have to learn fast when you awaken students' interest.

Of course, some things about teaching would be easier if we had the latest equipment and more time dedicated to science in the curriculum. But my school is probably typical of many across Europe, where every day, teachers make use of what they have – if it's your hands and feet, you can still gesture and dance. What I miss most is a community of science teachers to discuss and compare methods.

For me, the most rewarding thing about teaching is not the equipment, but the creativity you can express in this work, which is stimulated by your pupils. In every class, you can discover science through their eyes and try a different method to approach the same concepts. And as a trained scientist, I think I can transmit the taste and excitement of doing science!

Video-clip collection of the European Space Agency

Image courtesy of ESA & NASA

Films about science or even pseudo-science can be powerful tools in the classroom. **Heinz Oberhummer** from the Cinema and Science project provides a toolkit for using the video-clip collection of the European Space Agency.

Distant view of the comet Tempel 1, the target of NASA's *Deep Impact* mission (artist's impression)

Comet Tempel 1 observed in visible light and infrared light (artist's view)

Image courtesy of NASA, Jet Propulsion Laboratory-Caltech, and T. Pyle (Spitzer Science Center)

In the classroom, video clips about science or even pseudo-science can be used to stimulate discussion and raise interest in scientific subjects. The Cinema and Science (CISCI) website[w1], due to launch in December 2006, will describe a wide variety of film scenes, providing explanations and background information to help teachers prepare inspiring, film-based lessons.

This article on the video-clip collection of the European Space Agency[w1] (ESA) provides a sample of the content being developed by CISCI, including explanations for pupils and background information for teachers.

The Hubble Space Telescope

The Hubble Space Telescope is a collaboration between ESA and NASA[w2]. It is a long-term, space-based observatory. The observations are carried out in visible, infrared and ultraviolet light. In many ways Hubble has revolutionised modern astronomy, not only by being an efficient tool for making new discoveries, but also by driving astronomical research in general.

The website of the Hubble Space Telescope[w3] provides a wealth of images and video clips to view and download.

Basic explanation

Comets consist of ice and dust and are therefore often called 'dirty snowballs'. When comets approach the Sun, the ice melts and boils and particles are thrown out. These particles are then dispersed by wind from the Sun, forming the characteristic comet tail. Tempel 1 is a cigar-shaped comet about 224 cubic kilometres in size.

In the video clip, we see the impact of the 370-kilogram projectile (impactor) released by the mother spacecraft *Deep Impact* with the inner part of the Tempel 1 comet on July 4, 2005. The comet is named after Ernst Wilhelm Leberecht Tempel, who discovered it in 1859. The mission is named after the film *Deep Impact*, a 1998 blockbuster film.

The impact on the comet Tempel 1 was observed by the spacecraft, the Hubble Space Telescope and observatories around the world. First results show that there is about twice as much dust than ice in the comet, sug-

BACKGROUND

Cinema and Science (CISCI)

The CISCI project involves ten partners from Europe and the USA, and is part of the larger NUCLEUS project funded by the European Commission. The planned 160 content units will cover physics, biology, chemistry, mathematics, informatics and other science subjects and will be available on the CISCI website[w1] in English and the languages of the CISCI partners.

gesting that comets are 'icy mudballs', rather than 'dirty snowballs', as previously believed.

Advanced explanation

Mission *Deep Impact*

Some of the scientific questions that the *Deep Impact* mission was designed to answer were:

- What are the basic properties of the comet: how is its surface formed, how dense is it, how strongly is it held together and how massive is it?
- What is the composition of the comet?
- Can the course of a comet be altered to reduce the effect of, or to avoid, a collision with Earth?

The asteroid Apophis

On the evening of April 13, 2029, the asteroid Apophis, with a volume of 320 cubic kilometres, will pass Earth at a distance of only 36 650 kilometres. This is about the height of our geo-stationary satellites and about ten times closer than our moon. Apophis will then be visible with the naked eye over Europe.

On April 13, 2036, Apophis will then pass Earth at a height of only 3400 kilometres (about half Earth's radius). According to present calculations, the chance of it hitting Earth is about 1:8000. It would crash into the Pacific Ocean with a speed of about 50 000 kilometres an hour, corresponding to an explosive force of about 100 million tons of TNT. It would create a 2500-metre-deep crater in the ocean, causing tsunamis up to 20 metres high. The Asian tsunami in 2004 was only half that high. The costs in infrastructure alone along the North American coast would amount to approximately US$400 billion. However, sustained global effects are not anticipated.

The asteroid Apophis is named after the Egyptian god of evil, destruction and darkness. Two of the co-discoverers of the asteroid, Roy Tucker and David Tholen, are fans of the TV series Stargate SG-1; it is probable that they named the asteroid after a character in this series, played by the actor Peter Williams (see website about character Apophis in Stargate SG-1, below).

Table 1: Details of the video-clip collection of the European Space Agency

Title	Video-clip collection of the European Space Agency
Description of film	Collection of astronomical clips
Film producer	European Space Agency
Scientific subject and topic	Physics and astronomy
Website	www.spacetelescope.org/videos
Purchase film	www.spacetelescope.org/hubbleshop/webshop/webshop.php?show=sales&section=cdroms

Table 2: *Deep Impact* scene details

Time interval	heic0508f.mov 0:00:00 - 0:00:18
Scientific keywords	Comet, asteroid, impact
Title of scene	*Deep Impact* probe slams into comet
Description of scene	Animation showing the collision between the 370-kilogram projectile released by the spacecraft *Deep Impact* and the comet Tempel 1 on July 4, 2005

Redirecting Apophis

NASA is now making plans to land a transponder on the asteroid Apophis. A transponder is a tracking system similar to the ones used in commercial aircraft. This transponder could then determine the exact trajectory of Apophis, after which the asteroid could be hit and redirected using a spaceship with a mass of about 4 tons, to reduce the risk of an impact with Earth in 2036. In principle, this is possible and was demonstrated on a smaller scale by the mission *Deep Impact*.

Web references

w1 – European Space Agency (ESA): www.esa.int

w2 – National Aeronautics and Space Administration (NASA): www.nasa.gov

w3 – The Hubble Space Telescope: www.spacetelescope.org

Resources

Websites about the mission *Deep Impact*

NASA *Deep Impact* – science and technology, results, gallery and news: http://deepimpact.jpl.nasa.gov/home/index.html

Deep Impact, Wikipedia – scientific background: http://en.wikipedia.org/wiki/Deep_Impact_%28space_mission%29

Websites about Apophis

Download a widget that counts down to the possible impact of Apophis with Earth: www.widgetgallery.com/?search=apophis&x=0&y=0

NASA Earth Risk Impact Summary of Apophis: http://neo.jpl.nasa.gov/risk/a99942.html

Apophis in Stargate SG-1, Wikipedia: http://en.wikipedia.org/wiki/Apophis_%28Stargate%29

The Spirits of Nature by Ottar Vendel – article about Egyptian gods: www.nemo.nu/ibisportal/0egyptintro/1egypt/index.htm

Websites about asteroids

NASA Lunar and Planetary Science – Asteroids: http://nssdc.gsfc.nasa.gov/planetary/planets/asteroidpage.html

Asteroid, Wikipedia – scientific description: http://en.wikipedia.org/wiki/Asteroid

Asteroid Introduction – basic summary of comets, including images: www.solarviews.com/eng/asteroid.htm

Asteroids – educational site about comets: www.windows.ucar.edu/tour/link=/asteroids/asteroids.html

NASA/ESA Hubble Space Telescope Video Archive for 'Asteroid': www.spacetelescope.org/bin/videos.pl?searchtype=freesearch&string=Asteroid

Websites about impacts of comets or asteroids

Impact event, Wikipedia – scientific description: http://en.wikipedia.org/wiki/Impact_event

Earth Impacts Effects Program – calculate the environmental consequences of impacts on Earth: www.lpl.arizona.edu/impacteffects/

Solar System Collisions – calculate the effects of impacts on different planets: http://janus.astro.umd.edu/astro/impact/

Websites about *Deep Impact* (film)

Internet Movie Database – background information: www.imdb.com/title/tt0120647/

Websites about Stargate SG-1(TV series)

Internet Movie Database – background information: http://us.imdb.com/title/tt0118480/

Stargate SG-1, Wikipedia – scientific description: http://en.wikipedia.org/wiki/Stargate_SG-1

Power, Sex, Suicide: Mitochondria and the Meaning of Life

By Nick Lane

Reviewed by Sølve Tegnér Stenmark, Malakoff Upper Secondary School, Moss, Norway

Power, Sex, Suicide: three words that immediately aroused my interest in reading this book. The subtitle, *Mitochondria and the Meaning of Life*, explains what the book is about – the crucial role of mitochondria in our lives.

This book is not appropriate for young students just starting to study biology, but for higher-level students and their teachers, it is fascinating. I would recommend it for all students, teachers and others who are interested in questions like: How did life evolve? Why do we have sex and two sexes? Why and how do we age?

For those who studied biology some decades ago, or who are searching for new insights into the meaning of life, this book is full of recent scientific research and some speculative, but plausible, conclusions about the story of life. A useful glossary will help the reader to understand biological terminology.

The author's main theme is that the endosymbiotic event that took place 2 billion years ago is the most important event in the evolution of life. Mitochondria were originally a kind of bacteria living independent lives. Endosymbiosis, a process in which mitochondria were engulfed by larger cells and became organelles inside those cells, then enabled the development of multicellular and more complex organisms. Without this remarkable event, no eukaryotes or more complex life forms would have evolved. Without mitochondria, the world as we know it would not exist.

Nick Lane begins his book by discussing the origin of life and the origin of the eukaryotic cell. Then we are taken to the world of bacteria and Archaea. Why have bacteria remained resolutely bacteria for millions of years, while an unusual union between a bacterium and an archaeon created the eukaryotic cell? The 'power' described in the book's title comes from the mitochondria themselves, as Lane describes in detail how they synthesize ATP through the electron-transport chain and oxidation/reduction.

Lane then deals with why sex arose and the origin of the two genders. When two cells fuse at fertilisation, there is competition between the two sets of mitochondrial DNA to populate the new individual. Mitochondrial DNA is inherited asexually down the maternal line, and the author suggest that this is the origin of the two genders.

The culmination of the book is the discussion on ageing and the 'clock of life'. Given the higher mutation rate in mitochondrial DNA than in nuclear DNA, the author suggests that mitochondrial mutations contribute to ageing and disease, and that apoptosis (cell suicide) is necessary to dispose of damaged cells. Most importantly, degenerative diseases could be slowed down by slowing down the rate of free-radical leakage from the mitochondria.

This is a wonderful book not only for learning more about mitochondria, but also for addressing important questions: Who are we? Why are we here on earth? Why do we have sex? Why are there two sexes? Why do we fall in love and have children? And why must we grow old and die? This enlightening book provides a good starting point for fruitful discussions of all these questions.

Details

Publisher: Oxford University Press

Publication year: 2005

ISBN: 0192804812

The Science Behind Medicines

Reviewed by Tim Harrison, School of Chemistry, University of Bristol, UK

The Science Behind Medicines CD-ROM is a teaching resource produced by GlaxoSmithKline and aimed at biology and chemistry teachers of post-16 students. It has sections on drug discovery, structural formulae, bacterial infections, asthma and viral infections.

The material has been mapped to a number of science courses at both traditional and vocational GCSE and A- levels in the British education system. Despite the stated age range, elements of the CD-ROM could be used as lesson 'starters' for younger students who are studying the basics of microbes or disease.

The section on bacteria details the uses, classification and structure of bacteria. This goes on to look at diseases caused by bacteria and how they are fought. The development of penicillin, how antibiotics work, bacterial resistance and recent advances to combat this are explained.

The section on asthma has an introduction to the disease, and includes topics such as the role of adrenaline, cell receptors and their function, bronchodilators and the improvements sought for new bronchodilators.

In the section on viral infections, many aspects of viruses are discussed: viral structure, mechanism of host-cell infection, antiviral drugs, HIV, AIDS, influenza, and the future of antiviral drugs. To clarify explanations, the structure of DNA is also described. Historical aspects of both viral and bacterial infections are not forgotten. A piece on the discovery of the structure of DNA is also included.

To make it easier for students to understand the text, a comprehensive glossary of terms is available throughout the resource, which activates when the mouse rolls over highlighted terms.

The section on structural formulae takes the user through several stages to read and draw molecular formulae from ethane to penicillin G. This section is useful for those who are not yet experienced in representing molecules in this way, as structural formulae are used throughout the other sections.

The only disappointment with this otherwise excellent CD-ROM is that sections of text and images cannot be copied. This limits its use, as students cannot use it to prepare revision notes, projects or presentations. Nevertheless, *The Science Behind Medicines* CD-ROM should be included on school servers everywhere and copies could also be made available in school libraries.

Details

Publisher: GlaxoSmithKline

Information about the CD-ROM and other free resources from GlaxoSmithKline is available here: www.gsk.com/community/supporting_education/free_resources.htm

Ordering

Copies of the CD-ROM are available free by emailing resources@edist.co.uk

Success Strategies for Women in Science: A Portable Mentor

By Peggy A. Pritchard (editor)

Reviewed by Angelika Börsch-Haubold, Germany

A professor once told me in a job interview that he prefers to hire women for his laboratory "because they get things done". Nonetheless, although a blunt question as to whether you plan to have children is certainly out of fashion, female scientists still experience situations that are politically incorrect. As long as women hold fewer than 20% of senior academic positions in science (in the USA and Canada; in central Europe it is well below 15%), this situation will continue. You may not be able to change the system, but you can prepare yourself before you enter it. This is why communications specialist Peggy A. Pritchard has compiled the essay collection *Success Strategies for Women in Science.*

Pritchard argues that every young scientist needs a mentor, a person higher up on the career ladder who is willing to share her experiences on how to get ahead. As not all students can approach such a person directly, she selected a circle of successful women scientists who give their personal advice in this "portable mentor". In its 12 chapters, the reader is led through a wealth of information concerning professionalism that is usually not part of the science curriculum. 'Communicating Science' is one of the core chapters, in which students preparing their first talks can learn how to convey confidence and win over the audience. The more experienced scientist is reminded to learn at least the first few sentences of her presentation by heart. Less formal occasions, such as meeting colleagues, also benefit from preparation, and communication with the lay public either directly or via the media is best done using plenty of examples and metaphors.

The chapter 'Working Abroad' gives young scientists good reasons for broadening their horizons. The description of 'Networking' will help those who feel pressurised by the need to assemble a distinguished portfolio of discoveries to understand that teamwork is a win-win situation. An awareness of 'Personal Style' and good interpersonal skills are important when you start 'Climbing the Ladder'. Manage your time and train your brain, recognize turning points and cope with setbacks, ask for individual work solutions when you have children – the reader learns much more from this book than just advice on straight career building.

Unfortunately, this otherwise excellent book is marred by its opening chapters, which will especially puzzle scientists who are trained in careful reading and clear thinking. Here the reader is confronted with three rather redundant forewords. Next, Chapter 1 concentrates too much on success as the only goal of career management while other parts of the book quite sensibly deal with the need for 'Balancing Professional and Personal Life' and 'Transitions'. Finally, Chapter 2 offers a very general description of a certain gender-related training programme that was conducted in Germany between 2001 and 2004.

My recommendation to readers is therefore to skip over the first 40 pages to reach the wealth of practical, concisely written advice which is enlivened by short clippings of personal biographies. References at the end of each chapter include easily accessible websites, and the book ends with a comprehensive index. As far as communication goes, the book is the mentor.

Although aimed mainly at female advanced science students, the wide-ranging advice on how to optimise job performance makes the book a general guide to professional conduct. My personal favourite is the list of 'personal traits that help': gain a reputation for integrity, work on a high energy level, handle conflicts in a positive, productive manner, guard your language and develop an appropriate personal style. It probably is a good idea to start working on these issues as early as possible, and although the book has 'women' in its title, men should read it, too.

Science teachers in schools are important role models. They may be the first mentors for gifted pupils and their degree of professionalism has a great impact on adolescents who still have to decide where to go. Teachers will profit directly from the chapters on communication skills, time management and mental strength, and they should pass on the information to their students. In addition, girls who are interested in studying science should be encouraged to read the biographical sections so that if they are ever subtly informed of their worker-bee status in the laboratory hierarchy, they become neither angry nor discouraged.

Details

Publisher: Elsevier Academic Press

Publication year: 2006

ISBN: 0120884119

The Physics of Superheroes

By James Kakalios

Reviewed by David Featonby, UK

Superman, Batman, Lightning Lad, Spiderman – they all apply the principles of physics to perform their extraordinary feats... or do they? Which laws are suspended, and which are extended? Which are indeed forgotten completely? James Kakalios's view is that many fundamental principles of physics can be better understood by examining the activities of superheroes in comic strips, some famous and some not so well-known. As the foreword comments, "Comic book heroes are fun, inclined planes aren't". Thus for teachers, this book is a fantastic resource of examples which, at all levels, can enliven some of the more mundane areas of the physics syllabus.

With sections on mechanics, energy (heat and light) and modern physics, students can be challenged to question the activities of superheroes, touching on many aspects of physics. All the heroes I have heard of, and a few more besides, are mentioned, and a good index allows the reader to consult entries on different heroes as well as widely separate topics such as gravity and gamma rays, temperatures and tension. Kakalios does not limit himself to the fantasy world however, but attempts to relate each topic to the everyday real world of motor cars, microwaves and molecules, enhancing the reader's understanding.

As this is an American book, I found the use of pounds and feet, rather than consistent SI units, somewhat frustrating, but the need for us European teachers to "do the sums ourselves" may not be a bad thing. The book is illustrated with many examples from the comic strips themselves, though these would have been more helpful in colour. Maybe at some point in the future, the publishers would consider producing a series of colour slides for use in the classroom.

So if you have not yet read *The Physics of Superheroes*, I urge you to buy a copy and enjoy the debate on why Superman was the "man of steel" and became the most unrealistic superhero of all, how Spiderman's strands have their limitations, and whether he understood electromagnetism.

This is a book that every science teacher should read. It is the kind of book that can be taken on holiday, read over a long period or in short digestible chunks. Either way, I am sure that once read, some of its contents will be used over and over again.

Details

Publisher: Duckworth Press

Publication year: 2006

ISBN: 0715635492

Real Mosquitoes Don't Eat Meat: This and Other Inquiries into the Oddities of Nature

By Brad Wetzler

Reviewed by Sølve Tegnér Stenmark, Malakoff Upper Secondary School, Moss, Norway

I was examining a list of more than 20 books available for reviewing when I discovered this odd title. I am not especially interested in mosquitoes, and I know very little about them. But a colleague's encouragement and my own curiosity led me to choose this book from the list.

When I received the book, I started reading at once and continued for the rest of the evening.

What kept me so interested were all the quirky questions, such as: Do animal have orgasms? Why are other primates so much stronger than us? What causes you to see stars after a hard blow to the head? Is it safe to drink out of plastic bottles? When dogs sniff at each other, what are they smelling? Is it ever too cold to snow?

The book comprises 168 questions and answers, divided into four chapters. Chapter 1, The Great Beyond, contains questions about meteorology, astronomy and the Moon. The next chapter answers questions about the body. If you are more interested in our planet, Chapter 3 contains many questions and answers on this topic. The last chapter covers the Carbon Factor: Life and Nothing but Life.

All the questions and answers are taken from the American magazine *Outside*, and are written by the author of the magazine's 'Wild Life' column – a space where readers' questions about natural science and outdoor lore are answered. Some of the answers, although only few, are not so relevant for European readers, because they are directly related to America – for example, 'What percentage of the US is paved?'

All the answers are given by American scientists, expert outdoorsmen and professors. They are all experts in their narrow fields, and their answers are easily understandable by everyone. You don't need to have a degree in biology or astronomy to enjoy reading this book.

Another big advantage with this book is that you don't need to start on page one and read the topics in order: jumping back and forth brings the reader to quite different themes and crazy oddities on our earth. And many nice illustrations make reading even more fascinating.

I have already used some of the funny stories and explanations in my classroom, asking my students if they know 'When a spider builds a web from tree to tree, how does it string the initial thread across a wide distance?' We had an interesting lesson about spiders, food chains and ecosystems as a result.

I can highly recommend *Real Mosquitoes Don't Eat Meat* to any teacher who thinks it is often hard to answer difficult questions from pupils. But it is not just teachers who will benefit; this book is worth reading for everyone.

Details

Publisher: WW Norton & Co

Publication year: 2005

ISBN: 0393061574

Learning from Patients: The Science of Medicine

Reviewed by Michalis Hadjimarcou, University of Cyprus, Cyprus

The goal of this DVD is to show how information collected from patients often allows scientists to achieve a deeper understanding of the genetic and molecular basis of a specific disease. This level of understanding is crucial to developing treatments for disease and, consequently, to relieving patients' suffering.

The first of two DVDs contains four captivating presentations from two prominent investigators in the field of biomedical sciences, delivered at the Howard Hughes Medical Institute's Holiday Lectures on Science in December 2003. The audience consisted of high-school students. In the first two presentations, Bert Vogelstein (Johns Hopkins University School of Medicine) explains the nature of cancer, what causes it and how it can be prevented and treated. In the final two presentations, Huda Y. Zoghbi (Baylor College of Medicine) presents her discoveries on two neurological disorders, spinocerebellar ataxia type I and Rett syndrome.

The second DVD contains the animations and video clips from the presentations; biographies of Vogelstein, Zoghbi, and two graduate students who work in research labs; and a set of five special features – a bioethics discussion with the active participation of the students, information about the use of animals in research (transgenic mice), an interactive activity that engages the viewer in pedigree analysis, and presentations on two highly significant genetics topics, the proteins p53 and proteasome.

The main target group of this DVD set is biology teachers and upper secondary-school students with an interest in the biological sciences and medicine. However, after watching these presentations, *anyone* could be inspired to follow a career in these fields. The viewer watches real-life scientists talk about their investigations to unravel the mysteries of diseases that could affect any one of us. The lectures are lively and interactive; they include excellent animations about the genetic, molecular and cellular mechanisms that cause the diseases as well as short video clips in which patients and their families talk about their problems and hopes. The student audience asks questions, providing the opportunity to have common questions answered by the specialists.

The viewer not only acquires scientific information about the diseases under investigation and the efforts to cure them, but also learns what it means to work in a research lab. People often think of scientists as eccentric individuals who hide away in their secret labs where they perform strange experiments that nobody understands. This impression is obviously wrong and the material in the DVDs does an excellent job revealing the truth about scientists and their work. Conducting research in a lab might mean a lot of hard work, but these DVDs show that it could prove to be a rewarding and fun experience. The life of a scientist in the lab is not a solitary one; instead, it involves collaboration among co-workers on a daily basis and even direct contact with patients.

In recent years, the world has experienced spectacular advances in the field of genetics and biomedical sciences. This progress has generated a number of crucial ethical questions as to how to manage an individual's genetic information. The bioethics discussion in the second DVD is very informative on this subject and could easily be used to promote similar activities in the classroom.

Details

Publisher: Howard Hughes Medical Institute

Publication year: 2004

Ordering

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

Free science journals

The worldwide web is a wonderful source of information, but the sheer amount of content can be overwhelming. Where do you start looking for science news? In each issue of *Science in School*, we will suggest useful websites for particular purposes.

Are you looking for a good article to use in a lesson? Or do you just want to browse a science journal or two for inspiration? Here is a selection of free online science journals and some useful tools for tracking down the books, articles and journals you need.

Some free online journals

Blue Sci: *www.bluesci.org*
Blue Sci is a free online science magazine produced by students of the University of Cambridge, UK.

CBE-Life Sciences Education: *www.lifescied.org*
CBE-Life Sciences Education is a free, online, peer-reviewed journal of science education, published by the American Society for Cell Biology.

Frontiers: *http://192.171.198.135/frontiers/*
Frontiers is a free online journal of articles on research projects in astronomy and particle physics funded by the Particle Physics and Astronomy Research Council, UK.

***Nature:* www.nature.com**
Some of the contents of the wide range of *Nature* journals, especially special articles and selected features from the *Nature Reviews* journals (e.g. *Nature Reviews Microbiology* and *Nature Reviews Genetics*) are free online.

New Journal of Physics: *www.iop.org/EJ/journal/NJP*
The *New Journal of Physics* is an open-access, online research journal covering the whole of physics, published by the Institute of Physics, UK and the Deutsche Physikalische Gesellschaft, Germany.

New Scientist: *www.newscientist.com*
Although not all content in this popular science magazine is free to non-subscribers, many of *New Scientist*'s latest articles are.

PLOS Biology: *www.plosbiology.org*
PLoS Biology is a peer-reviewed, open-access journal published by the Public Library of Science (PLoS), a non-profit organisation committed to making scientific and medical literature a public resource.

Plus magazine: *http://plus.maths.org*
Plus is a free online magazine which aims to introduce readers to the beauty and applications of mathematics.

Sci-Journal: *www.sci-journal.org*
Sci-Journal is a free online journal which publishes the work of young scientists. The journal is based at the University of Southampton, UK.

Seed Magazine: *www.seedmagazine.com*
Seed Magazine is popular science magazine; the freely available website includes articles from the magazine as well as other regularly updated content.

The Scientist: *www.the-scientist.com*
Much of the recent content of *The Scientist*, which follows developments in the life sciences, is free online.

Search tools

Google Scholar: http://scholar.google.com
Using the normal Google search engine, you can retrieve all sorts of information – some reliable, some less so. Google Scholar allows you to have more confidence in your results by searching the scholarly literature across many disciplines and sources: peer-reviewed papers, theses, books, abstracts and articles.

PubMed: www.pubmed.org
PubMed is used by researchers in the life sciences to scan the scientific literature, and allows you to search by topic, author, or journal. The results list is linked to the article abstracts; if the complete article is freely available or if you have a subscription to the journal it is published in, you can link to the article.

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Putting the fizz into physics!

Lucy Attwood from Oxford Danfysik, UK, explains the mysterious appeal of champagne.

Champagne, champagne, champagne. It has launched a thousand ships, toasted countless exam results, witnessed millions of proposals and, I'm pretty sure, initiated an innumerable number of headaches!

People have celebrated with champagne (the sparkling wine accidentally discovered in the Champagne region of France) since the 17th century. Practically everybody I know loves it because of its fabulous fizz, and most associate the beverage's quality with the size and quantity of its characteristic bubbles.

So where do the bubbles come from?

During the fermentation process of wine manufacture, yeast reacts with grape sugar to produce alcohol and carbon dioxide gas. In standard wine production, the gas is released, but when producing sparkling wine, the gas is instead trapped under pressure inside the bottle. There it remains, dissolved in the liquid, until a suitably special occasion dictates that the cork should be ceremoniously popped.

Once open, the higher concentration of carbon dioxide in the wine than in the atmosphere results in an imbalance, which reaches equilibrium through the formation of bubbles; bubbles that escape from the liquid until balance is restored. Bubbles, bubbles, bubbles – adding sparkle for the eye and tingle for the tongue.

The bubbles don't just form anywhere, however; they are triggered at points in the glass or bottle where there is a microscopic defect such as a scratch or dust particle. The irregularity, known as a nucleation point, prompts carbon dioxide molecules to come out of solution and create a bubble. The bubble expands as more molecules diffuse into it from the surrounding liquid, which has a much higher concentration of carbon dioxide.

Once the bubble is big enough to have acquired sufficient buoyancy, it detaches from the nucleation point and rises to the surface. Alone again, the irregularity grabs more carbon dioxide molecules from the liquid and another bubble is formed, and another, and so on until you have a steady stream of bubbles rising vertically through your drink.

So next time you're at a party and somebody hands you a rather expensive-looking flute of fizzy champagne, remember... it's probably just a dirty glass!

Try it at home

You can easily demonstrate the formation of bubbles at nucleation sites using salt. The surface of a salt grain is covered with microscopic flaws, which make perfect gathering places for carbon dioxide molecules. Dropping a little salt into a glass of champagne creates hundreds of new nucleation sites, resulting in an impressive display of sparkle.

Important warning: using champagne for this experiment is extremely dangerous and could result in severe damage to the bank balance. Under no circumstances should champagne be used for this demonstration; instead, use beer or another carbonated beverage!

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Science in School aims to promote 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; education research; book reviews; and European events for teachers. An online discussion forum will enable direct communication across national and subject boundaries.

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

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