Autumn 2007 Issue 6

SCIENCE in SCHOOL

In this Issue:

Eyes on the horizon, feet on the ground

Nobel Prize winner Tim Hunt talks about his passion for science

Also:

Highlighting the best in science teaching and research

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www.eiroforum.org

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Cover Image

Chemistry is where life starts by Elena Pascal from Romania, aged 18

Contents

Welcome to the sixth issue of *Science in School*

In our feature article, we share with you the thoughts of Nobel Prize winner Tim Hunt as he talks to Philipp Gebhardt about his passion for science, the importance of pure research, the influence of enthusiastic colleagues – and the role of serendipity in scientific discovery.

Scientific research is important, but some fields of research are seen as more important than others. 'Biodiversity' is now a popular word in the media, but why do we hear so little about the biological wealth of our seas? Iris Hendriks, Carlos Duarte and Carlo Heip investigate. Diversity at a different level is also the key to the work of bioinformatician Nicky Mulder. She is looking at differences between bacterial genomes to find out what makes *Mycobacterium tuberculosis*, the cause of tuberculosis, so dangerous.

An understanding of how mutations arise and spread through populations is fundamental to Nicky's research. This is a surprisingly difficult concept to teach, but Pongprapan Pongsophon, Vantipa Roadrangka and Alison Campbell show how it can be demonstrated with little more than a bag of buttons. However, genetic information does not spread only through populations: Russ Hodge reviews some recent research that demonstrates how important RNA is in communicating information at a cellular level.

Teaching is such hard work; wouldn't it be nice to get outside help? Marc van Mil's DNA labs employ university students to bring genomics (including all the necessary equipment) directly into the classroom. If that sounds too ambitious or expensive, you could follow Sheena Laursen's lead and train keen teenagers to share their knowledge and enthusiasm with their fellow students.

Even students who are less enthusiastic about science can be inspired by a project like Karen Findlay's. She and her students researched, wrote and produced a film about the ethics of a controversial medical condition. Another unusual approach to science education is the 'Imagine' project: Daan Schuurbiers and Marije Blomjous describe how Dutch

school students work with scientists to turn scientific proposals into business plans and make a difference in the developing world.

How far would you go in pursuit of the perfect lesson? Stripped (nearly) naked in a giant freezer, Phil Avery is preparing for an educational trip to the Antarctic. Why not send him your suggestions for sub-zero experiments? From the ends of the Earth to the ends of the galaxy and beyond: Örs Benedekfi takes us on a trip to the stars. In the fourth part of our 'Fusion in the Universe' series, he investigates how a star dies and what a nearby supernova explosion would mean for us on Earth.

In 79 AD, the inhabitants of Pompeii faced a catastrophe of a different kind. In an article linking art, chemistry and physics, Montserrat Capellas explains how modern analyses are shedding light on Pompeii. Gianluca Farusi likewise looks to the past for inspiration, demonstrating the interaction of chemistry, art and botany with a classroom activity to produce mediaeval ink from galls.

Also focusing on chemistry are two very different articles about the effects of chemicals on our bodies. Katie Wynne explains how her research into oxyntomodulin may provide a new therapy for obesity. If you think this doesn't apply to you, why not try Angelika Börsch-Haubold's scented classroom activities: how does the structure of organic compounds affect their smell?

If none of these articles have satisfied your scientific curiosity, help is still at hand: Halina Stanley reviews some of her favourite 'ask a scientist' websites.

Finally, thanks to all of you who completed our online questionnaire. It was very helpful to learn which articles you most liked and why. We also received many useful ideas for future content: watch this space as we follow some of your suggestions!

Eleanor Hayes
Editor, *Science in School*
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Forthcoming events

9-15 September 2007

York, UK

Science festival: The BA Festival of Science

In September, the University of York, the city of York and the surrounding area will experience an explosion of science. From excursions and hands-on family days to debates on current hot topics and unique opportunities to question the UK's top scientists, the BA Festival of Science offers something for everyone.

Schools can be involved through a programme of specifically designed activities for students of all ages, their teachers and their supporters. As Europe's largest celebration of science, it offers the opportunity to find out about latest developments in an exciting and informative way by connecting with a range of scientists, engineers, technologists, museums and businesses. There is also a strand of education events aimed specifically at science teachers. Why not take part in the *Science in School* workshop?

Local UK schools will receive full details and booking information in the summer term. To make sure you are on the mailing list, email or call, mentioning the schools programme.

More information:
www.the-ba.net/festivalofscience
Contact: festival@the-ba.net or
+44 (0)20 7019 4963

9-15 September 2007

CERN, Switzerland

Training course: CERN high-school teacher programme

CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students aged 13-16.

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

This course is for participants from Portugal and takes place in Portuguese.

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

14 September 2007

Universität Kassel, Germany

Workshop: English-language biology and chemistry lessons in German schools

Biology and chemistry teachers who teach in English are invited to a workshop organised by the Verband deutscher Biologen and the Vereinigung der Schulen mit deutsch-englisch bilingualem Zug in gymnasialen Bildungsgängen in Hessen.

Participants who already have experience in bilingual teaching are requested to submit worksheets or teaching ideas for a joint collection of teaching materials. Teachers from outside Germany are warmly welcome. Workshop fee: €10

Contact: Matthias Bohn (mbohnde@aol.com)

14-20 September 2007

CERN, Switzerland

Training course: CERN high-school teacher programme

CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students aged 13-16.

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

This course is for participants from Germany (Baden-Württemberg, Saarland and Sachsen-Anhalt and takes place in German.

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

29 September 2007

Cork Institute of Technology and Blackrock Castle Observatory, Republic of Ireland

Training course: Frontiers of Physics 2007

All teachers interested in physics teaching are invited to attend a day of lectures, demonstrations and workshops for post-primary teachers of physics, organised by the Institute of Physics and the city of Cork. The working language is English and the registration fee is €30.

More information: www.physics.cit.ie/frontiers2007
Contact: Paul Nugent (paulnugent@eircom.net)

10-12 October 2007

European Molecular Biology Laboratory, Heidelberg, Germany

Training course: ELLS LearningLAB

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

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

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

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

18-23 October 2007

Petnica Science Center, Serbia

Conference: Network of Youth Excellence workshop/conference

The Network of Youth Excellence (NYEX) is a UNESCO-sponsored network to share good practice between worldwide initiatives that encourage research possibilities for motivated secondary-school students.

The next conference will have three main topics:

1. Towards successful national policies that support young talents in science
2. Effects of out-of-school science education
3. Professional support for young talents in science – examples of good practice.

To take part in the conference and/or to give a presentation, submit your application by 1 May 2007.

More information: http://nyex.info/58-11706.html
Contact: Vigor Majic (vigor@psc.ac.yu) or Lilla Barabas (secretary@nyex.info)

19-21 October 2007

Plaza del Pilar, Zaragoza, Spain

Science teaching festival: Ciencia en Acción

Ciencia en Acción recognises, promotes and rewards the efforts of teachers of all levels in order to help all students to extend their science background and their appreciation of the role of science.

The festival takes place in Spanish and Portuguese, and is open to science teachers from all Spanish- and Portuguese-speaking countries. Deadline for applications: 5 July 2007.

More information: www.cienciaenaccion.org
Contact: Rosa Maria Ros (ros@mat.upc.es)

31 October – 2 November 2007

CERN, Switzerland

Training course: CERN high-school teacher programme

CERN, the world's largest particle physics laboratory, organises courses for physics teachers who would like to increase their knowledge of particle physics and cosmology, who want to find out more about the world of frontier research, and who wish to bring modern physics into their classrooms. The course materials are aimed at students aged 13-16.

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

This course is for participants from France and takes place in French.

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

2-3 November 2007

European Molecular Biology Laboratory, Heidelberg, Germany

Conference: 8th EMBO/EMBL Joint Conference on Science and Society

Teachers and their students are invited to attend this year's EMBO/EMBL Joint Conference on Science and Society entitled 'The future of our species: evolution, disease and sustainable development'.

The four sessions of the conference cover:

- Emerging, re-emerging and persistent diseases
- Global sustainability and biology
- Treatment and enhancement
- Human evolution: once we were apes.

The conference fee is €40 (€20 for students).

More information: www.embo.org/scisoc/conference07.html
Contact: scisoc@embo.org

19–25 November 2007

Schwerin castle, Germany

Science fair: SWEETS science forum

The Space Weather in Europe – An Educational Tool with the Sun (SWEETS) project aims to raise public awareness of weather in space. During European Science Week, activities will take place in 27 European countries, including a space-weather mobile truck tour, a web quiz, festivals, a rocket and balloon campaign and a space-weather film. The main festival will take place at the castle in Schwerin, Germany.

More information: www.sweets2007.eu
Contact: info@sweets2007.eu

19–25 November 2007

Porto, Portugal

Science fair: Thunderstorms in Space Weather

As part of the Space Weather in Europe – An Educational Tool with the Sun (SWEETS) project, the Centro de Astrofísica da Universidade do Porto, Portugal, will organise a science fair featuring the planetarium show 'Thunderstorms in Space Weather', where members of the public can make solar observations with telescopes, join a workshop to make a sun clock or take part in many other activities.

Young visitors receive the Portuguese version of the ESA *Starlight* colouring book.

More information: www.astro.up.pt
Contact: Ricardo Reis (ricreis@astro.up.pt)

Until 30 November 2007

Italy, Austria and Switzerland

Competition: Junge Forscher gesucht! – Giovani ricercatori cercansi! (Wanted: young researchers!)

In this search for talented young researchers, young people are required to develop scientific projects on many topics, including art and music. Regional finalists, selected on the basis of a report they submit, present their project to an international jury and the public. Prizes of €1500-3000 are awarded.

The competition is open to people aged 16-20 living in South Tyrol (Italy), Trentino (Italy), Tyrol (Austria) or Grisons (Switzerland) and is held in the regional languages German and Italian.

To enter the next competition, register before 30 November 2007. The final event will take place in March 2008 at the University of Innsbruck in Austria.

More information: www.explora-science.net/wettbewerb

Until 12 December 2007

Many UK venues

Lectures: Institute of Physics schools lecture series 2007

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

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

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

More information: www.iop.org

23-26 October 2008

Berlin, Germany

Science teaching festival: National Science on Stage festival

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

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

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

All year

Schullabor Novartis, Basel, Switzerland

Workshop: 'Gentechnik Erleben' (Experience Genetic Engineering)

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

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

More information: www.schullabor.ch
Contact: gesche.standke@novartis.com

All year

Schools and other venues in England

Roadshow: Cool Seas

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

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

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

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

All year

10 locations around the UK

Training courses: Science continuing professional development

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

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

All year

Glasgow Science Centre, Glasgow, UK

Free teacher visits

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

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

All year

Many Scottish venues, UK

Roadshow: Science Circus

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

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

All year

Pembrokeshire, Wales, UK

Field trip: Rockpools

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

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

All year

Pembrokeshire, Wales, UK

Workshops: Primary school

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

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

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

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

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

All year

Paris-Montagne, Paris, France

Science Academy

Throughout the year, Paris-Montagne runs an outreach programme in all Parisian suburbs. The programme is for high-school students interested in sciences but not confident enough to enrol in undergraduate studies, due to social and cultural hindrances. The organisation offers personal tutoring and the possibility to discover the world of research by meeting researchers in various fields and by carrying out their own research in real laboratories during their holidays (100 in April 2007, and many more expected in August and October 2007). The most dedicated participants in the programme are offered the chance to take part in a summer camp during the Paris-Montagne science festival (21-25 July 2007).

More information: www.scienceacademie.org

All year

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

Free teacher previews

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

More information: www.intech-uk.com

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

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

Eyes on the horizon, feet on the ground: interview with Tim Hunt

Image courtesy of Ed Swinden

Tim Hunt

Professor Tim Hunt, winner of the 2001 Nobel Prize in Physiology or Medicine, talks to **Philipp Gebhardt** about his passion for science, the importance of pure research, the influence of enthusiastic colleagues – and the role of serendipity in scientific discovery.

In 2001, Tim Hunt was awarded the Nobel Prize in Physiology or Medicine together with Leland Hartwell and Paul Nurse 'for their discoveries of key regulators of the cell cycle'[w1].

Multicellular organisms develop from a fertilised egg by a process of many cell divisions. During the life of the organism, individual cells die and are replaced by the process of cell division. There are several events that must occur in a eukaryotic cell before it can divide into two daughter cells. This series of phases – including the replication of the genome, cellular growth and the segregation of the chromosomes – is the process known as the cell cycle (see images).

All the steps in the cell cycle must be tightly controlled to avoid damage and subsequent developmental abnormalities, such as the formation of tumours. Control takes place at 'cell cycle checkpoints', points at which cellular mechanisms can intervene if something goes wrong. Tim Hunt discovered that the passage through the cell cycle checkpoints requires cyclins, newly discovered proteins that are synthesised just before each checkpoint and destroyed immediately after the checkpoint has been passed. The cyclins themselves activate other proteins, kinases, that enable cells to pass into the next stage of the cycle. His work has major implications for biology and medicine, especially in understanding how cells form tumours. He currently works at Cancer Research UK[w2].

What made you want to study biology?

I think it was largely the influence of my school. I decided to be a biologist when I performed particularly well in a school biology exam at the age of eleven. We had a very good science teacher and I looked forward to science lessons very much; they were much more interesting than the Latin and Greek that we mostly did. I wasn't very good at physics, but biology required no effort. I also had a very good chemistry teacher later on, so going to university to study biochemistry – this is in the late 1950s – was very natural. I never really had to make any decisions; I was just doing what I liked and found fascinating.

It was quite a shock when I went up to university, because there I found there were people who knew much more than I did, who understood much more than I did and who were much cleverer than I was. *[Laughs]* Then I found that actually I could hold my own, and again I did well in the exams. I was able to take the courses I wanted: I explored a little bit and dabbled in psychology, for example. I found it interesting but I was no good at it. The whole point of education to me is to find out what you like and what you are good at. Then it doesn't feel like work any more – you just do it. It's fun!

All young scientists learn that well-planned experiments are crucial for successful research, but sooner or later we also discover that every

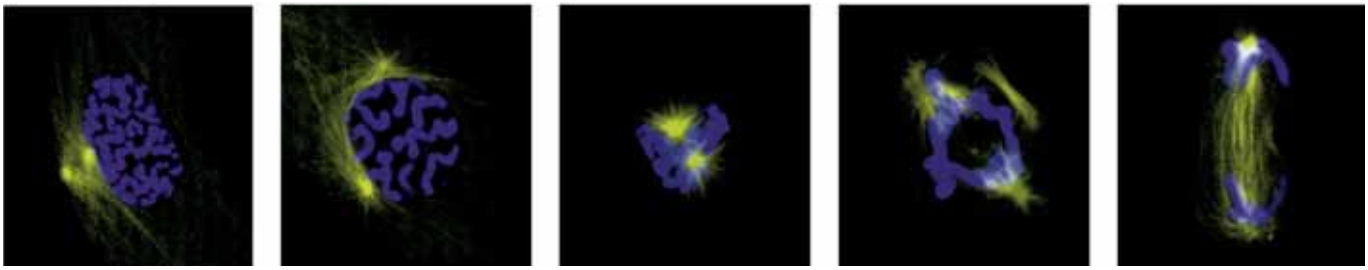

Image courtesy of Jan Ellenberg

A live mammalian (kangaroo rat) cell going through the different stages of the M-phase in the cell cycle. From left to right: prophase, prometaphase, metaphase, anaphase, telophase. DNA (blue) and microtubules (yellow) are labelled with fluorescent proteins or vital dyes respectively

experiment also needs good interpretation. Often the results are totally unexpected and that's where the real work starts…and often serendipity comes into play. What role did serendipity play in your research career?

Oh, a major role…again and again and again. The first real discovery I made when I was a graduate student, and some colleagues and I were trying to find out whether ribosomes were uniformly distributed on messenger RNA. This involved running sucrose gradients, experiments that took quite a long time. Once we went out for lunch while the experiment was running and stayed out a bit too long. But still, being lazy, we analysed the result. As a result of that piece of laziness, we discovered something new that we'd never have discovered otherwise! We found that there were fewer ribosomes on the messenger RNA making alpha chains than making beta chains. That was my first paper in *Nature*! In those days, there was no pressure to publish; we just thought it was an interesting result, so we sent it in. It was quite an important result, but it was complete accident, an utter piece of serendipity – just an experiment that was left a little bit too long.

I must say that we then misinterpreted the finding and did other experiments in which we didn't do proper controls, so we got the answer wrong. A good friend, Harvey Lodish, later corrected us and provided the correct interpretation. That was the big lesson: serendipity shows you something that you didn't suspect, you try to figure it out with 'well-planned experiments', you misinterpret the experiments, a colleague sets you right…. It's fun and it's a good learning experience.

How should a team leader preserve and foster the creativity of his or her co-workers?

I am not too keen on leaders, actually; I prefer a loose confederation of people. Sustaining people's morale and enthusiasm is tremendously important and I am not so sure how good I am at that. You have to be so critical of yourself and of the people around you; often they take that very hard. The truth is that it's very, very difficult to find things out. And unless you are extraordinarily self-critical, you get ideas that are wrong and because you love the ideas so much, you are not prepared to disprove them.

It's much easier when you are working with your peers. There's a famous interview with James Watson and Francis Crick – "Why did we succeed and the others not"; Francis Crick said that one of the reasons was that they could be really frank with one another and not take it personally: "That's a bad idea. It was your idea, but it's still a bad idea and you have to look for a better idea." But it can be very crushing when someone more senior tells you that.

How has your research career evolved?

Well, I suppose my career has evolved. *[Laughs]*. My friends and I somehow always had the money to carry on – but not very much money. When I returned from America to England, my salary dropped fivefold! We were very poor and had to worry about whether there was enough to eat, but we were having so much fun. We were in a wonderful, vibrant, intellectual environment; we were finding things out and that was more important than a career. The freedom to have a grant just to do research is a wonderful blessing. For about ten years, I never had more than three years tenure at a time and the same is true for some of my most successful friends. You have no responsibilities, you can go anywhere in the world, do anything you like. But you do have to find something out, otherwise people won't give you the next grant. Then I got a job and that was the end…. *[Laughs]*

I often say to people 'I am so glad I am not twenty-something anymore'. I think it's a lot harder now than it was when I started out. In my particular field, so little was known that almost any stone that you turned over had something interesting crawling out

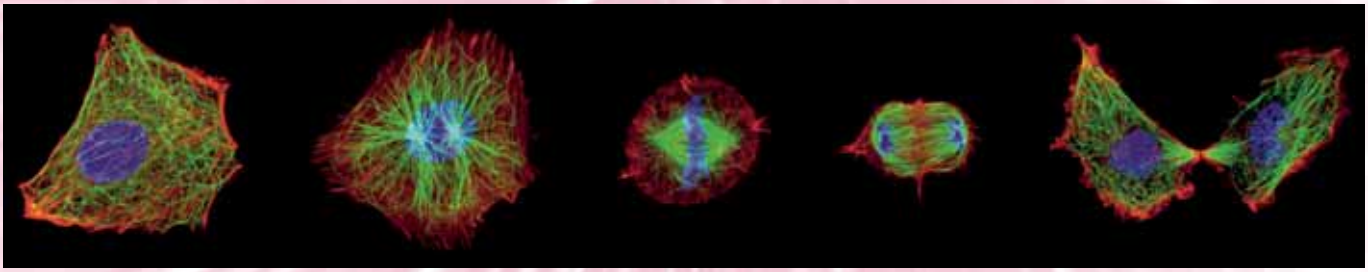

Image courtesy of Jan Ellenberg

Fixed mammalian (rat) cells in different stages of the M-phase in the cell cycle. From left to right: interphase, prophase, metaphase, anaphase, cytokinesis. DNA (blue) and microtubules (green) and actin filaments (red) are labeled by fluorescently labelled antibodies or dyes respectively

from under it. I think that's harder now in biology.

What are you researching now?

I am working on a couple of questions about cell-cycle control. We discovered that cell-cycle transitions are catalysed by protein kinases, but the question now is how many proteins do these kinases have to phosphorylate, and to what degree, for cells to enter mitosis? And what about the control of the phosphatases that reverse the process? That turns out to be a very difficult problem; we have been struggling with it for several years and I don't know whether we will ever come to a satisfactory conclusion. The other very interesting thing is that the protein that I discovered – the cyclin – is distinguished by an abrupt disappearance and we still don't really understand what the mechanism is.

It is a very competitive field but it's good fun. It's also difficult: it has been a decade since we found the underlying mechanisms but we still don't really understand how it works. I think I'll probably still be puzzled when I retire – whenever that may be.

You still sound very excited about your research.

It comes and it goes, I must admit. When I won the Nobel Prize, I thought that maybe it was time to stop. You know that it's exceedingly unlikely that you will ever make such a great discovery again, so why not just stop? Stop and try to help other people.

For a while, I involved myself in lobbying for the European Research Council, for example – something I am passionate about. Ultimately, though, I found that the only thing I am really good at is doing experiments, and the fun of working in a lab and finding things out came back. So that's what I am doing now.

Image courtesy of the US National Oceanic and Atmospheric Administration/Department of Commerce

Sea urchin

[Eggs and oocytes from the African clawed frog *Xenopus laevis* have become an important tool in biological research. These relatively big cells can be manipulated easily and are used for the study of developmental processes. In molecular biology they provide a controlled system for the expression of manipulated proteins. Tim Hunt and his colleagues used these frogs' eggs to analyse the proteins that play a key role in the complex network of cell-cycle regulation. They not only showed that this regulatory system, identified previously in the eggs of sea urchins

and clams, exists in the cells of vertebrates but also characterized the other molecules involved.]

Paul Nurse, with whom you shared the 2001 Nobel Prize, once said that "good science is carried out by creative individuals working within a scientific society which is socially interactive, with lots of freedom to follow their scientific ideas." The public supports this because they expect something back, such as improvements in health or wealth. How would you explain the social benefit of research on frogs' eggs to a non-scientist?

It isn't easy! I think one almost has to justify it as a cultural activity: it's better to know things and if you know things, it's very, very beautiful.

Also, the benefits of pure research are often quite unexpected. Apparently, Michael Faraday was demonstrating electricity to an audience in the 1830s and a woman asked him, 'Of what use is your discovery of electricity?' Faraday is supposed to have said, 'Madam, of what use is a newborn child?' I feel rather like that about my *Xenopus* research. When Faraday discovered electricity, the transformation that it has made to our society cannot have been foreseeable. He was just finding out about the way the world works, and I think it's the same with working on frogs' eggs.

Where do you see the strengths of the European research society compared with others, for example, in the USA?

I worry about the European research effort compared with the US research effort. Somehow, the Americans are so much more successful at engendering and sustaining a vibrant and creative research ethos. It's partly because they have tons more money – although people sometimes deny that. I think they have an amazing openness to new ideas and a kind of celebration of pure research in many quarters – not just by scientists. If you go to any American university,

Image courtesy of Tomasz Sienicki

Sea urchin

you will find that the buildings were put up by wealthy local people. That sort of thing doesn't happen in Europe so much.

European universities are in a very bad state of repair in general. It's a shocking thing that American universities seem, by any criteria, to be among the most successful: 15 out of the 20 top universities in the world are in the USA! You would expect to find the University of Paris and the University of Berlin up there in the top league – but they are not. I think we should ask ourselves very carefully why not and whether there is something that we can do to change that.

In your opinion, is the European Union taking the right measures to move European science forward?

I am very optimistic that the formation of the European Research Council will help. I think, in the past, the emphasis has been too much on practical benefit – with agriculture, with medicine, with technology and so forth. I am a great believer in having a vibrant pure research community because that produces bright, creative individuals who will be successful in whatever they ultimately do. I am not saying that all scientists should be pure researchers for their entire lives, or that the entire research effort should be pure research – obviously not. But I do think that, in Europe, there is not enough emphasis placed on having universities that allow creativity and fun, and value the importance of just understanding. We are too obsessed with the utilitarian justification for science and not enough with the joys of science for its own sake.

Please complete the following sentence: "The best place to do research…"

…is in a place where lots of other very smart people are doing research. I was very happy in Cambridge because it had such a strong tradition of excellence in research. It was a little bit intimidating – you were well aware you were no Newton. On the other hand, the fact that so many fantastic scientific discoveries had been made in this funny, rather boring, town was quite important: science was the most interesting thing you could do.

What advice would you offer people at the start of a research career or considering it as an option? What are important attributes to have?

I think, mainly, you just need curiosity and to enjoy finding things out. You've got to want to know. It is not an ordinary career and it isn't ordinary work.

Role models are important, too. When I started at Cambridge, there were many Nobel laureates around and they had been spectacularly successful at understanding the way that cells work. That was very helpful because you actually knew these guys, you sometimes sat at lunch with them, and you could see that they were the best you could possibly be at science and yet they were human beings. They could make stupid remarks; they weren't omniscient. It gave one some hope that one's own modest efforts might succeed.

Image courtesy of EMBL Photolab

Sea urchin

And one last sentence to complete: "Receiving the Nobel Prize changed my life in a way that…"

… I didn't foresee. I think the main difference is that I've become a much more self-confident person.

Web references

w1 – An overview of the cell cycle and details of Tim Hunt, Leland Hartwell and Paul Nurse's work is given in the press release announcing their Nobel Prize: http://nobelprize.org/nobel_prizes/medicine/laureates/2001/press.html

To learn more about the cell cycle, play the 'Control of the Cell Cycle' game on the Nobel website: http://nobelprize.org/educational_games/medicine/2001/

For more information about the Nobel Prize, including biographies of the Prize winners, see http://nobelprize.org/

w2 – Cancer Research UK is the UK's leading cancer charity: www.cancerresearchuk.org

Resources

The audio file of the complete interview is available here: http://onlinesymposium.predocs.org/media/career-development-session/timhuntinterview/index.html

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Philipp Gebhardt is a PhD student at the European Molecular Biology Laboratory in Heidelberg, Germany, studying proteins involved in the dosage compensation phenomenon. This is a process that ensures that the gene products of the sex chromosomes are produced at the same rate in males and in females. Otherwise, females (with two X chromosomes) would produce twice the quantity of gene products encoded on the X chromosome as males (with only one X chromosome).

REVIEW

Nobel Prize winner Tim Hunt shares his personal experiences and reflections on science, its utilitarian applications, its role in our developed society and especially its cultural value and beauty.

Isabella Marini, Italy

Public domain image; Image source: Wikimedia Commons

Frescos at the Villa dei Misteri, Pompeii, by a Pompeian artist around 40 BC

Recovering Pompeii

Do your students find it hard to see the application of science to other subjects? **Montserrat Capellas** from the European Synchrotron Radiation Facility in Grenoble, France, explains how modern chemical analyses are shedding light on ancient Pompeii.

Artists in ancient Pompeii, Italy, painted the town red 2000 years ago with a brilliant crimson pigment that dominated many of the doomed town's wall paintings. On 24 August 79 AD, the volcano Vesuvius erupted, burying nearby towns in pumice and ash. Instead of destroying Pompeii, however, it preserved it and the bodies of its inhabitants under the earth. Included in the World Heritage List by UNESCO in 1997, the ancient town of Pompeii is now the most visited archaeological site in Europe.

The Villa Sora, in the nearby town of Torre del Greco, remained buried until 20 years ago, when excavation works revealed the building. Since the discovery of the remains of the house, the distinctive red colour of the wall frescoes has turned black in many places, in a rapid degradation process that is not yet well understood scientifically. The source of the red colour in Torre del Greco and Pompeii is mercury sulphide (HgS), commonly named cinnabar. This is a deep red pigment used extensively to cover the background of paintings, giving a uniform red background to pictures. Yet, in certain circumstances, it can become unstable, turning into dull grey-black shades.

Scientists have been wondering for many years why the red walls in Pompeii were turning black. As early as the 1st century BC, Vitruvius, in his treatise *De Architectura*, mentioned the problem, and gave the recipe for a sort of protective varnish based on Punic wax (a waxy soap made of beeswax and soda lime): "Those who are desirous that the vermilion should retain its colour, should, when the wall is coloured and dry, rub it with a hard brush charged with Punic wax melted and tempered with oil: then, with live coals in an iron pan, the wall should be thoroughly heated, so as to melt the wax and make it lie even, and then rubbed with a candle and clean cloth, as they do marble statues. The coat of Punic wax prevents the

Public domain image; Image source: Wikimedia Commons

The Last Day of Pompeii (1827-1833) by Karl Pavlovich Briullov

effect of the Moon's as well as that of the Sun's rays thereon which injure and destroy the colours in work of this nature."

Despite the Punic wax, ancient Pompeian walls have lost their colours in recent years. The most common explanation is that the exposure to the Sun transforms cinnabar into another phase (in which the same atoms, mercury and sulphur, are arranged differently), metacinnabar, which is black. However, the causes and mechanisms have remained a mystery and conservators have been losing a race against time to prevent the degradation – until now.

New results

A Franco-Italian team of researchers studied four samples of wall paint from Villa Sora using the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, to monitor the chemical processes taking place in the walls. The samples of wall painting were taken from both altered and unaltered areas and submitted to microanalyses to shed light on this dramatic blackening.

The team identified the elements present in both well preserved (red) and altered (grey-black) samples. In addition to the sulphur and mercury originating from the pigment, and the calcium present as calcite in the mortar, they detected low levels of other elements, including aluminium, silicon and potassium. However, the most interesting element found was chlorine, which could provide answers to the mysterious blackening process.

By mapping micro X-ray fluorescence signals (see box) over red, grey or black surfaces, scientists were able to directly correlate the distribution of elements to the visible appearance of paintings. This technique is often used on paintings, but normally employs electron microscopy rather than the more sensitive synchrotron analysis. The synchrotron elemental mapping of one of the samples

X-rays as a tool to study Pompeii

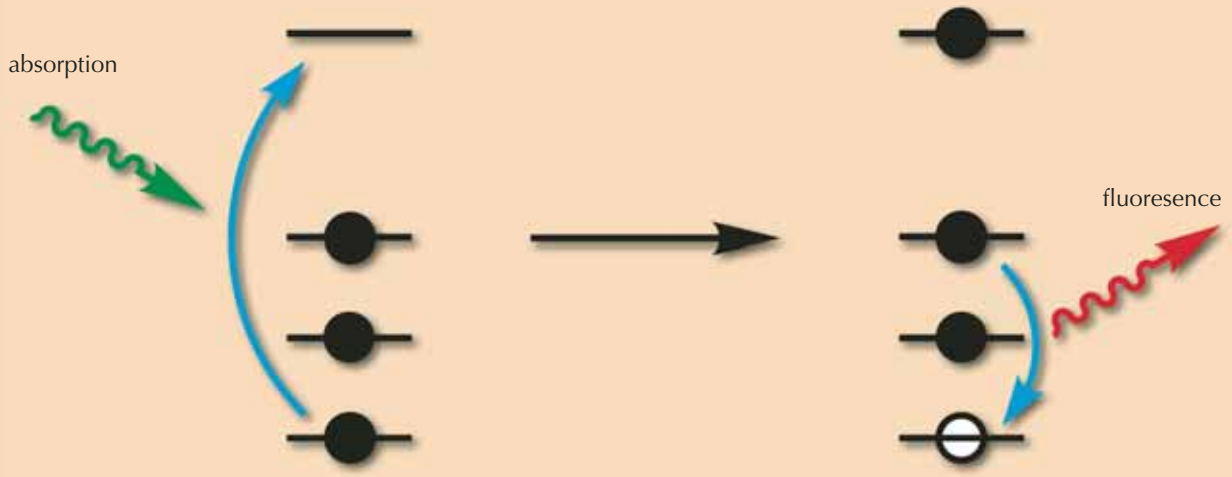
The experiments performed at the ESRF needed a very small (from 100 µm to less than 1 µm) and intense beam of X-rays to detect low concentrations of elements and to provide detailed chemical information. They were performed on the X-ray microscopy beamline (ID21) by combining the techniques of micro X-ray fluorescence mapping and micro X-ray absorption spectroscopy. The former was used to detect the presence of chlorine and sulphur, the latter to identify their speciation, i.e. the way they are bound to other atoms. Below are simple explanations of X-ray fluorescence and spectroscopy, which may be suitable for younger school students.

Principle of X-ray fluorescence

A simple way to understand the principle of X-ray fluorescence is to consider that atoms (the small elements that compose matter) are like houses, with occupants which are named electrons. These occupants are quite lazy, and do not like to live on high floors. So, they will first occupy the ground floor; when there is no more room there, they will occupy the first floor, and so on and so forth. As in life, there are small houses (small atoms, with few electrons) and big houses (big atoms, with many electrons).

The principle of X-ray fluorescence is to shine X-ray light on these atoms. This light will behave like a lift in the house that transfers the electrons living on low floors to floors higher up the house; this process is called 'absorption', as light is absorbed by the atom (the electron is absorbed by the lift). As these electrons depart, some empty space will be available on these low levels. Consequently, electrons living higher are quite happy to move downstairs. During this transition, they will express their happiness by emitting some light, or fluorescence. In a small house, the transition will be small, so the shout of joy will be small, whereas in a big house, some transitions – and the corresponding shouts of joy – may be large. By measuring the fluorescence signal (the energy of fluorescence, which is the distance between the departure and arrival floors), one can distinguish small and big atoms, and more precisely, identify each atom according to its characteristic shout of joy.

Image courtesy of Calvero; image source: Wikimedia Commons



Electrons absorb X-ray light and move to a higher energy level (left). When electrons move to a lower energy level, they release energy in the form of fluorescence (right)

BACKGROUND

Principle of X-ray spectroscopy

This method is based on the variation in the X-ray energy of the light needed to excite the atoms, which corresponds to the height of the lift. Let us imagine that the atom is illuminated with a low energy, i.e. that the house has a small lift that goes only from the ground floor to the first floor. If both these floors are full, no electron from the ground floor will take the lift as there is no free space for it on the first floor. There is thus a condition that must be satisfied before an electron can take the lift (or an atom can absorb light): the lift height must be sufficiently large to enable the transition from low floors to higher, empty floors. For example, a lift that is higher than the height of the house will always lead to absorption.

There is a critical case where the lift is just sufficient to lead electrons to the garret, or attic. In fact, electrons prefer to go to the garret rather than being completely thrown out of the house. So the probability of an electron taking the lift to the garret is higher than the probability of it going outside. By measuring the absorbance, we measure the probability that an electron takes the lift. For each lift height (X-ray energy), the absorbance is measured. The reason that scientists are interested in electrons travelling to the garret (being excited to the highest energy level without leaving the atom) is that the height of the garret tells us about the chemical environment of the atom.

In other words, let us consider a lonely house. We can identify this house using fluorescence. Now, let us suppose that this house is surrounded by other houses (atoms). Some connections will be created between them, such as footbridges, on top of the houses. To accommodate a safe footbridge, the house will be slightly rebuilt, changing the level of the garret somewhat in each house. The result is that the garret height depends on the surrounding houses (which houses are in the neighbouring area, how far away they are, and so forth). By measuring the height of the lift to the garret, we can deduce the nature of the footbridge, and consequently the chemical environment of the house (what other atoms surround it, for example). This process is called atomic speciation.

Image courtesy of Mario Pagano

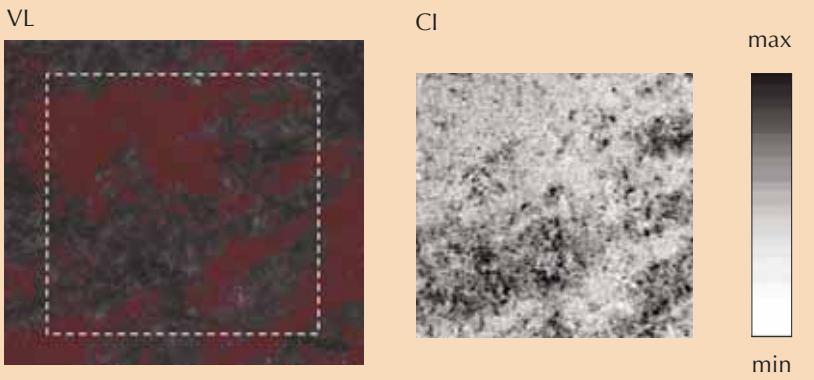
A wall showing the heavy damage due to blackening of cinnabar in the Poppea's villa in Oplonti

showed that the chlorine distribution perfectly matched a grey debased patch. Chlorine was found to be associated with sodium and mercury, showing that chlorine has reacted with the pigment and that common salt (NaCl) was involved in the degradation process.

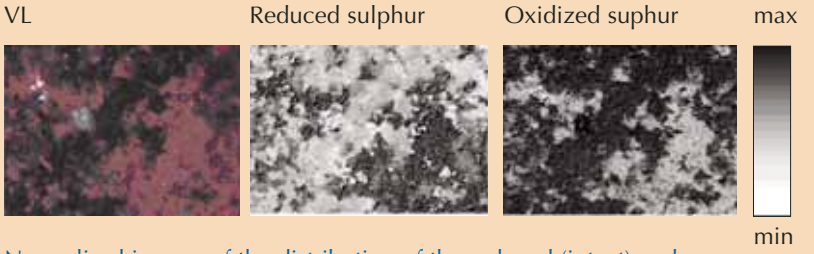
Chlorine is known to cause cinnabar to darken in the presence of light. Researchers speculated that the chlorine in the paintings could originate from two sources of salt. First, as Pompeii and Torre del Greco lie by the sea, the paintings were likely to have absorbed salt from the air. Ironically, the second source of salt could be the 'protective' Punic wax, which according to Pliny the Elder was made using seawater.

What does it all mean?

So far, the ESRF findings had confirmed the traditional explanation: that the red cinnabar was transformed to the black metacinnabar. Analyses of another, darker, part of the painting, however, revealed a high accumulation of sulphur in areas where chlorine was not present. The speciation, or chemical environment, of the sulphur was investigated to discover what the surrounding atoms were. This was important, because although cinnabar and metacinnabar have the same composition (Hg and



Visible light (VL) microscopy image and atomic distribution of chlorine of one of the samples with moderate alterations (obtained by micro X-ray fluorescence with an exciting beam of 3.9 keV)



Normalised images of the distribution of the reduced (intact) and oxidised (altered) sulphurs on the most degraded sample (8 x 7 mm^2)

S), they can be distinguished by their different atom arrangements. This analysis refuted the hypothesis that cinnabar had undergone a phase transformation into metacinnabar: no metacinnabar was detected at all.

To the scientists' surprise, they found another compound instead: calcium sulphate, also known as gypsum. This was the sulphurous compound found in the black regions where there was no chlorine. So, instead of a simple phase transition, sulphur had been subjected to a real oxidation, transforming from a reduced sulphide (S(-II)) to an oxidized sulphate (S(+VI)) state. Most probably, gypsum ($CaSO_4.2H_2O$) resulted from the reaction of sulphur dioxide (SO_2) in the air with the calcite ($CaCO_3$) in the mortar:

$$SO_2(g) + CaCO_3(s) + 2H_20(g) + {}^1/_2\, O_2 \rightarrow CaSO_4.2H_20(s) + CO_2$$

This explanation is supported by the fact that chlorine can catalyse the linkage reaction

$$HgS \rightarrow Hg + S$$

by which cinnabar dissociates into mercury and sulphur in the presence of light, providing a source of sulphur for further reactions with oxygen in the air and the subsequent formation of SO_2. Thus although the second, darker, patch contained sulphur without chlorine, the chlorine in other areas (such as the first, grey, patch) had been sufficient to generate sulphur dioxide which degraded the pigment in other areas.

Thus the synchrotron analyses cast doubt on the traditional theory, that the red cinnabar pigment degraded directly into metacinnabar in the presence of light, and supported the more recent theory that cinnabar dissociates in the presence of chlorine to produce sulphur, which then (in the form of sulphur dioxide), reacts with the calcite in the mortar to form calcium sulphate. This reaction is favoured by the presence of HgS in the pigment, explaining why areas that were not painted with red cinnabar pigment were not discoloured.

Cross-sectional studies

The scientists looked further and investigated the cross-section of one of the samples to map the depth of alteration in the painting. A sample was embedded in resin and polished perpendicularly to the painted layer. In this way, all the layers of the painting, from the mortar to the surface, were accessible. The scientists realised that the degraded layer, containing oxidised sulphur species and sulphates, was only around 5 μ thick and that beneath the surface, the cinnabar had remained intact.

These ancient paintings were frescoes, in which the paint was applied to wet plaster, allowing the pigment to sink in, giving a pigment layer of around 100 μ. The cross-sectional study, therefore, provides two types of information. First, it made it possible to distinguish those elements present in the original painting (calcium, mercury and sulphur) and those which came from the environment (potassium, silicon, aluminium, chlorine and gypsum). This was important, as gypsum itself was sometimes used in the mortar; as it was detected only in the surface layers, it had clearly not been used in the mortar for these paintings. Second, the cross-sections showed that the colour degradation was limited to a very superficial layer, offering hope that the paintings can be restored to their full, colourful glory.

"The research carried out at the ESRF has an extraordinary importance not only for conservation of wall paintings of Villa Sora, but in general for preservation of Roman

wall paintings discovered in the most important Roman archaeological sites [such as Pompeii and Herculaneum]," explains Corrado Gratziu, a member of the research team, and a professor emeritus in geology at the University of Pisa, Italy, who specialises in petrology of sedimentary rocks.

Future research

Despite having refuted the classical explanation of cinnabar blackening, the research into the ancient red pigment is far from finished. The complex pathway involving the reaction of both chlorine and sulphur dioxide has raised new questions. "The chemical distribution of the samples is not uniform, which means that atmospheric conditions probably play a role in this change of colours," explains Marine Cotte, one of the researchers. "The Sun surely influences this process, but the rain may possibly do too," she adds. "Sunlight accelerates some reactions, while rain can wash the painting and dissolve the more soluble compounds." Atmospheric contamination or bacterial activities may also contribute to sulphation mechanisms.

The next step for the team is to examine more samples, not only from frescoes in the archaeological site but also from those already excavated and on display in museums. "In this way, we have more data and can compare the results between paintings exposed to different atmospheric conditions and better establish the causes for their degradation," explains Marine.

Resources

Cotte M, Susini J, Metrich N, Moscato A, Gratziu C, Bertagnini A, Pagano M (2006) Blackening of Pompeian cinnabar paintings: X-ray microspectroscopy analysis. *Analytical Chemistry* **78**: 7484-7492. doi:10.1021/ac0612224

REVIEW

This article is particularly suitable for teachers looking for new ideas to show their pupils the importance of chemistry and physics in different fields (e.g. archaeology, heritage conservation,…) and for secondary school students fascinated by the study of antiquity. In a plain style enriched by precise chemical information and illuminating metaphors on electrons' behaviour, the reader can discover how modern investigators solve mysteries about 2000-year-old materials and technologies.

Recovering Pompeii can be used in the classroom to address different science topics (chemistry: atomic and molecular structure, redox, catalysis; physics: atomic structure, electromagnetic radiation; earth science: meteorology, volcanism) as warm-up activity to raise interest in the applications of scientific research. It can be exploited as background reading before a visit to an archaeological site or to research facility like a synchrotron radiation plant. The article is also suitable to test students' comprehension of language and scientific content.

For example, the following questions could be posed:

1. The colours of the studied frescoes were:
   a) red, grey and green
   b) red, brown and grey
   c) red, grey and black
   d) red, black and brown
2. Which of the following compounds does not contain sulphur?
   a) cinnabar
   b) calcite
   c) metacinnabar
   d) gypsum
3. Choose the correct statement about the study of frescoes by means of X-rays:
   a) X-ray fluorescence measures light absorption and X- rays spectroscopy measures emission
   b) X-ray fluorescence measures light emission and X- rays spectroscopy measures absorption
   c) both X-ray fluorescence and X- rays spectroscopy measure light emission
   d) both X-ray fluorescence and X- rays spectroscopy measure light absorption

Teachers could use the article to discuss;

- the role of chemistry and physics in different fields (research, industry, heritage conservation,...)
- the importance of team work in research as well as in other situations
- the interdisciplinary approach of modern archaeology.

Finally this material could be very useful to start an interdisciplinary project linking science and humanities, to help students understand the underlying unity of culture.

Giulia Realdon, Italy

Of Roman roads, train yards and inspectors: recent discoveries in RNA research

RNA is a crucial biological molecule that is seldom mentioned in detail in textbooks. In the first article in a series, **Russ Hodge** describes some exciting recent research on RNA.

Detlev Arendt, Peer Bork and Florian Raible looking for the fastest and slowest evolvers

Image courtesy of EMBL Photolab

Often the same RNA can be spliced into alternative forms, creating messenger RNAs that will be used in the synthesis of different proteins. Splicing involves removing non-coding sequences called introns – sometimes also removing coding sequences called exons. The loss or inclusion of an exon creates different forms of the protein that may have dramatically different effects on the cell

Image courtesy of EMBL Photolab

Imagine a Roman in ancient times, standing on a summit, surveying the landscape as he plots the course of a new road. Two thousand years later his roads are still visible as they cross European cities and the countryside, as straight as if drawn by a ruler, deviating only in the face of the most stubborn obstacles. In the 1950s and 1960s, scientists mapped out a similar sort of route for biology as they described the connections between different types of molecules in the cell.

Their plan is known as the *central dogma* of molecular biology: "DNA makes RNA makes proteins," as James Watson scribbled in one of his notebooks when he and Francis Crick began their assault on the structure of DNA. With the dogma, the two men proposed a new relationship between the cell's major kinds of molecule – a one-way flow of information from nucleic acids to proteins. Soon after their discovery of the double helix, Crick gave lectures in which he presented the dogma as a grand research plan for molecular biology (Crick, 1970): scientists should devote themselves to uncovering the exact cellular mechanisms underlying the transformations.

By the 1970s, the basics of how RNAs and proteins were created were understood, but it was becoming obvious that a single straight road could not describe the chemistry of the cell. Just as a score of modern side-streets branch off those ancient Roman roads, many deviations have been found on the route between genes and proteins. At first these seemed to be rare exceptions to the dogma; in the meantime, they have been recognised as common and crucial in most biological processes in complex organisms. Some of the findings are so new that they have not yet made it into textbooks and may be unfamiliar to teachers. This article is the first in a series for *Science in School* that will discuss some of this recent research.

Some of the most exciting findings involve RNA, once thought to be little more than a means to an end in making proteins. Over the last decade these molecules have come to be seen as crucial players in the cell's control of the information in its genome. Understanding how RNAs are handled has led to insights into disease and powerful new kinds of biotechnology, including efforts to use RNAs in therapies to counteract the effects of defective genes.

Alternative splicing

The RNA of the central dogma is *messenger RNA*, which serves as a template for making proteins. In eukaryotes, the RNAs usually have to be processed before achieving the messenger form. Most freshly made RNAs are like long trains with many boxcars (freight wagons), whose cargo needs to be sorted to fit the needs of different customers. Empty cars are detached, and the cars in front and behind are rejoined. The cellular parallels of the empty cars are called *introns*, large regions within genes that do not encode proteins. Protein-encoding DNA sequences are called *exons*. Often one exon contains the recipe for one module within a protein. Even these are not always used. A customer might not want all the wares on a train, so some of the boxcars that contain cargoes may be removed along with the empty ones. And a cell might not need all of the modules of a particular protein, so various exons might be combined to produce different forms.

This process, called *alternative splicing*, was discovered independently in 1977 by Richard Roberts of New England Biolabs, USA, and Phillip Sharp of the Massachusetts Institute of Technology, USA (Berget et al., 2000). The finding was so significant that it earned them the Nobel Prize in Physiology or Medicine in 1993[w1]. At the time splicing was thought to be rare; Sharp estimated that only about 5% of human genes were likely to undergo alternative splicing. The complete human genome sequence has revealed that the average gene contains 8.4 introns, all of which have to be removed through splicing. Although some human RNAs are probably always spliced the same way, scientists now estimate that at least 75% undergo alternative splicing.

Human genes have considerably more introns than those of most other organisms; the average for flies and other insects lies between 2.4 and 5.4

introns per gene. (Even so, the current world-record holder for alternative splicing is a fruit fly gene called *dscam*, which can generate 38,016 distinct proteins.) Some researchers believed that the high number of human introns meant that genes were becoming more complex over time. However, a recent study by the groups of Detlev Arendt and Peer Bork at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, shows that the ancient common ancestor of insects and vertebrates almost certainly had genes more like those of humans, with more introns (Raible et al., 2005). Genes have become more streamlined over the course of evolution in flies and other quickly reproducing species.

There are also interesting differences between species when it comes to the total length of introns compared to exons within genes. In the genes of the worm *Caenorhabditis elegans* and many other species, introns and exons contain about the same number of 'letters' (nucleotides). The situation in humans is very different: introns in a single gene frequently total tens of thousands of nucleotides and are, on average, five times the length of the exons. This may have an impact on the evolution of human genes, as revealed in a study by Cristian Castillo-Davis of Harvard University, USA, and Eugene Koonin and Fyodor Kondrashov of the National Center for Biotechnology Information, USA (Castillo-Davis et al., 2002). Transcribing RNA is a slow and energy-expensive process: making RNAs from a single gene with huge introns can require several minutes and thousands of molecules of ATP. The authors found that the introns of frequently used genes are on average 14 times shorter than those of rarely used genes. Their conclusion: natural selection has been shortening introns in the most common genes, saving time and energy.

Once the cellular machinery needed to carry out alternative splicing evolved, it could be put to use in many different ways. Mixing and matching modules produces proteins that behave differently. They help to create diverse types of cells and figure prominently in the development of different tissues. Alternative splicing of an RNA called *Slo* in the ear of the chicken improves the bird's hearing by giving it cells sensitive to different frequencies of sound. In flies, three critical proteins are spliced differently in males and females, creating important differences between the sexes. Although females have two X chromosomes and males only one, females don't produce twice the amount of proteins from the genes on the chromosome, thanks to the differences in these proteins. Diane Lipscombe and her colleagues at Brown University (Rhode Island, USA) have found that alternative splicing is especially common in the brain of mice and other mammals (Lipscombe, 2005). Some of the molecules are crucial to memory and learning.

Splicing is a factor in a wide range of diseases. Half of the people who suffer from *neurofibromatosis*, a severe genetic disease in which tumours develop alongside nerves and other tissues, have mutations that change the splicing of RNAs made from the *neurofibromin* gene. Patients with beta-thalassaemia suffer from anaemia as a result of non-functional beta-globin proteins in their red blood cells; this severe disease is caused by mis-splicing of the responsible gene. Other examples are changes to the *BRCA1* gene (linked to breast cancer) and *CFTR* gene (leading to cystic fibrosis). It is estimated that about 50% of disease-related mutations in exons affect the way RNAs are spliced. Tumours and neurodegenerative diseases are often accompanied by unusually spliced RNAs that are not normally found in healthy tissues.

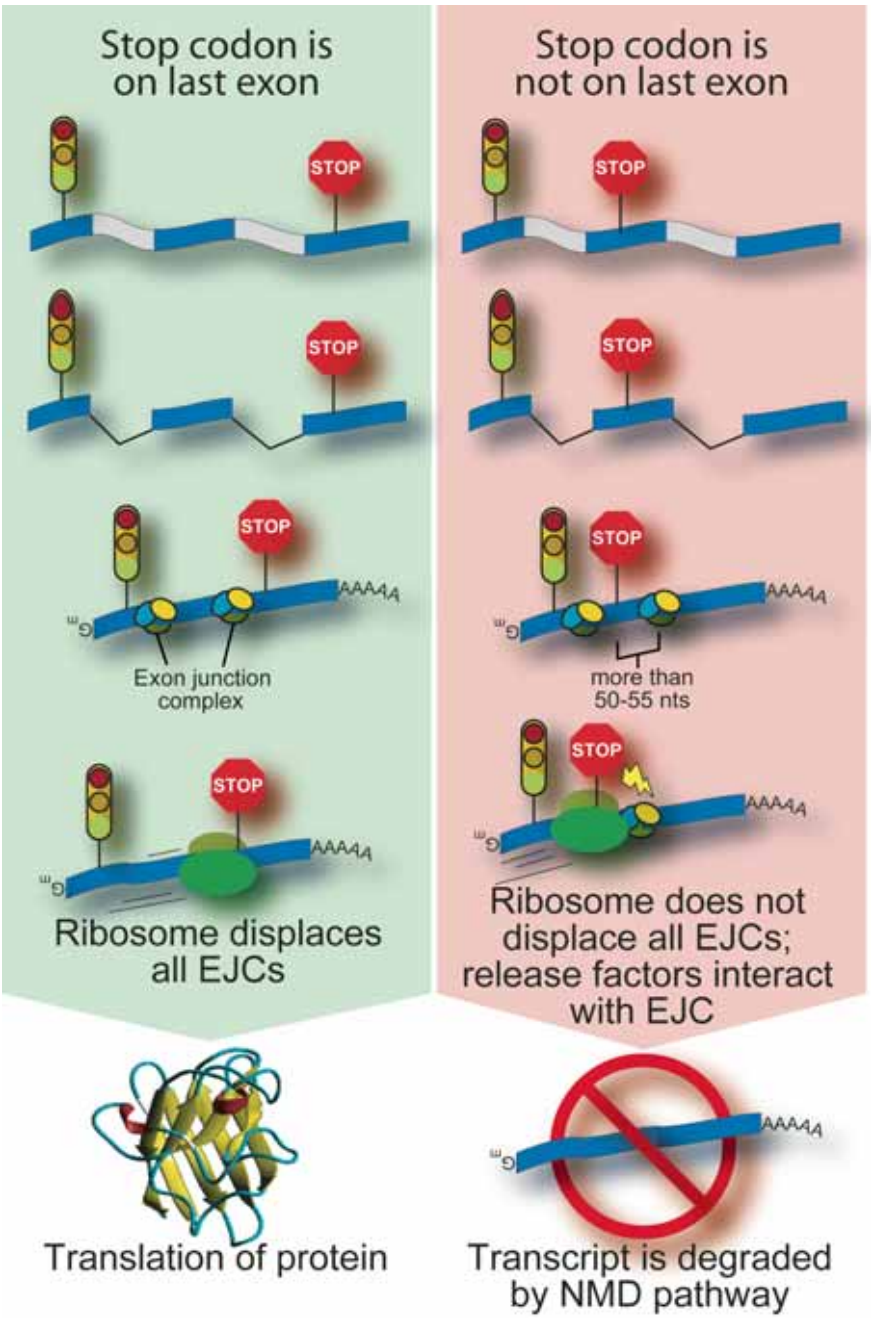
Quality control

In 1979, Regine Losson and François Lacroute of the CNRS in Strasbourg, France, discovered that the cell has a system to inspect RNAs and carry out quality control (Losson & Lacroute, 1979). Nearly three decades of research have shown that the system is not perfect, but it manages to protect eukaryotic cells from the dangerous effects of most mutations. Defects in genes that change the shape, structure or functions of a protein usually have bad effects on the cell. Mistakes in splicing can also produce such molecules, so the inspection system – called *nonsense-mediated mRNA decay* (NMD) – needs to be on alert all the time.

NMD takes place when an RNA enters the cell cytoplasm, but scientists have connected it to splicing, which takes place before the RNA leaves the nucleus (Sun et al., 2000). The cell attaches a cluster of proteins to sites where introns have been removed, like attaching a sign on a boxcar to show that some of the following cars are missing. The cluster consists of at least six proteins and is called the *exon junction complex* (EJC). This complex is placed at splice sites and its position has an important influence on the fate of the RNA.

The translation of an RNA into protein is carried out by a molecular machine called the *ribosome* which docks onto a messenger RNA, reads its code and assembles a chain of amino acids that matches the sequence. Any EJCs on the molecule are simply moved out of the way. At the end of the protein-encoding part of the RNA, the ribosome encounters a three-letter signal called the *stop codon* and releases the finished protein. Mutations often alter the spelling of an RNA so that a stop codon appears somewhere in the middle of the molecule. This creates a code within the RNA that doesn't make sense to the cell (the 'nonsense' in NMD) and may leave an EJC on the

Image courtesy of Ed Green



RNA, which promotes NMD (see figure). To help prevent potentially harmful proteins from being produced, NMD recognises EJCs that are found more than about 50 nucleotides after a stop codon. The process of translation is interrupted, and other molecules come to carry the RNA away and break it down.

But some RNAs escape NMD and produce harmful proteins which can lead to disease. Even when NMD works, the result may be disease, because NMD may remove an RNA that is damaged but nevertheless necessary. In 1989, Lynne Maquat's laboratory at the Roswell Park Memorial Institute (New York, USA) showed that NMD contributes to beta-thalassaemia, the most common genetic disease in the Western world. Beta-thalassaemia reduces the body's production of haemoglobin, which is needed to carry oxygen through the blood. The disease arises in people who inherit a mutant form of a gene called beta-globin; NMD catches the mutation and the body breaks down beta-globin RNA – removing an important molecule. In this case, an intended safety mechanism is actually attacking the body.

Until recently, NMD was considered to be little more than a means of trapping RNAs with errors; now it is known to be a more general tool that the cell uses to control the quantity and quality of certain molecules. This happens because the normal process of alternative splicing sometimes produces RNAs with nonsense codons; for some reason, the cut-and-paste operation produces a bit of nonsense code in the middle of an RNA. In 2004, R. Tyler Hillman, Richard Green and Steven Brenner of the University of California, Berkeley (USA), carried out a computer analysis which showed that about one-third of the time, alternative splicing places a stop codon more than 50 nucleotides in front of a splice site. This activates NMD, which eliminates most of the RNA before it can be transformed into proteins (Hillman et al., 2004).

The same year, Harry Dietz's group at John Hopkins University School of Medicine (Maryland, USA) studied this effect in mammalian cells. They shut down the NMD machinery by removing a protein called Upf1, which is essential for the process. This changed the behaviour of a huge number of genes: about 10% of the genes they studied became more productive, probably because spliced forms were slipping through that normally would have been caught by NMD and destroyed (Mendell et al., 2004).

This means that NMD, like alternative splicing, is a commonly used side-street on the road between genes and proteins. There are many more, some of which will be discussed in a

future issue of *Science in School*. If the suspense is too great, here is a riddle to keep you busy: the colour of purple petunias is due to a single copy of a particular gene. What happens to the petunia's colour if you add a second copy of that gene to the flower?

REVIEW

Advances in biotechnology over the last 40 years have impacted on areas such as agriculture, food science and medicine. Turning our scientific knowledge of the central dogma of molecular biology into useful applications, especially in research into disease and medical treatments, requires a more detailed understanding of the functions of the molecules of life.

This series will introduce advances and new theories which may be too recent to appear in textbooks. It will also illustrate the international and universal quest to learn more about how the molecules of life operate.

This article provides excellent background reading and parts of it could be used to increase and test students' understanding of the central dogma, RNA properties or protein synthesis. In particular, the article would be applicable to considerations of the uses of biotechnology, the importance of ongoing research and the recognition of scientific endeavour.

Marie Walsh, Republic of Ireland

References

Berget SM, Moore C, Sharp PA (2000). Spliced segments at the 5' terminus of adenovirus 2 late mRNA. *Reviews in Medical Virology* **10**: 355-371

Castillo-Davis CI, Mekhedov SL, Hartl DL, Koonin EV, Kondrashov FA (2002) Selection for short introns in highly expressed genes. *Nature Genetics* **31**: 415-418. doi:10.1038/ng940

Crick F (1970) Central Dogma of Molecular Biology. *Nature* **227:** 561-563

Hillman RT, Green RE, Brenner SE (2004) An unappreciated role for RNA surveillance. *Genome Biology* **5**: R8. doi:10.1186/gb-2004-5-2-r8

Lim S, Mullins JJ, Chen CM, Gross KW, Maquat LE (1989) Novel metabolism of several beta zero-thalassemic beta-globin mRNAs in the erythroid tissues of transgenic mice. *The EMBO Journal* **8**(9): 2613-2619

Lipscombe D (2005) Neuronal proteins custom designed by alternative splicing. *Current Opinion in Neurobiology* **15**: 358-363. doi:10.1016/j.conb.2005.04.002

Losson R, Lacroute F (1979) Interference of nonsense mutations with eukaryotic messenger RNA stability. *Proceedings of the National Academy of Sciences USA* **76**: 5134-5137

Mendell JT, Sharifi NA, Meyers JL, Martinez-Murillo F, Dietz HC (2004) Nonsense surveillance regulates expression of diverse classes of mammalian transcripts and mutes genomic noise. *Nature Genetics* **36**: 1073-1078. doi:10.1038/ng1429

Raible F et al. (2005) Vertebrate-type intron-rich genes in the marine annelid *Platynereis dumerilii*. *Science* **310**: 1325-1326. doi:10.1126/science.1119089

Sun X, Moriarty PM, Maquat LE (2000) Nonsense-mediated decay of glutathione peroxidase 1 mRNA in the cytoplasm depends on intron position. *EMBO Journal* **19**: 4734-4744. doi:10.1093/emboj/19.17.4734

Web references

w1 – The transcript of Philip Sharp's Nobel lecture about alternative splicing, 'Split Genes and RNA Splicing', is available online: http://nobelprize.org/nobel_prizes/medicine/laureates/1993/sharp-lecture.pdf

A brief overview of Richard Roberts and Philip Sharp's work is given in the press release announcing their Nobel Prize: http://nobelprize.org/nobel_prizes/medicine/laureates/1993/press.html

For more information about the Nobel Prize, including biographies of the prize-winners, see http://nobelprize.org/

Resources

Many papers by Crick are freely available on the *Nature* website: www.nature.com/nature/focus/crick/

Coming soon

In a future issue of *Science in School*: *Invisible engineers: microRNAs, small interfering RNAs, and other non-coding RNAs*

Russ Hodge is a science writer at the Max Delbrück Center for Molecular Medicine in Berlin, a member of the Helmholtz Association of German Research Centres. He is the former head of the Office of Information and Public Affairs at the EMBL in Heidelberg, Germany, and a regular contributor to *Science in School*.

Oxyntomodulin: a new therapy for obesity?

Katie Wynne and **Steve Bloom** from Imperial College London, UK, describe their work on a hormone that could tackle the causes of obesity.

Image courtesy of Katie Wynne

The obesity epidemic has overtaken Europe. It is estimated that 200 million of the 350 million adults living in the EU are overweight or obese. In fact, the proportion of overweight and obese men is even higher in some European countries than it is in the USA. Of greatest concern is the fact that the number of overweight children in the EU is increasing by 400 000 every year, a warning that the obesity problem will be far worse in the future.

Obesity increases the risk of heart disease, diabetes, stroke, respiratory disease, arthritis and cancer. This disease burden has a disastrous effect on health and costs 7% of the total EU health-care spending. The risk of developing obesity-related conditions can be reduced by losing as little as 5% of body weight. However, public-health campaigns to promote healthy eating and exercise have not stopped Europeans becoming progressively fatter. Currently available drug treatments in combination with diet produce only modest short-term weight loss and are limited by side-effects.

BACKGROUND

Clinical drug trials

New drugs must go through a series of trials, known as phases, in order to test whether they are effective and safe.

PHASE I: Early trial in a small number of usually healthy volunteers to establish a safe dose and look for potential side-effects

PHASE II: Larger group trial of volunteers (up to 100) with the illness to be treated, to establish short-term effectiveness and safety. Both studies described in this article were early Phase II trials.

PHASE III: Large group drug trial in volunteers (up to several thousand) with the illness, over an extended period of a year or more to compare the treatment with an existing therapy or a placebo.

PHASE IV: Drug trial usually performed after a treatment has been licensed, to establish the effectiveness of the treatment when it is used more widely and to investigate long-term risks and benefits.

This process is essential to ensure that the benefit of the treatment is greater than any possible side-effects, but it means that it can take several years for a new drug to reach the public.

Potential obesity drugs entering each phase of clinical trials between 1994-2007. Although many potential drugs are investigated, few reach the market: only two are currently licensed in the USA.

Phase	I	II	III	IV
Number	124	259	169	55

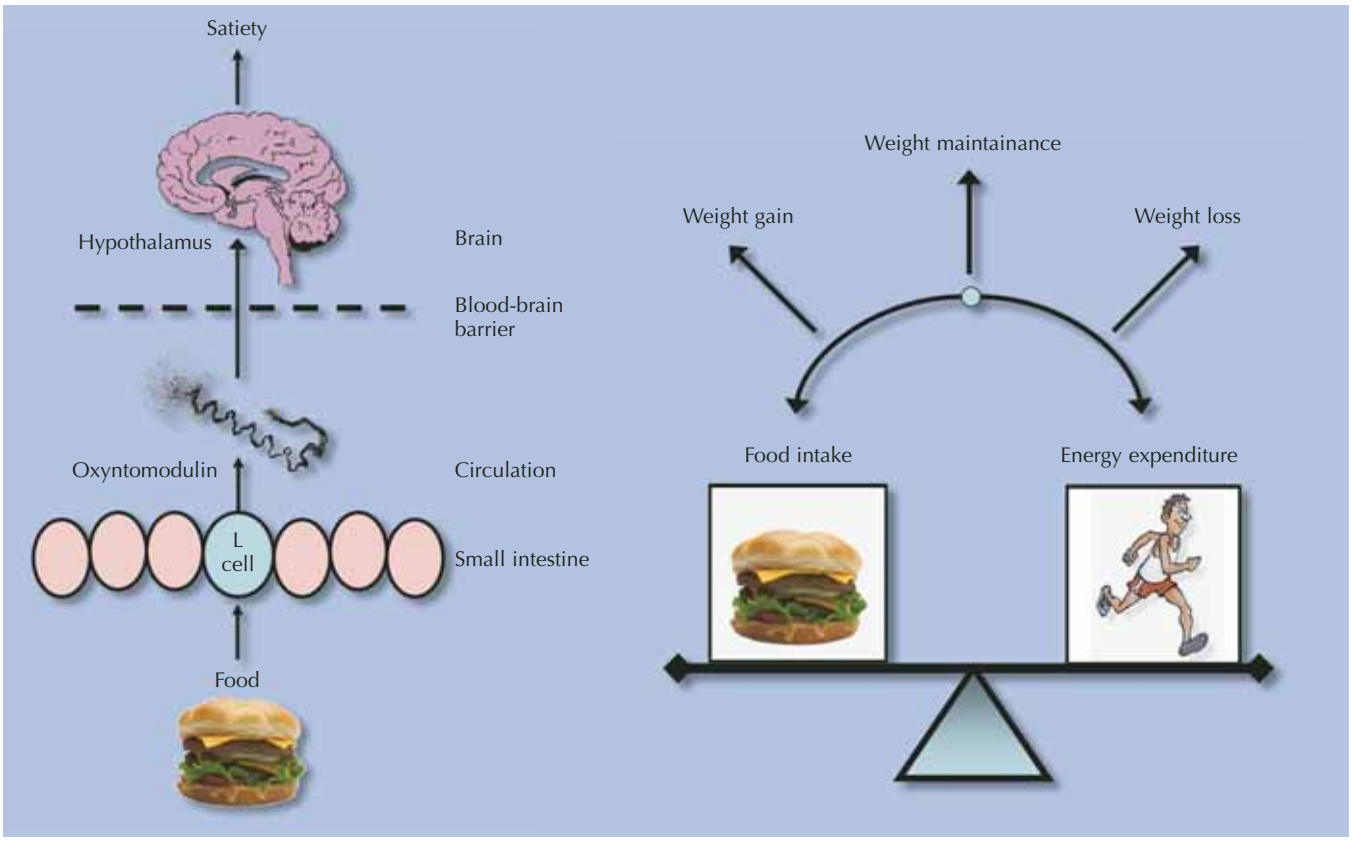


Image courtesy of Katie Wynne

Image courtesy of Katie Wynne

Oxyntomodulin induces satiety

The energy balance

Major gastro-intestinal surgery for obesity can result in permanent weight reduction, but the frequency of severe post-operative complications limits its use to extreme cases. Research groups worldwide are urgently searching for an effective anti-obesity treatment. The Department of Metabolic Medicine at Imperial College London has led the field in appetite research and has recently published exciting work regarding the role of the gut hormone oxyntomodulin as a novel therapy for obesity.

Oxyntomodulin is one of a group of gut hormones: small molecules released from the gastrointestinal tract with several physiological actions including effects on digestion and appetite. Oxyntomodulin was identified over two decades ago, when it was found to reduce stomach acid and delay emptying of stomach contents in rodents. However, the available data showed no effect on gastric emptying in humans and its role in the control of appetite has only recently emerged. Oxyntomodulin is released from the small intestine after each meal in proportion to the calories eaten. Early studies showed that administration of synthetic oxyntomodulin reduces appetite, suggesting that natural oxyntomodulin signals to the brain a feeling of 'fullness' or 'satiety' after eating (see above).

This research stimulated interest in developing the peptide as a possible anti-obesity therapy, harnessing the body's own satiety signal in order to reduce food intake. Body weight is maintained by the balance between food intake and energy used, or 'energy expenditure' (see above). Total energy expenditure can be divided into the energy used by the body for metabolic processes at rest and that used during activity. Obesity occurs when overeating and low levels of physical activity tip the balance in favour of weight gain. We have recently performed studies in healthy overweight and obese volunteers to investigate the effect of oxyntomodulin on food intake, energy expenditure and body weight.

A double-blind, placebo-controlled study was performed in which 15 healthy overweight and obese volunteers were trained to give themselves oxyntomodulin injections under the skin, just before each meal, three times daily. Food intake and energy expenditure were measured over four days and compared with a similar period during which the same volunteers administered a saline placebo. During the study, the volunteers and investigators were unaware of the identity of the administered substance. Food intake was recorded at a study meal in which food was provided in excess and the volunteers ate until they felt full. Activity-related energy expenditure was calculated from combined heart rate and movement monitoring in the participant's

BACKGROUND

The hypothalamus

Oxyntomodulin acts on the hypothalamus, an area of the brain known to be important for the control of energy balance. Oxyntomodulin and other circulating signals are able to cross the barrier between the blood and the brain, via a specialised area next to the hypothalamus. The hypothalamus can then receive and integrate these signals. Neurotransmitters are released, which send messages from the hypothalamus to many different brain regions and result in changes in behaviour. Thus, an increase in the circulating levels of oxyntomodulin results in a feeling of satiety and allows an increase of activity levels. This may be a logical combination of effects, as it would allow a period of intense activity to occur when there is enough food to supply energy.

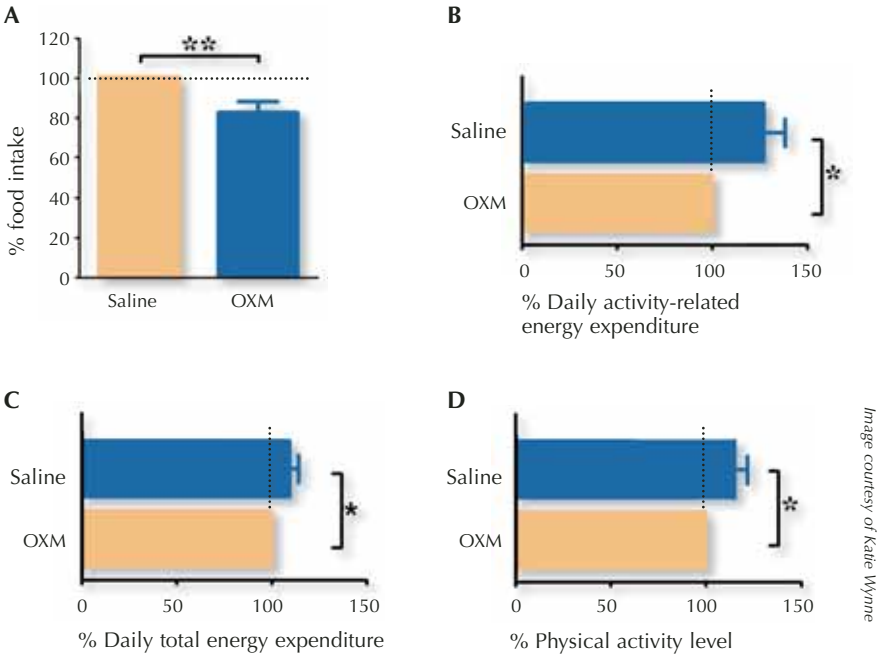


Image courtesy of Katie Wynne

Effects of oxyntomodulin treatment. The error bars represent standard error of the mean. Any difference marked with an asterisk is statistically significant: one asterisk represents a significant difference when $p < 0.05$; two asterisks represent a significant difference when $p < 0.01$

normal environment using a new biosensor. Resting energy expenditure was calculated using indirect calorimetry, which measures the amounts of oxygen consumed and carbon dioxide produced in each breath by the volunteer.

The results of this study showed that after an injection of oxyntomodulin, volunteers ate on average 128 Kcal or 17.3% less (see above, A) without altering their enjoyment of food. In addition, the participants' energy expenditure due to activity was markedly increased by 143 Kcal/day or 26.2% during the period of oxyntomodulin treatment (see above, B). The increase in activity resulted in an increase in total energy expenditure of 9.4% (see above, C), although resting energy expenditure was unchanged. These overweight and obese people started with expected low levels of physical activity, but oxyntomodulin administration increased physical activity back toward normal levels (see above, D), resulting in more energy being used each day. These findings suggest that oxyntomodulin could be an ideal intervention for the obese, as it has a double effect of suppressing appetite and concurrently increasing physical activity toward normal levels.

To investigate the effects of oxyntomodulin administration over a longer period of time, a further double-blind, placebo-controlled study investigated the effects of repeated administration of oxyntomodulin on body weight and levels of fat hormones in healthy overweight and obese volunteers. In this study, 14 people gave themselves injections of oxyntomodulin and 12 people administered saline placebo over a four-week period. During the study, the investigators and volunteers did not know which participants were receiving treatment.

Oxyntomodulin treatment substantially reduced food intake and this effect on appetite was still present at the end of the study, without any loss of efficacy. Most importantly, body weight was reduced by 2.3 kg in the oxyntomodulin group, compared with 0.5 kg in the placebo group (see above). Therefore oxyntomodulin treatment resulted in an additional 0.45 kg weight loss per week, a greater rate than that achieved by any currently licensed anti-obesity drugs. Leptin and adiponectin levels were also measured in the study volunteers, as these markers of fat stores are released in proportion to the

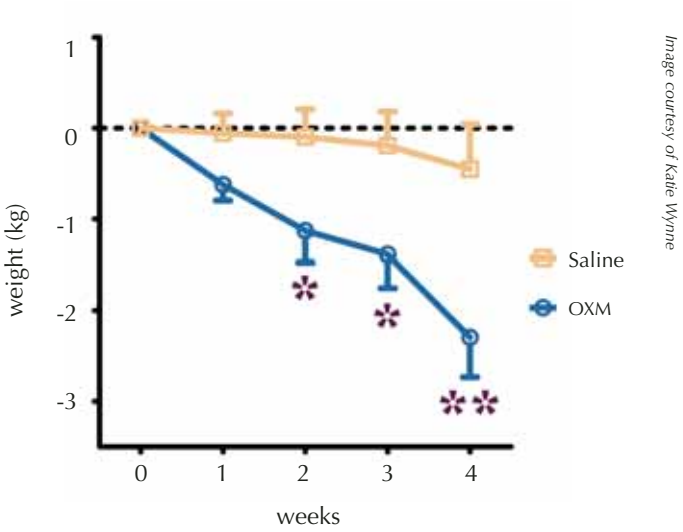


Image courtesy of Katie Wynne

Weight change in the two treatment groups. The error bars represent standard error of the mean. Any difference marked with an asterisk is statistically significant: one asterisk represents a significant difference when $p < 0.05$; two asterisks represent a significant difference when $p < 0.01$

amount of fat tissue. After four weeks of oxyntomodulin therapy, changes in the circulating levels of the fat hormones leptin and adiponectin were consistent with a reduction in body fat. Therefore, our data shows that oxyntomodulin therapy decreases body weight and fat stores in overweight and obese subjects.

The obesity crisis is fuelled by the easy availability of highly palatable, calorie-dense food and a lack of physical activity. Normal dieting tends to reduce the amount of energy each individual uses, making it particularly difficult for obese people to lose weight. Oxyntomodulin, by contrast, reduces food intake and also increases energy usage back toward normal levels, an effect thought to be mediated via the hypothalamus (see box). Appetite suppression is well maintained over a four-week period. During this time, we observed considerable weight loss in the obese subjects accompanied by changes consistent with a loss of body fat.

Currently, the only successful treatment for obesity is surgery, but its use is limited by the dangers of the operation and subsequent side-effects. Surgery which causes food to bypass part of the intestinal tract alters the levels of circulating gut hormones, including increasing the levels of oxyntomodulin, which results in a loss of appetite. The successful weight loss observed after surgically induced modulation of oxyntomodulin suggests that drug treatment with oxyntomodulin over many years may be effective without the complications that restrict the use of surgery.

Large clinical trials are now needed to confirm the therapeutic potential of oxyntomodulin over a longer period.

REVIEW

Obesity, diets and healthy eating habits are of high interest to teenage and young adult students. This article provides solid scientific data on the central brain control of food intake and physical activity, and opens many new topics for discussion:

1. The control of protein synthesis and possible malfunctions within gut cells
2. The circulation of oxyntomodulin and its feedback to the release of neurotransmitters via the hypothalamus, and the information exchange between brain and body
3. The hypothesis that a feeling of satiety can lead to higher physical activity
4. The effects on hormone metabolism – both positive and negative – of injecting hormones
5. Current interest in anorexic and bulimic eating disorders, and the complexity of balancing body weight.

In addition, this article is an excellent example of scientific and medical research procedures for searching for cures for everyday health risks. The contents can be easily adjusted for middle-school students, whose interest will lie primarily in weight gain or weight loss. Older students will be challenged by the brain-body interactions of food intake and physical activity, as well as by cellular control mechanisms of physiological functions. The detailed description of clinical drug-trial procedures can be used to enrich cutting-edge biology teaching.

Friedlinde Krotscheck, Germany

These Phase III trials (see box) would involve testing the effectiveness of the hormone in hundreds and thousands of volunteers over a period of several years. This large-scale research is needed to be certain that the treatment will be effective and to look carefully for any uncommon side-effects that may not have been noted in smaller studies. Using the body's own method of controlling weight may be a viable method of treating obesity without the serious side-effects caused by currently licensed drugs. In the future, this could provide a new way to tackle the obesity epidemic, with oxyntomodulin providing an effective weapon.

Resources

The research described here was published as:

Wynne K et al. (2005) Subcutaneous Oxyntomodulin Reduces Body Weight in Overweight and Obese Subjects: A Double-Blind, Randomized, Controlled Trial. *Diabetes* **54**: 2390-2395

Wynne K, Park AJ, Small CJ, Meeran K, Ghatei MA, Frost GS, Bloom SR (2006) Oxyntomodulin increases energy expenditure in addition to decreasing energy intake in overweight and obese humans: a randomised controlled trial. *International Journal of Obesity* **30**: 1729-1736. doi:10.1038/sj.ijo.0803344

Department of Metabolic Medicine, Imperial College London website: http://wwwfom.sk.med.ic.ac.uk/medicine/about/divisions/is/meta/

International Obesity Task Force Report on Obesity: www.iotf.org/aboutobesity.asp

International Obesity Task Force Report on Childhood Obesity: www.iotf.org/childhoodobesity.asp

The Wellcome Trust's *Big Picture* series provides teachers and students (aged 16 and above) with up-to-date information on research findings in biomedicine, and the social and ethical implications of this research. These resources can be downloaded or ordered online. A recent issue of the *Big Picture* focused on obesity: www.wellcome.ac.uk/node5951.html

Counting Buttons: demonstrating the Hardy-Weinberg principle

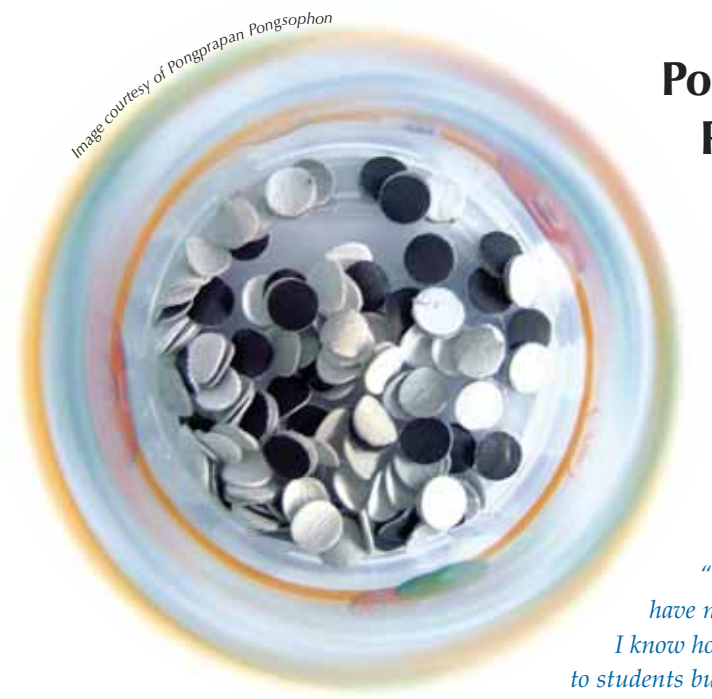


Image courtesy of Pongprapan Pongsophon

Pongprapan Pongsophon, **Vantipa Roadrangka** and **Alison Campbell** from Kasetsart University in Bangkok, Thailand, demonstrate how a difficult concept in evolution can be explained with equipment as simple as a box of buttons!

"The Hardy-Weinberg principle is the most difficult concept for me. I have not been clear about this topic since I started teaching it ten years ago. I know how to solve Hardy-Weinberg problems and can explain the procedures to students but…I really don't see what we use it for and how it relates to evolution. To me, this topic is more mathematics than biology."

Mrs Karnika, a secondary-school biology teacher in Bangkok

The Hardy-Weinberg principle is one of the most difficult topics in evolution for many teachers and students (Mertens, 1992). They may feel threatened by mathematics and the quantitative aspects of population genetics, and may be unable to apply the principle to make sense of evolutionary phenomena. Many of them wonder about the relevance of the Hardy-Weinberg principle to understanding evolution. To help Mrs Karnika and other teachers who face the same difficulties, I would like to introduce the Counting Buttons activity. This is a simple demonstration of the Hardy-Weinberg equilibrium and how natural selection affects the allele frequency of a population. This activity is appropriate for high-school and university students studying evolution. The activity was originally developed by staff in the Department of Genetics at Kasetsart University in Thailand and later modified, as part of a PhD project, for use with high-school students.

Evolution is a change in allele frequency in a population over a period of time (Skelton, 1993; Strickberger, 1996). A population is a group of individuals of the same species in a given area whose members can interbreed and hence share a common group of genes known as a gene pool. Each gene pool comprises all alleles for all characteristics of all individuals. The allele frequency is the number of alleles of a given type as a proportion of the total number of alleles for that trait. In 1908, Hardy and Weinberg constructed a model of a population that was not evolving, and laid out the conditions in which such a population would exist (Abedon, 2005): a large population size with no migration, no mutation, no natural selection, and random mating. If we track allele frequencies in a population over a succession of generations and find that the frequencies of alleles deviate from the values expected from the Hardy-Weinberg equilibrium, then the population is evolving.

The Counting Buttons exercise simulates both a population in genetic equilibrium and a population under-

BACKGROUND

The Hardy-Weinberg principle in context

When, almost 150 years ago, Charles Darwin made public his theory of evolution by natural selection, the idea had one serious weakness. Like most biologists of his time, Darwin supposed that the characteristics of parents were 'blended' in the offspring. Over several generations this would, however, lead to a reduction in variation, giving natural selection little on which to operate. A chance encounter between a biologist and a mathematician on a cricket pitch some 50 years later played a crucial role in solving the problem.

The first steps were taken at the start of the 20th century, when Gregor Mendel's work on inheritance in plants was rediscovered. It suggested that characteristics are discrete and do not blend. Mendel also observed that although a characteristic may seem to vanish in a particular generation, it is merely hidden by a 'dominant' characteristic – thus it can reappear, unchanged, in a subsequent generation.

Rather than bolstering Darwin's theory, however, these discoveries were taken by many to be incompatible with natural selection. If the units of inheritance were discrete, how could the small, continuous variations observed by biologists be produced? And why, if Mendel was correct, didn't the frequency of dominant characteristics increase in the population?

Unable to solve this latter problem, the British biologist Reginald Punnett asked G. Harold Hardy (with whom he played cricket) to help. Hardy, a pure mathematician, generally treated applied mathematics with contempt. In 1908 he wrote to the editor of the journal *Science*:

"I am reluctant to intrude in a discussion concerning matters of which I have no expert knowledge, and I should have expected the very simple point which I wish to make to have been familiar to biologists. However, some remarks ... to which Mr. R. C. Punnett has called my attention, suggest that it may still be worth making...."

The 'very simple point' that Hardy went on to prove was that in a relatively large population where there is no migration, in which mating occurs at random and in the absence of selection or mutation, the frequency of genes will remain the same. Variation would be preserved over the generations.

'Hardy's principle' contributed towards the reconciliation of Darwin's natural selection with Mendelian genetics that developed gradually over the 1920s and 1930s to form our modern ideas about evolution.

In 1943 the principle became known as the Hardy-Weinberg principle (or the Hardy-Weinberg equilibrium or law) when it emerged that the same idea had been proposed independently in 1908 by a German physician, Wilhelm Weinberg.*

Today the science of population genetics, of which it is part, provides the most important theoretical basis for evolutionary biology and can be used to test almost all evolutionary ideas.

Dean Madden,
National Centre for Biotechnology Education, UK

* It was later discovered that an American, William Castle, had suggested a similar idea in 1903.

going natural selection. Natural selection acts on organisms' phenotypes: physical traits, metabolism, physiology and behaviour, "and adapts a population to its environment by increasing or maintaining favorable genotypes in the gene pool" (Campbell & Reece, 2002). In a changing environment, natural selection favours any existing genotypes that have already adapted to the new conditions.

Note to teachers: Teachers should review students' understanding of Mendelian genetics, especially monohybrid crosses, before running this exercise. This is an activity for groups of four to five students, and should take three hours.

Objectives of the activity

After completing this activity, students will have simulated a population at genetic equilibrium and examined the effect of natural selection on the allele frequency of a population over five generations.

Materials

1. Three kinds of button: black on black, black on white, and white on white (50 each). Each button is actually made from two buttons glued together (see page 34).
2. Tables 1, 2, and 3 for recording parents and offspring, and calculating allele frequencies[w1]
3. Plain paper, graph paper

Each button represents one diploid individual in a population. Each side of the button represents an allele: black on black is an individual with genotype RR, black on white is Rr, and white on white is rr.

Each pair of buttons will produce four offspring; the genotypes of the offspring are determined according to Mendel's first law.

Example tables

The complete tables can be downloaded from the *Science in School* website[w1].

Table 1: Mating

No.	Genotypes of parents			Genotypes of offspring		
				RR	**Rr**	**rr**
1			→			
2			→			
3			→			
4			→			
5			→			

Table 2: Allele frequency (no selection)

Generations	Number of each genotype			Frequency of allele R	Frequency of allele r
	RR	**Rr**	**rr**		
0 (initial)	16	32	16	0.5	0.5
1					
2					
3					
4					
5					

Table 3: Allele frequency (selection)

Generations	Number of each genotype			Frequency of allele R	Frequency of allele r
	RR	**Rr**	**rr**		
0 (initial)	16	32	16	0.5	0.5
1					
2					
3					
4					
5					

CLASSROOM ACTIVITY

CLASSROOM ACTIVITY

Example results

Table 4:

No.	Genotypes of parents			Genotypes of offspring		
				RR	Rr	rr
1	RR	Rr	→	2	2	0
2			→			
3			→			
4			→			
5			→			

When there is no selection pressure, the frequency of the two alleles fluctuates slightly (Table 5). When there is a selective pressure against the homozygous recessive genotype (that is, if rr individuals die before they reproduce), the frequency of the r allele in the population declines over time (Table 6).

Table 5: Allele frequency (no selection)

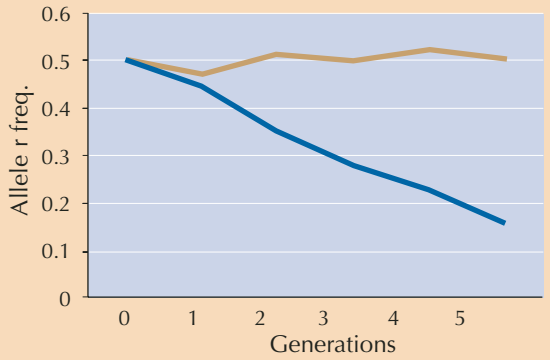
Generation	Number of each genotype			Frequency of allele R	Frequency of allele r
	RR	Rr	rr		
0 (initial)	16	32	16	0.5	0.5
1	D_1 = 17	H_1 = 34	R_1 = 13	0.53	0.47
2	D_2 = 14	H_2 = 35	R_2 = 15	0.49	0.51
3	D_3 = 16	H_3 = 32	R_3 = 16	0.50	0.50
4	D_4 = 15	H_4 = 31	R_4 = 18	0.48	0.52
5	D_5 = 16	H_5 = 33	R_5 = 15	0.50	0.50

Table 6: Allele frequency (selection)

Generation	Number of each genotype			Frequency of allele R	Frequency of allele r
	RR	Rr	rr		
0 (initial)	16	32	16	0.5	0.5
1	D_1 = 21	H_1 = 29	R_1 = 14	0.55	0.45
2	D_2 = 30	H_2 = 24	R_2 = 10	0.65	0.35
3	D_3 = 36	H_3 = 21	R_3 = 17	0.72	0.28
4	D_4 = 41	H_4 = 17	R_4 = 6	0.77	0.23
5	D_5 = 48	H_5 = 12	R_5 = 4	0.84	0.19

D = dominant
H = heterozygous
R = recessive

Allele r frequencies of five succeding populations under non-selection and selection



Changes in allele frequency over time, under selection and no selection

Image courtesy of Pongprapan Pongsophon

Three kinds of buttons

Procedure

Experiment I: a population at equilibrium

1. Place 16 black/black, 32 black/white, and 16 white/white buttons in a box. These buttons represent the initial population (generation 0).
2. Shake the box, randomly select two buttons at a time, and record their genotypes in the 'parent' column of Table 1. Put these pairs to one side.
3. Repeat step 2 until the box is empty. You should have 32 pairs of genotypes in the parent column.
4. Use Mendel's law of segregation to calculate the genotypes of the four offspring for all 32 pairs, and record their frequencies in the 'offspring' column of the mating table (Table 1).
5. From your spare buttons, find those that represent the genotypes of the offspring. These 128 buttons represent the genotypes of the first offspring (generation 1) in a community.
6. Discard all of the parent buttons in the parent column. Sort the offspring buttons into three groups: black/black, black/white and white/white.
7. Count the number of buttons in each group and divide this number by two in order to maintain the population size at 64. Otherwise, your population will grow exponentially!
8. Write these numbers down in the 'genotype' column of Table 2.
9. Use the number of each genotype to work out the frequencies of the R and r alleles and write them in the appropriate columns in Table 2.
10. Put the buttons representing the first offspring generation back into the box.
11. Repeat steps 2-10 four times to obtain genotype and allele frequency data from a total of five generations.
12. On graph paper, plot the frequency of the recessive allele (r) against time.

Experiment II: an evolving population

Suppose the individuals with genotype rr die out before they reproduce. You will need to eliminate white/white buttons from each generation after the first.

1. Put 16 black/black and 32 black/white buttons into the box, and shake it.
2. Randomly select two buttons at a time and record their genotypes in a new copy of Table 1.
3. Repeat step 2 until the box is empty. You should have 24 pairs in the parent column.
4. Calculate the genotypes of all offspring and write them in the offspring column of Table 1. Discard the parent buttons.
5. Find the buttons representing the offspring genotypes.
6. Now you will have 96 buttons in the offspring column representing the genotypes of the first offspring generation.
7. Sort the offspring buttons into three groups: black/black, black/white and white/white.
8. Count the number of buttons in each colour group and multiply each group by K (K = 64/N; N is the sum of the three genotypes) to make the population size of the next generation remain at 64 (its initial population).
   N and K values vary from generation to generation. In the first round, N = 96 and K = 2/3. Multiply the number of each genotype by 2/3. The sum of the outcomes should be 64. If multiplication produces a decimal number, you can raise or lower a fraction to the next whole number to make the sum of all genotypes equal to 64. Write the number of each genotype in Table 3 in the genotype columns.
9. Put the buttons corresponding to the numbers from the first generation row back into the box and do not forget to remove white/white buttons from the box because they die before they are able to reproduce.
10. Repeat all steps above four times to obtain R and r allele frequencies over five generations.
11. Plot the frequency of the r allele over time and compare this with the graph from the first experiment.

Note: The students might find that, in some rounds, there is a single unpaired button left in the box after selecting pairs of buttons. This remaining button must be removed from the population because it does not have a chance to mate with other individuals.

Questions for discussion

Compare the graphs of allele frequency from the stable and the evolving population. Do they differ?

How does natural selection affect allele frequencies of a population over time?

Will a dominant allele of a trait always have the highest frequency in a population and a recessive allele always have the lowest frequency? Explain your answer.

Teachers should be aware that students may misinterpret the graphs, focusing only on two or three points and not noticing that there are fluctuations from generation to generation. The teacher should also emphasise that in a natural population it usually takes more than five generations before we can detect any change in allele frequency. Evolution takes time.

After conducting the second experiment, some students might conclude that natural selection always increases the frequency of a dominant allele and decreases the frequency of a recessive allele in a population. However, not all selections would result in a progressive decrease in a recessive allele. The allele – dominant or recessive – that is selected out is determined by the environmental conditions at the time. In order to avoid this misunderstanding, it is advisable for the teacher to ask the students to consider examples in which the recessive allele is common, or the dominant allele is rare: type O blood is a recessive trait but the majority of people in some populations have this blood type; Huntington's disease is a dominant trait but only 4-10 individuals in 100 000 have it. More examples of other kinds of natural selection are described in O'Neil (2006).

Summary

Counting Buttons is a simple and concrete way to demonstrate the Hardy-Weinberg principle. By engaging in this activity, students will gain insight into a population at equilibrium and into natural selection as a force for biological adaptation. Students will have to apply Mendelian law and mathematical skills to make sense of the data and interpret the results. Counting Buttons is an example of how to teach biology in an integrated fashion and to use mathematics to make sense of complex biological phenomena.

"Counting Buttons helped me make sense of the Hardy-Weinberg principle. Now, I can explain to students what the principle is used for and how to link it to other topics of evolution meaningfully. I feel more confident and enjoy teaching this topic. Obviously, the students paid more attention to the lesson. They were very happy to work hands-on and collaboratively in this lab exercise."

Mrs Karnika, after running Counting Buttons

References

Campbell NA, Reece JB (2002) *Biology*. 6th Ed. San Francisco, CA, USA: Benjamin/Cummings

Mertens TR (1992) Introducing students to population genetics and the Hardy-Weinberg Principle. *The American Biology Teacher* **54**: 103-107

O'Neil D (2006) Recombination. http://anthro.palomar.edu/synthetic/synth_7.htm

Skelton P (1993) *Evolution: A Biological and Palaeontological Approach*. Milton Keynes, UK: Open University Press

Strickberger W (1996) *Evolution*. 2nd Ed. London, UK: Jones & Bartlett

Web references

w1 – All the necessary tables can be downloaded here: www.scienceinschool.org/2007/issue6/hardyweinberg/

REVIEW

At any level, the Hardy-Weinberg principle is a difficult concept to grasp. It is virtually impossible to see how it acts and how selection may affect the frequency of alleles. This ingenious idea for active learning of a seemingly abstract concept simulates how the Hardy-Weinberg principle applies to both a stable and an evolving population. Buttons representing homozygous dominant and recessive, and heterozygous, genotypes are used to review the understanding of Mendelian genetics and then to investigate how allele frequency changes in stable and evolving populations.

Three hours for the whole activity is a reasonable estimate. The activity would be ideal as two separate lessons: one for a stable population and one for an evolving population. This will prevent the students from becoming bored with pulling buttons out of bags or confused by the different mathematics required to model each population. The mathematics for the evolving population requires some concentration to understand and may take students a while to calculate.

The questions for discussion should provoke some good exchange of ideas. The points made about allele selection would raise awareness of some dominant and recessive genetic diseases and could be used for further research, perhaps linking them into genetic engineering and genetic diagnosis and, if time permits, debates on the ethics of selection.

Shelley Goodman, UK

Image courtesy of Pongprapan Pongsophon

Monastic ink: linking chemistry and history

One of the many purposes of science is to support the humanities. With this in mind, **Gianluca Farusi** and his students set out to investigate and prepare iron-gall ink, a historically significant material for the transmission of knowledge.

Image courtesy of www.pixelio.de

The historical setting

Many mediaeval miniatures of St. John of Patmos demonstrate the importance of ink: they portray the Devil attempting to steal the saint's precious ink. In the Middle Ages, two kinds of black ink were generally used: carbon ink (a suspension of carbon, water and gum) and iron-gall ink (obtained from oak galls). Carbon ink was used as early as 2500 BC whereas iron-gall ink was used from the 3rd century AD onwards, by individuals such as Leonardo da Vinci, Johann Sebastian Bach, Rembrandt van Rijn and Vincent van Gogh. According to recent research, traces of iron-gall ink have been found on the Dead Sea scrolls and on the lost Gospel of Judas[w1].

The reaction that forms the ink pigment was not used in the ancient world to produce ink, but it was known: in his *Naturalis Historia (Natural History)*, Pliny the Elder (23 AD – 79 AD) describes how to distinguish verdigris [$Cu(CH_3COO)_2{\cdot}2Cu(OH)_2$], used to process leather, from the cheaper copperas ($FeSO_4{\cdot}7H_2O$) with which it was often adulterated. He writes:

" …The fraud may be detected using a leaf of papyrus which has been steeped in an infusion of nut-galls: it immediately turns black when adulterated verdigris is applied …".

Although he could see the transformation, he did not understand it. Now, we know that this ancient test relies on the reaction between the ferrous cation (iron(II)) and gallotannic acid that is at the root of the iron-gall ink preparation (see below).

The educational context

When one of my chemistry students asked me what kind of ink mediaeval monks used, I was inspired to develop a project on monastic ink (see box). In addition to offering an instructive slant on science, it emphasises the links between science and the humanities.

We decided to use the recipe listed by the Venetian Pietro Canepario from his *De atramentis cuiuscumque generis* (*All Kinds of Ink*; 1619). In rhyming vernacular Italian, he describes the

CLASSROOM ACTIVITY

Iron-gall ink ingredients

Images courtesy of Gianluca Farusi

Figure 1: Acorn gall

Figure 2: Marble gall

Figure 3: Cypress gall

The first certain reference to iron-gall ink is in Martianus Minneus Felix Capella's book *De Nuptiis Philologiae et Mercurii et de septem Artibus liberalibus libri novem (On the Wedding of Philology and Mercury and of the Seven Liberal Arts in nine books;* 420 AD), which mentions a mixture of galls and gum. Although other recipes have been preserved, all agree on the basic ingredients: galls, ferrous sulphate (copperas), water and gum arabic.

Galls

Galls are abnormal, induced growths found on the leaves, stems, flowers or roots of plants. The gall-forming agent, often a fly or wasp, deposits an egg into the young plant tissue, and the gall grows around the larva, which feeds and develops within the protective growth. Secretions from the larva, including saliva and excreta, are believed to control the development of the gall.

The chemical composition of galls varies depending on the gall-forming agent and the plant in question. The Aleppo gall is particularly rich in tannic acid (65%) and gallic acid (2%); the Bassorah gall (also known as the mad apple of Sodom) contains 26% tannic acid and 1.6% gallic acid; whereas the Acorn gall contains 45-50% tannic acid. All three also contain high concentrations of gallotannic acid. In our project, we used acorn and marble galls (typical oak galls), as well as cypress galls (Figures 1, 2, 3).

All three types of gall can be found across Europe but anything containing tannins could also be used to produce the ink; tea, for example. Alternatively, you could use tannic acid.

Ferrous sulphate or copperas

In ancient times, copperas ($FeSO_4 \cdot 7H_2O$) was extracted by evaporating water from ferrous earths. Later, at the end of the 16th century, it was produced by adding sulphuric acid to iron nails. We used ferrous sulphate, a common substance in the chemistry laboratory.

Water

Since tap water may contain impurities (such as chlorine) that alter the ink quality, we used distilled water. Historically, rainwater was probably used.

Gum arabic

Gum arabic, a natural gum extracted from acacia trees and used as a food stabiliser, maintains the quality of the ink in three ways:

1. It keeps the iron complex (the pigment) in suspension
2. It thickens the ink and prevents it from flowing too fast from the pen
3. It reduces the speed at which the ink soaks into the paper, giving a better and longer-lasting stroke.

Materials and method

- Galls, 3 parts by weight
- Water, 30 parts by weight
- Ferrous sulphate, 2 parts by weight
- Gum arabic,1 part by weight

Figure 4: Crushed acorn gall

Figure 5: Filtering the water and crushed gall mixture

Images courtesy of Gianluca Farusi

1. Break the galls into pieces, then grind them in a coffee mill (Figures 4).
2. In a beaker, add the water to the ground galls. Leave the mixture to ferment in a sunny corner at room temperature for 3 days.
3. Filter the mixture (Figure 5) and add the ferrous sulphate to the solution. Stir well and leave for 3 days.
4. Add the gum arabic, stir the mixture and you have your ink (Figure 6). Time to start writing (Figure 7)!

Figure 6: The three inks

Figure 7: The results!

Images courtesy of Gianluca Farusi

CLASSROOM ACTIVITY

composition by weight of the ink: "Una, due, tre e trenta a far la bona tenta" ("with one, two, three and thirty parts try to do it well"). Now we know that this ratio of gum arabic, ferrous sulphate, galls and water is not the best for iron-gall ink: because it is too acidic, it eats into the paper over time. However, my goal was not to prepare the best possible ink, but rather to encourage my students to investigate history by using chemistry and to understand the cultural and educational roles of chemistry.

Next, the students investigated galls, and set out to collect common types – oak (both acorn and marble) galls and cypress galls – to allow us to compare three different inks.

We wanted to determine the best type of ink, but according to what criteria? We decided not to stray too far from Canepario's time, and referred to *De subtilitate* (*The Arcane Links Between Things*) and *De rerum varietate* (*The Variety of Things*) by Gerolamo Cardano (1501-1576). According to Cardano, a good ink flows well, and is thick, black and bright. We tested our inks, writing with both Pasteur pipettes and pen nibs, and found that acorn-gall ink best fitted these criteria. My personal favourite, however, was cypress-gall ink: although it is less black than acorn-gall ink, it smells wonderfully of resin.

Of course, we ended with a discussion of the chemistry: we considered the reactions taking place at each stage of our ink production, as well as subsequent reactions between the ink and paper, their significance for historical documents and how further damage could be prevented.

The students loved the project, particularly the interdisciplinary and historical aspects. One student remarked that chemistry "seems to be the clue to both modern and ancient puzzles".

The chemistry involved

Although the reactions are easy to perform, the chemistry involved is rather complex. This experiment works well if younger students (ages 14-15) do the laboratory work, after which older students (ages 17-18) explain to them the chemistry and biology involved.

After the galls have been broken up, the reactions occur in two stages: the fermentation of gallotannic acid to gallic acid followed by the formation of the ink pigment.

1. Galls contain large amounts of gallotannic acid (Figure 8) but relatively little of the gallic acid needed to make the ink pigment. In the fermentation stage, the galls release the enzyme tannase from the *Aspergillus niger* and *Penicillium glaucum* fungi that are found in the galls. Over three days, tannase catalyses the hydrolysis of gallotannic acid to gallic acid and glucose (Figure 9).
2. The ink pigment is formed in two further stages: a Lewis acid-base reaction followed by a redox reaction.

a) Gallic acid and ferrous sulphate form ferrous gallate (a colourless water-soluble compound; Figure 10), plus , H_3O^+ and SO_4^{2-}.

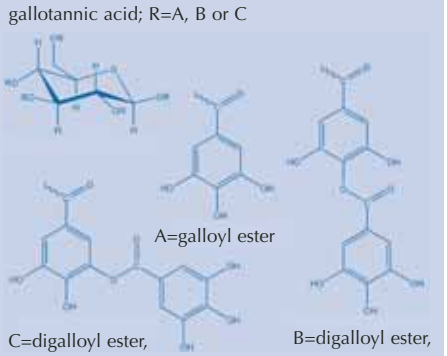
b) Almost immediately, the ferrous gallate reacts with oxygen to produce water and ferric pyrogallate, a black insoluble octahedral complex in which the ligands of each ferric cation are two molecules of gallic acid (Figure 11).

The ink pigment is ferric pyrogallate. Owing to the presence of H_3O^+ ions, the solution is acidic.

Long-term damage

Iron-gall ink may have been used for 1800 years, but it does not withstand the test of time well. Over the course of centuries, the ink fades, and discolours and damages the paper. This is due to an excess of ferrous ions: the 2:3 ratio of ferrous sulphate to galls is stoichiometrically incorrect, with more ferrous sulphate than is necessary to react with the gallic acid.

Figure 8: Gallotannic acid consists of a glucose molecule, the hydroxylic groups of which are esterified by a mixture of gallic, digallic and polygallic acids



Images courtesy of Gianluca Farusi

Figure 9: Gallotannic acid is hydrolysed to gallic acid and glucose

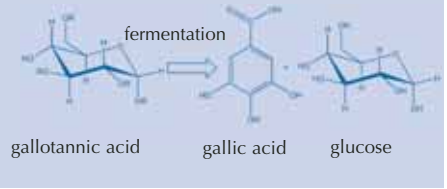


Figure 10: Gallic acid and ferrous cations react to form ferrous gallate

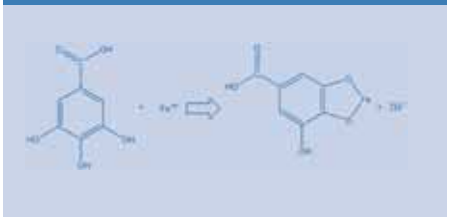
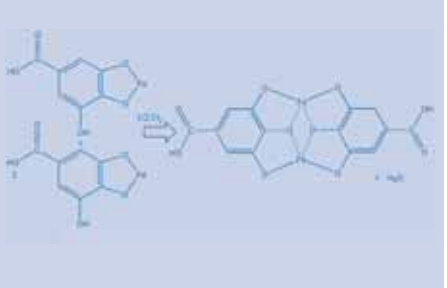


Figure 11: Ferrous gallate reacts with oxygen to give ferric pyrogallate and water



Some of these surplus cations oxidise to form Fe^{3+} oxide which, as it is paler than ferric pyrogallate, fades the original black colour of the ink. Other excess cations catalyse a damaging chain reaction:

$Fe^{2+} + O_2 + H^+ \rightarrow Fe^{3+} + HOO\cdot$

$Fe^{3+} + HOO\cdot + H^+ \rightarrow Fe^{3+} + H_2O_2$

$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO\cdot + OH^-$

(Fenton reaction)

$RH + HO\cdot \rightarrow R\cdot + H_2O$

$R\cdot + O_2 \rightarrow ROO\cdot$

$ROO\cdot + R_1H \rightarrow ROOH + R_1\cdot$

$R_1\cdot + ...$

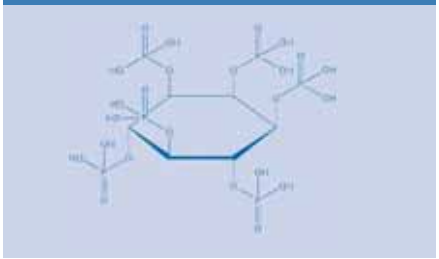
where Fe^{2+} is a surplus ferrous cation, O_2 is atmospheric oxygen and R is a cellulose moiety.

Furthermore, when an $HO\cdot$ radical attacks cellulose (RH) in the paper, it breaks many bonds and holes appear. In turn, the resulting cellulose radicals ($R\cdot$) react, forming more cross-links, so that the damaged paper is more closely meshed, less hydrophilic, and consequently drier and more brittle.

Conservation

One solution to this damage was thought to be ferrous cation chelation: surrounding the ferrous cations with appropriate ligands markedly reduces their oxidation to ferric cations, preventing further damage. However, finding a suitable chelating agent was a challenge: EDTA, for example, does not reduce the oxidation rate of Fe^{2+}.

Figure 12: Phytic acid (myoinositol hexaorthophosphate)



Recent research at the Netherlands Institute for Cultural Heritage[w2], however, offers hope. A treatment based on phytic acid (myoinositol hexaorthophosphate; Figure 12), a natural antioxidant in seeds, leads to the formation of an Fe^{2+}-phytic acid complex (Botti et al., 2005). This inhibits the Fenton reaction, a step in the chain reaction described above, and prevents further damage to the paper.

Conclusion

"There comes a day when both the time and the painstaking study of many generations will reveal what is now hidden; one life would not be long enough to finish such a boundless research… and so these phenomena will become clear over generations of researchers… There will come a day when our descendants will be surprised that we were so ignorant of such obvious things. Many discoveries await the coming centuries when even the memory of us has faded away. The world would be a really trifling affair if each generation did not find matter to inquire into… Nature doesn't reveal its secrets in one go."

Seneca, Quaestiones Naturales, *Book VII*

This topical passage from Seneca (4 BC – 65 AD) still holds true. I like to think that Pliny would be pleased to see how this generation is able to figure out what he could not.

References

Botti L, Mantovani O, Ruggiero D (2005) Calciumphytat zur Behandlung von Tintenfraß: Wirkungen auf das Papier (Calcium phytate, a natural antioxidant to counter paper corrosion caused by iron-gall ink). *Restaurator* **26:** 35-45

Web references

w1 – *National Geographic* website: www.nationalgeographic.com

w2 – Netherlands Institute for Cultural Heritage website: www.icn.nl

REVIEW

This article provides a novel cross-curricular project linking chemistry and history (with possible links to art, forensic science and biology). The idea of making historically accurate ink is interesting, and relies on relatively simple chemistry.

Such a project could form the basis of an investigation including, for example, a comparison of modern and/or traditional inks. The link to the prevention of ink degradation could further extend any investigation. Overall, this is an interesting article with some useful ideas for exploring advanced chemistry.

Mark Robertson, UK

Resources

The Ink Corrosion website: www.knaw.nl/ecpa/ink/index.html

This project was carried out with Gianluca Farusi's chemistry students at the technical school (Istituto tecnico industriale) Galileo Galilei in Avenza-Carrara, Italy, with the technical support of Luciano Dalle Luche. Gianluca also teaches stoichiometry at the Faculty of Medicinal Chemistry, University of Pisa, Italy.

The Boy Who Would Be Good: understanding ADHD through a film-making project

An art teacher with a science degree? **Karen Findlay** put this unusual combination to good use with an ambitious film project.

Art meets science

As an art teacher with a science degree, I'm predisposed towards thinking up exciting problem-based projects that draw together these two areas. I'm also the G&T co-ordinator at my school, which doesn't mean that I'm in charge of the cocktail cabinet in the staffroom. Instead, I have the responsibility of dreaming up unusual activities, involving complex concepts and principles, for gifted and talented (G&T) students. One of my recent ideas led to me making a successful funding bid through Big Screen Science, part of the UK Film Council's First Light initiative which provides funding for film-makers up to 18 years old, which was produced as a collaborative venture involving Ridgeway School in Plymouth and the Suited and Booted Film Company.

Although it was a lot of hard work, it's really satisfying to reflect upon a project that, while mainly student-led, covered important issues of science and ethics in an accessible manner, allowing schools across the UK to engage in this particular aspect of the debate.

Image courtesy of Karen Findlay

A dramatic approach to dealing with ADHD

Securing the funding and support of a top-quality production company for this project gave G&T students at Ridgeway School the opportunity to research and produce a short film tackling the fraught field of bioethics. We chose the topic of attention deficit/hyperactivity disorder (ADHD). This is a condition characterised by inattention, hyperactivity and impulsive behaviour; it is also the subject of a great deal of attention in UK secondary schools and a condition about which many of our students already had some (mostly anecdotal and incorrect) knowledge. The aim of the production was to stimulate debate and discussion among school children in general, prompting greater understanding of a condition that may affect others around them.

Image courtesy of Karen Findlay

Image courtesy of Karen Findlay

Image courtesy of Karen Findlay

Those involved were a core of 15 Year-9 students (ages 13-14), with others drafted in to perform roles such as extras. The students were remarkably mature in their approach to sharing the workload, operating as a single group for the most part but allocating specific tasks as they arose, in accordance with each other's strengths. All of the students worked on the story-boarding (the scene sequence), for example, but would research in pairs when a particular focus was needed. Students naturally gravitated towards their own areas of interest, such as camera-work, organisation, or script-writing.

We discussed possible topics for the project but decided on ADHD because it was relevant to the group, several of whom had family members and fellow students suffering from the condition. ADHD is a topical subject in UK schools and there is considerable debate about whether it is a real medical condition or simply a belief system. Nonetheless, the prescription of Ritalin, the most common drug used to control the condition, has increased 20-fold between 2001 and 2006.

The scientific literature relating to ADHD doesn't provide conclusive evidence of its cause, though studies have identified factors such as genetic influences, abnormalities in brain structure and chemical imbalances in the brain as being potential contributors. Environmental factors and prenatal influences such as smoking and the consumption of alcohol during pregnancy have also been linked to the condition. Although Ritalin can help to control the symptoms, side-effects can include sleep disturbance, weight loss and reduced growth rate. In addition, the use of Ritalin increasingly carries a stigma among UK school children and it is this that the project set out to address through promoting a better understanding of ADHD.

The Boy Who Would be Good is a drama in which the central character is an ADHD sufferer. To those around him, staff and students alike, his behaviour is irritating, anti-social and distracting; although he has been prescribed medication to alleviate the symptoms, he rarely takes it. Following a confrontation on the school bus, however, he goes back to taking his pills but begins to question whether they are changing his identity.

BACKGROUND

The practicalities

Getting a project like this off the ground involves jumping through a lot of hoops and it's a major undertaking for already-stressed teachers. It certainly has a significant 'wow' factor though, and can engage everyone at a level that is difficult to achieve in more prosaic ways. All that's needed (aside from your own blood, sweat and tears) is support from your school management team in collapsing the timetable for a week or so, some keen students, and of course a grant from relevant funding bodies.

The project took approximately three days to write, one day of acting master class and four days of filming, although the work was spread over several months. My time was mainly devoted to organisation, not forgetting the all-important risk assessments – which at one point involved us wearing hard hats and armed with sticks to fend off aggressive seagulls whilst filming on a high roof!

A cheaper and less stressful version of this project could be to get a group of students to produce a two-minute news item on an equally cerebral topic. This can be tackled in a day with the minimum of equipment but would still give a meaningful outcome. You will need a few basics – kids, video camera and editing software, which can now be acquired very cheaply, though it takes some practice to use well.

Bringing in experts (such as a cameraman, sound engineer and editor) may not be as expensive as you think. Looking close to home may bear fruit in this respect: for example, tutors on media or broadcast technology courses at your local college or university will jump at the chance to get their students involved in this kind of project; indeed, your own school may have older students who could be involved. Consider bringing in the English (or German, French, etc., depending on your home country) department for help with the script-writing, the art department for the story boarding and the drama department for the acting. Bear in mind that film-making professionals do not have to be involved all the way through. Naturally, the services of a professional film-making outfit will produce a superior finished product and since it could be used for years as a teaching resource and in school promotion, there may be funding available from your own school or departmental budget.

Once the expertise and hardware are in place, the task of choosing students arises. The key is to try to be as inclusive as possible, drawing upon individual strengths and abilities. Naturally, you want a degree of commitment so why not start with after-school clubs or 'gifted and talented' groups? The project opens up possibilities for those with initial interest to investigate related areas they may not have considered and that aren't part of the school curriculum; we had one girl who started off with an initial interest in acting but now wants to be a sound engineer.

I can't say that we encountered any insurmountable problems, though it's clear that scheduling the work could be difficult. I was fortunate to have an enlightened headmaster, who was very supportive throughout and gave me permission to take students out of lessons so they could attend workshops. The administration associated with the project was a large undertaking – there were forms to complete for just about everything: photographic release, permission slips, rotas, letters home, risk assessments, to name but a few. It can also be something of a challenge to organise locations but if you've managed to sort out everything else, this bit should be well within your capabilities.

This bioethical dilemma is the focus of a set of questions that accompany the film for use in classroom debates.

The students themselves came up with the storyline, drawing on expert help only when absolutely necessary and generally to solve practicalities rather than to provide content. The ending is quite controversial (the main character throws his medication away) and as a teacher I would have perhaps gone for a more 'classic' ending, but this was the students' work and it poses a question at the end in a very effective way. The funding allowed us to engage three professional actors who gave master classes to the students acting in the film. There were of course natural actors among the students, but others, having been exposed to different elements of the film-making process, (editing, for example) developed new career aspirations. Two of the students even went on to run a media workshop for young people in south-west England.

Although I was the main teacher involved, other members of staff were drafted in to help as needed. These

Image courtesy of Karen Findlay

REVIEW

Anyone who has ever attempted to teach knows how difficult it is to make it fun and interesting, while at the same time securing a high educational value. In this article, Karen Findlay describes her attempt to combine art and science by making a film about a medical condition (attention deficit/hyperactivity disorder, ADHD), for which her students were mostly responsible.

Apart from the fact that the film production (and the film itself) promotes interdisciplinarity and active student involvement, it also achieves several other educational goals, including awareness of a common medical condition, debate and discussion, and collaboration among teachers from different disciplines. Furthermore, this is a wonderful opportunity to give students the satisfaction of creating the kind of work that is normally done by adult professionals.

Teachers of either science or social science/humanities can benefit from the film introduced in this article, by using it as a source of information about ADHD and to stimulate debate regarding the ethical issues that arise from the application of specific medical practices.

The article could inspire other teachers to undertake similar projects with their students. Alternatives to film-making could be theatrical plays, songs and other art-oriented activities. Those who just don't have the time for something like this can take advantage of the work of others and use it to make their teaching more fun and productive. For example, there are many films involving science topics (such as natural disasters and disease outbreaks) that can easily be incorporated into the teaching schedule.

Michalis Hadjimarcou, Cyprus

included teachers from science and drama departments. There was the obvious direct link to drama, but a more subtle though equally important link to science: how to use research, which points are relevant, or how to express a scientific idea.

The film project was researched by reviewing the scientific literature, interviewing parents whose children are ADHD sufferers and discussing the condition with the local self-help group. In addition, Dr Julian Partridge, a scientist from Bristol University, was assigned to work with the students on the project. Dr Partridge has considerable experience in the field of bioethics and has worked with the BBC on a number of TV productions, including the highly successful series, *Blue Planet*. He commented, "the students were very imaginative – they came up with ideas that I would never have thought of."

Time for a film review….

Film is a medium that students can relate to very well, of course, but the idea of using it as a powerful tool for educating and prompting debate, rather than for simple passive observation, was an education in itself for most of the students involved. The making of the film covered many disciplines and technical skills and each student involved was able to find his or her area of strength within the team. It was particularly encouraging to see students who had previously declared themselves to be 'no good at science' immersing themselves in scientific literature or trying to understand the physics of light and sound as they relate to film-making.

In effect, the students were able to complete a mini-apprenticeship; operating the camera, and working out the best angles, lighting and different takes necessary to create one simple scene. They also gained experience of taking sound recordings, how blue screen works, and even the intricacies of film editing.

The finished ten-minute film can now be used in both science and citizenship lessons, with students being given a set of cards, each describing one effect of ADHD medication. Both the film and the cards are available to download from the school website[w1]. Students should sort the cards into reasons for and against taking the medication. Ultimately, individual students should assess the pros and cons of using chemicals to alter a person's behaviour and arrive at a conclusion, providing advice to a hypothetical person who has been diagnosed as suffering from ADHD.

This project was intended to help students appreciate how science is inextricably linked with their day-to-day lives and further, that it rarely produces totally conclusive answers. In pursuing the project and during the subsequent use of the film in class, students begin to understand how scientific knowledge and its application needs to be tempered by the application of moral and ethical judgement. The film also prompts consideration of the differences that may exist between medical interventions intended to benefit the individual and those designed for society at large.

Web references

w1 – Both the film and additional material can be downloaded from the Ridgeway School website: www.ridgeway.plymouth.sch.uk

Resources

For more information about ADHD, see:

National Institute of Mental Health website: www.nimh.nih.gov/publicat/adhd.cfm

Netdoctor.co.uk website: http://premium.netdoktor.com/uk/adhd/childhood/index.jsp

Adders.org, a website to promote awareness of ADHD: www.adders.org

Image courtesy of Karen Findlay

Karen Findlay teaches at Ridgeway School in Plymouth, UK.

Imagine... sharing ideas in the life sciences

With the help of enthusiastic school students and scientists, the Dutch school competition 'Imagine' supports the sustainable production of biodiesel in Mozambique, avocado oil in Kenya and the colorant byxine in Surinam. **Daan Schuurbiers** and **Marije Blomjous**, from the Foundation Imagine Life Sciences, explain what Imagine is all about.

'Advancing sustainable development by connecting life-science research and education' is the ambitious idea behind the Imagine school competition organised in the Netherlands. The idea is quite simple: life scientists are invited to submit proposals for the application of a technology in a less-developed country. Groups of school students aged 16-18 then turn these scientific proposals into business plans during a national school competition. The finalists present their business plans before a professional audience at an international conference. In the end, only one group wins the competition's grand prize: the realisation of their business plan and a visit to the country where the project will be carried out.

Life scientists have contributed a wealth of innovative applications of life-sciences research for the benefit of developing countries, such as using fungi to attack malaria-carrying mosquitoes, biological soil fortification or wastewater treatment through nanofiltration. Deriving practical, low-cost applications from fundamental laboratory research is not self-evident, but scientists see the challenge in putting their research to practical use. According to Joost Uitdehaag, one of the participating scientists: "Great initiative. It's a pleasant challenge to work on things other than your daily activities and it's inspiring to do something concrete for a developing country."

Making sense of science

The main challenge lies with the school students: it is up to them to make business sense out of the scientific proposals. A competition manual including the project descriptions is sent to the participants. It is their task to work out the scientific, financial and social elements of the proposal in enough detail to convince the audience that their project needs to be carried out. They are free to decide exactly how their action plan will look, but they need to incorporate their answers to the following questions:

- What technology is being used?
- Where exactly will the project be implemented?
- How does this affect people in the developing country?
- Who are you planning to approach?
- What will it cost?
- What problems could you expect?

Algae pond in Mozambique

Image courtesy of Foundation Imagine

Bram van Beek at the algae pond in Mozambique

Image courtesy of Foundation Imagine

Dr Kariuki explains how to make avocado oil

Image courtesy of Foundation Imagine

Image courtesy of Foundation Imagine

School students visit a Masai Mara village

In addition to acquiring a thorough understanding of the science and technology behind the idea, the students are confronted with a range of financial, political and social issues to solve. To help them with their questions, two separate activities are available over the course of the year:

1. Hands-on experiments at the scientists' laboratories help the students to understand the scientific background of the project. After acquiring information from the world-wide web and initial discussions with their science teachers, the students perform relevant experiments and can pose their questions to the scientists directly.
2. During a special 'knowledge day' held in the National Museum of Ethnology in Leiden, students have discussions with development-aid experts to get an idea of what it is like working in developing countries and which problems they can expect.

The final

A professional jury selects five business plans for the grand final of the competition, where the finalists present their plans to a professional audience and jury during an international conference. A promotional video made in co-operation with an experienced movie producer is shown to support each presentation. The students are trained in advance for this event: an instruction workshop brings them up-to-date on presentation tech-

BACKGROUND

The Imagine school competition has been running in the Netherlands since 2003; the fifth round will start in September 2007. The initiative originally stems from the Kluyver Centre for Genomics of Industrial Fermentation, a Dutch research consortium employing microbial genomics to improve micro-organisms for use in industrial fermentation processes. In 2005 the Foundation Imagine Life Sciences was established in association with Delft University of Technology to ensure the continuity of the school competition and implementation of the winning projects from previous years.

Image courtesy of Foundation Imagine

Chitosan beads

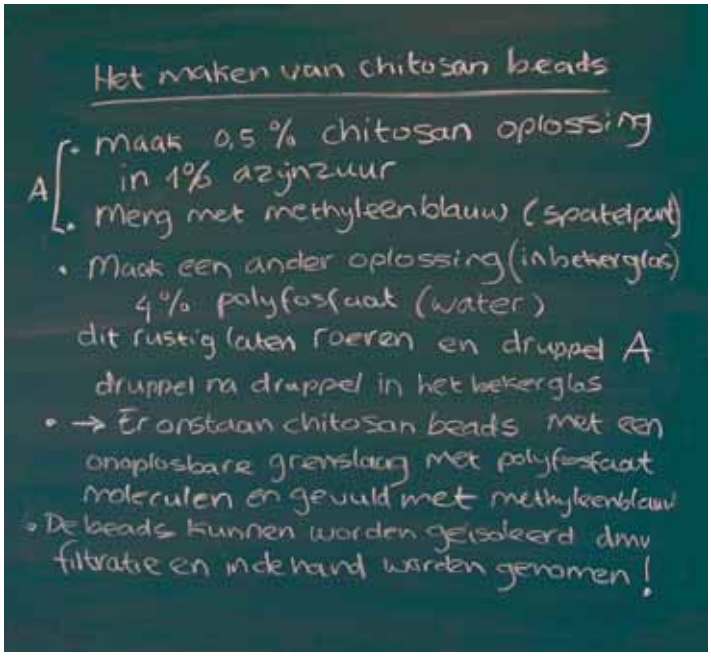


Image courtesy of Foundation Imagine

How to make chitosan beads

niques and PowerPoint tips and tricks, preparing them to give a high-quality and attractive presentation.

After the presentations the jury convenes to evaluate the reports and performances and to choose the winning group. Imagine supports the implementation of the winning project. After a period of fundraising and establishing contacts, the scientist and the winning school students visit the country where the project is being put into practice. After returning from Mozambique, Chang Liu, winning student of Imagine 2004, said "It was a lot more fun than I expected. I thought the contact with the scientists would be very formal. But we just had a great time together."

Goal: development

Four Imagine projects are now being carried out: the Dutch engineer Bram van Beek has constructed a pond in Mozambique to produce biodiesel from algae; Kenyan avocado farmer James Kariuki is turning overripe avocados into oil for cosmetic products; Bob Ursem, director of the botanical garden in Delft, is bringing new life to a plantation in Surinam, and plant researcher Johan Baars has developed a plan to grow oyster mushrooms to fight malnutrition in Ghana.

Making the ideas work

The strength of this competition lies in the unique combination of three objectives: to encourage researchers to implement their research for the benefit of society, to raise awareness

CLASSROOM ACTIVITY

School competition time schedule

Until August:	scientists submit proposals
Until September:	students register
September:	students are linked with projects
October:	students gather information
November:	laboratory experiments
December:	interviews with development-aid experts
February:	report submission and selection of finalists
March:	workshop presentation techniques
April:	final
From April:	the winning project is carried out

Image courtesy of Foundation Imagine

School students making chitosan beads

of development issues with school students, and to implement useful projects in developing countries. But this strength at the same time poses a challenge: organising the competition takes a lot of time and there are many potential pitfalls. If you are interested in setting up a similar competition in your own country, you may find the following details helpful.

First of all, good project proposals are not easy to write. You will need to find researchers who are willing to share their ideas and to put time and effort into the project. Next, their proposals should be checked for relevance, cultural acceptability and constraints such as intellectual property rights. This is a case-by-case exercise, requiring continuous attention throughout the year.

Motivating school students to join in is another challenge. You need to be aware of the national school system so that you can make the most of opportunities for project work within the curriculum. Attending teachers' conferences can help you to understand the challenges that teachers and students face.

Finally, carrying out technical projects in developing countries can pose problems. The history of development aid clearly shows the dangers of transmitting Western ideas to other cultures without adapting them: projects will not succeed if they do not fit into the local culture. The success of a project is not necessarily determined by its innovation, but by practical demand, cost-effectiveness, self-sufficiency and time constraints.

The key to addressing these challenges lies in interacting with the relevant networks. Cooperating with organisations that already have well established relationships with researchers, schools (for example the communication department of your university), or development organisations will help you to avoid some of the pitfalls.

The organisation of such a competition offers a steep learning curve and requires determination and enthusiasm from the organisers as well as from all those volunteers who are

BACKGROUND

Imagine aims to:

- Make young people aware of pressing issues around the globe and encourage them to take action
- Show them what role life sciences can play in alleviating urgent problems in developing countries
- Challenge life scientists to apply their expertise and tackle those problems
- Turn the combined efforts of scientists and school students into action
- Implement valuable projects where they are most needed and build on existing capacities.

willing to put in their time and effort. But seeing the projects succeed is very rewarding. By making these innovative ideas work in practice, Imagine encourages scientists, school students and people around the world to share their ideas in the life sciences.

Resources

The Foundation supports the establishment of similar competitions in other countries. If you would like further information, email info@foundation-imagine.org or telephone +31 15 278 6626. More information on the Imagine school competition is available here: www.foundation-imagine.org

Image courtesy of Foundation Imagine

Presentation during the final

The finalists present their proposals during an international conference

Image courtesy of Foundation Imagine

REVIEW

The article describes a current competition in the Netherlands that encourages (senior) students to develop business plans for ideas to aid developing countries which have been proposed by life-sciences researchers. Obviously, the organisation of a similar competition in another country would be a major undertaking but the benefits such a competition would bring to all of those concerned are innumerable.

During the competition, students gain an understanding of real-world problems, as well as experience of working with professional life scientists to understand and develop practical solutions to specific problems. Students also gain an understanding of the world of business and commerce as they are expected not only to explain the science behind the proposal to a lay audience, but also to provide the audience with costings and other development issues. Students are also expected to create a promotional video with the assistance of a professional producer – again an amazing experience for them.

Something that seems novel is that students actually receive instruction on many of the skills they will need during the completion, such as presentation skills. Such skills are extremely transferable and cannot help but increase the students' employability.

As an added advantage, the winning students are given the once in a lifetime experience of travelling to a developing country and seeing their work take shape and have a real effect on a community or family; something that they will never forget.

Mark Robertson, UK

Science centres working with schools: using peer-to-peer teaching to engage students

Sheena Laursen from Experimentarium in Denmark describes how the centre's Xciter project helps students motivate each other to delve deeper into science.

The Danish ROSE (Relevance of Science Education)[w1] investigation shows that science is not popular among 15-year-olds at school. Very few students – particularly girls – see science as the foundation for a promising career. If we wish to motivate young students to take a greater interest in science subjects, we need to look at new ways and new perspectives of teaching science in schools.

The Xciter perspective

The Xciters project[w2] combines the experience of communicating science in informal settings such as science centres with the more formal approach that exists in school settings. As a science centre, Experimentarium[w3] has a long tradition of communicating science by actively involving the audience; school-teachers attached to this project bring not only great experience in teaching science but also an in-depth knowledge of their students' understanding of science.

Image courtesy of Experimentarium

BACKGROUND

Comments on Xciters

From teachers

Bente Kold-Christensen from Maglegaard School near Copenhagen has participated in Xciters with students from three classes. Bente is currently educating new Xciters in close collaboration with former Xciters.

"It is a task I am looking forward to, as it will show whether we are able to give other children the same wonderful experience of passing science on to fellow classmates as the original Xciters had. It has to be cool to be good at science. All the students in my Year-8 class (age 14) are now experienced Xciters. The method is a great way of engaging students in science lessons. One of my colleagues recently saw my students in their role as Xciters and commented that if he hadn't seen their concentration with his own eyes he wouldn't have believed it! That's when you realise what a pleasure it is being a teacher."

Jeppe Thygesen from Gorlev School in the south of Zealand in Denmark has just completed the full Xciters course.

"It is a good way to work with science in school. It creates a broader focus and also a better environment for learning about science. The students' own knowledge and confidence grows as they pass on their knowledge and experiences, which they do very well.

Connecting science with everyday life also means that the facts are more easily remembered. The project has given the younger classes a good insight into the world of science and many of the younger students have asked if they can come back and see the 'bigger children' performing their experiments."

From students

"You learn a lot when you have to teach others."

"I didn't think I would be so good at this, but I found out that I actually was quite good."

"Our science subjects have become so wonderfully different, because you can't predict what is going to happen."

What is an Xciter?

Xciters are young science communicators in Year 6 (ages 13-14) who become catalysts for the project by spreading their knowledge and inspiring their peers. The overall goal of the Xciters project is to motivate older school students in Denmark (ages 12-16) to become more interested in science topics, and to increase the status of science subjects among these students. Xciters are interested in science, like to experiment and want to pass on their knowledge. The Xciters course gives them both the tools and the ability to achieve this.

In the long term, the Xciters project could encourage more students to choose further scientific studies and careers. Xciters is one of the activities in the PENCIL project[w4] and has gained funding from the Egmont Foundation to continue for five more years.

How Xciters works

Three students (ages 13-14) from each science class and their teacher apply to take part in a science communication course at Experimentarium. Those who are selected take part in two three-day training courses run by science education experts and explainers from Experimentarium. The courses, which take place during school time, mix scientific knowledge, hands-on experiments and communication tools, presenting new methods of teaching to the teachers and students.

As fully qualified Xciters, the young science communicators return to their schools and share their knowledge with fellow students through a combination of experiments and dialogue. They lead workshops for fellow Year 7 students, training all students in the year as Xciters and sharing with them their excitement about the project. The Xciters then work in pairs on peer-to-peer presentations for younger students (one or two years younger): planning which experiments to show and how to interact with their audience of up to eight fellow students.

Image courtesy of Experimentarium

Over the course of the year, Experimentarium visits the schools and stays in close contact with teachers. Teachers can read and download material on the Xciters website[w2] and contact Experimentarium staff if they have questions.

A series of scripts with detailed facts about the scientific topic supports the students in their mentoring efforts. Typical biology, physics or chemistry topics include the lung and the body's circulation, the physics of sound, and various states of water. A 'tips and tricks' manual provides the students with good science communication advice and tools. In the teacher's manual, inspirational pieces demonstrate how to present the different topics and how to communicate effectively.

Teaching materials on three topics can be found on the Xciters website. For example, in the 'eye' materials (available in English), students are guided through the steps of an eye dissection and are provided with the necessary factual knowledge such as the physiology of the eye and how lenses work. In addition, there are suggestions for involving the audience, creating dialogue, and questions to ask.

Peer-to-peer inspiration

Xciters is inspired by the 'learning by teaching' strategy or 'peer-to-peer' teaching often used in Danish schools when the focus is on emotional topics. This approach helps young people to discuss openly on a level they can refer to and understand. One advantage of using peer-to-peer teaching in science is that it puts the subjects into a context that is attainable and 'cool to be a part of'.

The pedagogical idea behind the project is that working toward communicating science is more motivating than just listening. Preliminary results indicate that the Xciter students become more interested in science. They also develop confidence in their communication skills, abilities and their knowledge of science subjects. Whether the students taught by the Xciters benefit is yet to be evaluated. What we do know is that the students taught by Xciters talk a great deal about what they have learned and about the experience afterwards, that the bond between the younger students and the older Xciter students is strengthened, and that the younger students look up to the older ones. Many have asked their teachers if they could become Xciters when they are older.

BACKGROUND

PENCIL

Xciters is one of the activities in the PENCIL project[w4] (Permanent EuropeaN resource Centre for Informal Learning). PENCIL, co-ordinated by Ecsite[w5] and funded by the European Commission as part of the NUCLEUS cluster[w6], aims to strengthen the operational relations between schools and informal science education in science centres and museums. Fourteen science centres and museums have developed pilot activities in partnership with teachers and schools; material is already available online. Academic and school partners are now working to identify key ways to transform informal science activities into innovative, high-quality tools for science teaching.

BACKGROUND

Experimentarium

Experimentarium is a science communication and activity centre for nature, technology, health and the environment. The aim of Experimentarium is to promote interest in natural science and technology. Since it opened in 1991, 5.6 million people have visited Experimentarium. Of the annual 350 000 guests, 110 000 are school visits. As well as housing science exhibits, Experimentarium develops a diversity of science communication and outreach projects, often in close collaboration with schools.

The Xciter method attracts both girls and boys, and they inspire and learn from each other. It seems that the girls naturally employ a communicative approach and boys seem to learn from their enthusiasm, whereas boys seem to be more confident in their knowledge and plunge into experiments from which, in turn, the girls learn.

Qualitative and quantitative evaluations

The first annual evaluation of participating teachers indicated that the project is fulfilling its primary objective: to increase interest in scientific subjects among the school students involved as Xciters. This ongoing evaluation by the Danish University of Education combines both qualitative and quantitative methods.

The beauty of Xciters is that the project need not be limited to school science – it can also be implemented and employed within other subject areas and educational fields. So the opportunities it offers to the scholars of today and tomorrow are many and varied.

Web references

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

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

and the ROSE study website: www.ils.uio.no/english/rose

w2 – The Xciters website: www.xciters.dk

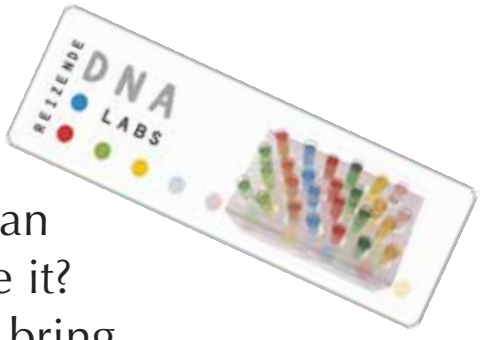
w3 – The Experimentarium website: www.experimentarium.dk

w4 – Information about PENCIL is available on the Xplora website: www.xplora.org

w5 – The website of Ecsite, the European organisation representing science centres and museums: www.ecsite.net

w6 – Information about NUCLEUS is available on the Xplora website: www.xplora.org

DNA labs on the road



Ever wished you could borrow a PCR machine for your lessons? And perhaps an expert to show your students how to use it? **Marc van Mil** introduces DNA labs that bring genomics directly to the classroom.

Gerrianne and Marianne, biomedical students at Utrecht University, the Netherlands, are getting ready to leave for Amsterdam. They have just packed their vehicle with a PCR machine, gel-electrophoresis equipment and all the materials necessary to turn a classroom into a real DNA laboratory. The pupils of the St. Nicolaaslyceum in Amsterdam are excited. A few days ago, they started the module 'Read the language of the tumour' with an introduction to DNA and cancer. Today, during the practical part of the module, they will be real DNA researchers and compare DNA from cancer cells of a (fictitious) patient with DNA of healthy cells. Based on their lab results, they must then advise a physician on the optimal treatment of this particular patient. This may seem like science fiction but it is business as usual in the Netherlands. Every weekday, university students travel in vans loaded with lab materials to secondary schools throughout the country to teach the latest in genomics research.

Gel electrophoresis is used to compare genes in healthy cells and tumour cells

Image courtesy of Marc van Mil

★★★

Mobile DNA labs

The DNA lab 'Read the language of the tumour' is one of five mobile DNA labs travelling through the Netherlands. Five Genomics Centres of Excellence from the Netherlands Genomics Initiative[w1] each developed a mobile DNA lab; they have been offered free of charge to all secondary schools in the Netherlands since January 2006. The four-hour educational modules for secondary-school pupils (ages 16-18) include a two-hour practical lab taught at school by university students with up-to-date genomics equipment and techniques. Teacher and pupil manuals are specifically developed for each lab and provided in advance so as to optimise the learning experience. Teachers can obtain additional information and register for the labs on the DNA lab website[w2].

The university students bring all the equipment, from pipettes to PCR machines and even a fluorescent microscope. They turn the classroom into a real genomics laboratory.

The experiments in the five DNA labs differ, but in all cases the pupils perform the real hands-on laboratory activities in their own classroom. They isolate DNA and use the PCR technique to analyse it, culture yeast in different conditions to measure the production of ethanol, crystallise proteins and use bioinformatics tools to look at protein structures.

DNA research in context

The five DNA labs deal with different topics in the life sciences: from producing bio-fuels to plant breeding, from using bioinformatics in crime-scene investigations to improving the treatment of diseases like Alzheimer's and cancer. Although these subjects may appear to be very different, they all rely on genomics research. More importantly, the DNA labs provide a context in which new insights in genomics are used to solve everyday problems. For instance, to increase the number of people who survive cancer, we need to know about specific mutations in DNA that turn healthy cells into cancer cells.

BACKGROUND

Spreading the idea...

If you would like to set up a similar project in your own country, the organisers of the DNA labs would be happy to offer advice. Contact the Education Officer, Marc van Mil (M.H.W.vanMil@UMCUtrecht.nl).

Developing the DNA labs

Developing the DNA labs was an initiative of the genomics research centres in the Netherlands. Within these centres, state-of-the-art knowledge about current genomics research is easily accessible. However, a good module for high-school pupils requires more than just the latest insights in research. Success of the DNA labs has depended on a close collaboration with high-school teachers and education professionals during development and testing.

In current science education, there is the belief that teaching science concepts using contexts makes them more meaningful, i.e. starting from science applications and implications in different practices, which in turn can empower consumers, patients and citizens of a democratic society. The DNA labs were developed in line with the recommendations of the Committee for Innovation in Biology Education on context-concept approach. In the Dutch high-school curriculum, DNA is an important yet rather isolated topic that pupils often perceive as complex and highly abstract. By teaching DNA within a meaningful context as a starting point, it becomes very clear why learning about this subject is so important.

University students

University undergraduate students play an essential role in this project. They are the ones who go into schools to teach the practical part of the module, serve as 'ambassadors' for science and provoke all sorts of questions from pupils about working in science and studying it at university. They thus serve as young and inspiring role models. For the undergraduates, this is a challenging job since it is often the first time they are actively involved in science communication and education. This experience provides them with the basic communication skills essential for all scientists and equips them with the tools to inform the general public about their work in a meaningful way. By teaching the DNA lab, students realise that teaching is not easy, but it is a very inspiring task.

Image courtesy of Marc van Mil

Pupils discuss how to isolate DNA from cow tissue

Before their first school visit, the students receive three days of intensive training. They are not only trained in didactic skills and dealing with a classroom full of pupils, but

Only a very tiny amount is needed for DNA analysis

Image courtesy of Marc van Mil

also taught to consider the role of scientists in genomics education and communication.

Evaluation of the DNA labs

The goal of the DNA labs is to offer relevant and up-to-date genomics education in the Netherlands, based on new insights in didactics. After more than a year of running the mobile DNA labs, we can now conclude that they are a great success. Pupils, teachers and university students are very enthusiastic. By July 2007, the heavily booked labs will have reached over 25 000 pupils in 275 different schools in the Netherlands. Furthermore, an independent evaluation has shown that the DNA labs promote understanding of the possibilities that genomics research offers for society and that they stimulate a positive attitude towards genomics.

For the students at genomics centres, the DNA labs are their favourite outreach activity. For teachers, DNA labs offer a unique opportunity to get modern equipment and the latest scientific insights into their schools. For the pupils, it is a very motivating and fun way of learning. International peer-review committees of the genomics centres have commented very positively on the DNA lab initiative and have recommended expanding it to other European countries.

The DNA lab organisers hope to work with other interested research institutes in Europe to develop an international platform for sharing experiences and improving education projects. Ultimately, the goal is to incorporate new insights into DNA research in the regular high-school curriculum. Schools should not have to depend on projects like these to gain access to new developments in science; they should be part of the curriculum. Research centres could help to use the latest insights to update the curriculum and have an important role in opening their doors to schools and sharing their discoveries and new developments in science. The mobile DNA labs are a good example of how this task can be achieved through a collaboration between all relevant parties. Scientists in research institutes have the knowledge, while high-school teachers and education professionals have the experience to develop meaningful education and teach in a way that suits high-school students. The DNA labs show that if these professionals work together, science education can be innovative, challenging and exciting.

The practicalities

Setting up the mobile DNA labs cost a lot of money. The power of the project is that the equipment the university students bring into the school is usually not available in a secondary school. The equipment for the mobile DNA labs costs several thousand Euros, but it is used in more than 100 different schools per year. If you wanted to set up a similar project at a lower cost, you could perhaps use old materials that are no longer needed.

Taking the equipment to the schools requires not only a van, but also good contacts with the schools and good logistics. However, the alternative of inviting pupils to the research centres is less effective. By going to the schools, the DNA labs can reach stu-

REVIEW

After reading this article, I wished that I worked in a Dutch school and had the possibility of having a mobile genetic engineering lab come to my classroom. If you are teaching biology to students aged 15-18 and want to bring practical work with DNA to your students, I really recommend reading this article.

Sølve Tegner Stenmark, Norway

dents all over the Netherlands (admittedly a rather small country) and teachers do not have to arrange transportation and a whole day off for their pupils. This makes the DNA labs a very accessible activity.

A further cost is the money paid to the undergraduates involved. An alternative, however, would be to incorporate the DNA lab activities into the university curriculum, as part of a science communication course.

★★★

After an hour and a half of hard work, the pupils in Amsterdam examine the results of their DNA analysis. In the next lesson they will reflect on their results and write to the physician with advice regarding the optimal treatment of the patient. After packing up the lab, Marianne and Gerrianne take a look at the notes the pupils left behind. Comments range from "Interesting!" to "Great fun!" and "Fascinating!". Satisfied, they load the van to return to Utrecht, ready to prepare for another day of DNA labs on the road.

Web references

w1 – The website of the Netherlands Genomics Initiative: www.genomics.nl

w2 – English version of the DNA labs website: www.DNAlabs.eu

w3 – The website of the Cancer Genomics Centre: www.cancergenomics.nl

Resources

For more information on genomics for high-school students (in Dutch), see: www.watisgenomics.nl

Marc van Mil is the Education Officer at the Cancer Genomics Centre[w3], based in the University Medical Centre Utrecht, the Netherlands. After his degree in biotechnology (specialising in education), he developed and tested the DNA labs; he then moved on to train undergraduates to perform the DNA lab.

Marc clearly loves his job: "I can combine my knowledge of cancer and genomics with my passion for teaching. I really like training the undergraduates. Before that, I performed the DNA lab myself more than thirty times in different schools and in workshops for teachers and the general public. I hope that our enthusiasm for the DNA labs will inspire the students and make the difference in the classroom."

It worked: this slimy bulb is DNA

Image courtesy of Marc van Mil

Image courtesy of Iris Hendriks, IMEDEA

Why biodiversity research keeps its feet dry

Some biodiversity researchers do get their feet wet. For instance, in sea-grass meadows (with *Posidonia*) near the coast of Mallorca, Spain

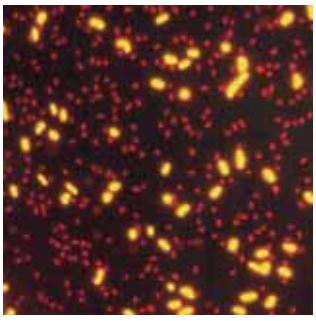
Marine ecologists **Iris Hendriks**, **Carlos Duarte**, and **Carlo Heip** ask why – despite its importance – research into marine biodiversity is so neglected.

Biodiversity on land receives much more attention – and attracts much more funding – than biodiversity in the oceans. This leaves 71% of the Earth's surface unprotected and relatively un-researched (Hendriks et al., 2006). The sheer depths of the oceans are similarly undiscovered: according to the Census of Marine Life[w1], 95% of all known species of ocean life are recorded close to the water surface. By contrast, species observed below 2 km account for fewer than 0.1% of known species. If you were to collect a fish or bacterium at this depth, it would very likely be a species never before described!

Modern marine researchers use a wide range of methods, both underwater and on dry land, to study oceanic biodiversity – they may send a submarine to the depths of the ocean in search of specimens, then analyse DNA samples in the laboratory. They explore the extent, value and function of life in the marine ecosystem (see box), and investigate who eats whom, and how this affects the nutrients in marine ecosystems locally and worldwide.

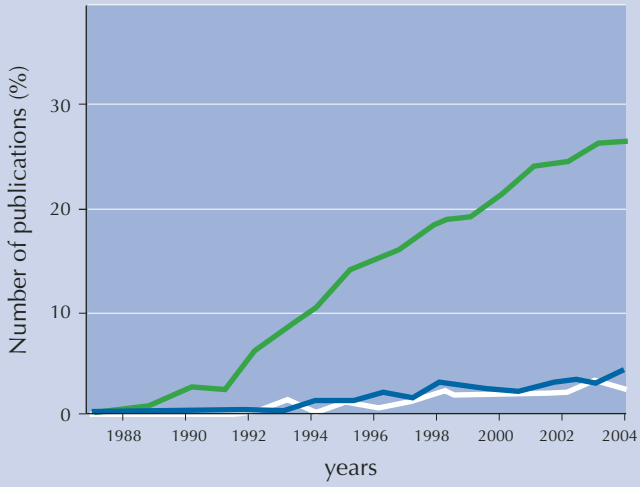
Image courtesy of Ute Wollenzien & Lucas Stal, Netherlands Institute of Ecology

Images courtesy of Ute Wollenzien & Lucas Stal, Netherlands Institute of Ecology



Who said marine microbes are not attractive? Together, the micro-organisms make up most of the ocean's biodiversity and 90% of its biomass

Images courtesy of Iris Hendriks, Carlos Duarte & Carlo Heip



If you take the number of scientific publications per year as a measure, the effort put into biodiversity research in terrestrial (green), freshwater (white) or marine (blue) habitats is clearly different. More people and money are needed for sea research!

Despite a valuable array of products from biological sources, some of which have been used in the battle against infectious diseases and cancer (Maris, 2006), commercial companies are not yet enthusiastic about 'bioprospecting'. It is difficult to produce high yields from invertebrate cultures, and the biotechnology industry claims that promising leads come faster and more frequently from a combination of chemistry and synthetic techniques.

By contrast, interest in marine micro-organisms – as a source of natural compounds and potential bases

BACKGROUND

Biodiversity and ecosystem function

Trillions of organisms move hundreds of thousands of tons of chemical elements and compounds between the water, air and earth every year. This cycle ensures the fertility of soils and the quality of water and air. We are still learning how these organisms work together to form an ecosystem, and what happens when a species is introduced or lost.

There are three major hypotheses to explain how an ecosystem reacts when it gains or loses a species. First, one species may compensate for the loss of another by taking over its role in the ecosystem. In this scenario, a new species would add nothing to the ecosystem that was not already offered by the 'flexible' species present. In the second scenario, each species' contribution is considered unique, and any loss or addition causes detectable changes to the ecosystem. Third, the effects of the loss or addition of a species depends on external variables, such as climate, and cannot be predicted.

Experimental manipulation of oceanic ecosystems is not easy, so scientists test these hypotheses by using mixed species of herbs and grasses instead. By growing a small number of plant species and comparing their growth and yield, the effects of the addition or eradication of a species can be studied. Although the interpretation of these grassland experiments and their applicability to other ecosystems is not straightforward, the investigations provide a model with which to test and further develop ideas.

Other 'natural' experiments can also provide valuable insight: the warming of the Earth and increased ship traffic across oceans can cause species to shift; and 'exotic' species can invade ecosystems and outcompete local inhabitants.

Images courtesy of Netherlands Institute of Ecology

Marine biodiversity is huge

for future medicines, foods and biotechnological products – is beginning to grow. Microbes may not seem as interesting as furry and feathered land animals and colourful plants, but they are an important part of ecosystems and food chains[w2]. And unlike invertebrates, they can be grown in large flasks and produce much higher yields. Marine researcher William Fenical and his colleagues from the University of California, San Diego, USA, for example, derived a compound from *Salinospora*, a bacterium found in deep-ocean sediment. It binds selectively to a protein found in tumour cells, and is now undergoing clinical testing for efficacy against multiple myeloma, a type of blood cancer.

A great loss

The marine environment faces many problems, including commercial fishing, coral bleaching, invading species, ecosystem degradation and extinction. Over-fishing and hunting of megafauna, such as large predatory fish (Myers & Worm, 2005), have removed much of the oceans' fish biomass. Key coastal habitats that nourish marine biodiversity and provide key functions to society – such as mangroves, sea-grass meadows, salt marshes and coral reefs – are declining between two and ten times faster than tropical forests. Excess nutrients, sedimentation and contaminants are leading to a widespread deterioration of water quality, promoting oxygen deficiency and a loss in biodiversity near coasts (Lotze et al., 2006).

Another crucial problem is acidification caused by increasing CO_2 emissions. This is a global threat, as acidic seawater can eventually dissolve or disintegrate calcifying marine life such as coral reefs, mussels, and uni-

Image courtesy of Netherlands Institute of Ecology

Small but perfectly formed

cellular planktonic organisms. This is damaging not only to nature but also to the economy, as bivalves like mussels and oysters are important food sources. Healthy coral reefs are also crucial, as they house many commercially important fishes and support ecotourism. So how can we solve this global problem?

Effective?

Although more than two-thirds of the Earth's surface is covered by water, protected marine areas account for only 2.1 million km^2, compared with 17.1 million km^2 of protected terrestrial environment. Paradoxically, the major difficulty in creating marine nature reserves is the fact that the oceans are the patrimony of all nations: governments have been unwilling either to take unilateral action or to co-operate in preserving our marine heritage. Furthermore, evidence for extinctions in the ocean is still scarce: demonstrating extinctions is difficult when much of biodiversity of the oceans remains to be discovered.

Most protected marine areas are smaller than 100 hectares: far too small to be effective. Only the Great Barrier Reef in Australia (more than 345 000 km^2) and a newly protected area near Hawaii, USA (360 000 km^2), approach the effective size (Mora et al., 2006). Also, most protected areas are isolated, whereas evidence suggests that food webs are connected across oceans. To design a network of protected areas that truly preserves biodiversity, we need to better understand the connections between ecosystems.

Disconnected

Although links between ecosystems are significant, it is important not to overestimate the degree of connectivity. Conventional wisdom holds that extinctions are unlikely in the oceans, because marine organisms can be carried easily from place to place, replenishing populations that die out. However, recent research indicates that marine species may not be as widespread, populations might not be as interconnected, and the marine environment is probably not as resilient to extinction as was once thought. For example, recently discovered deep-sea habitats such as hydrothermal vents, cold seeps, brine lakes and whale carcasses harbour specialised communities that are isolated by hundreds or thousands of kilometres of sea floor.

Luckily, despite a bias towards terrestrial research, studies on marine biodiversity have increased greatly over the past few decades. Scientists must design effective marine reserves, elucidate food-web mysteries and find new species before it is too late. But we can all look after our oceans to preserve their biodiversity: be conscious of what fish we eat[w3], value all species, join conservation societies, urge our governments to act (together), and participate in sea and coastal observations. It is time to get our feet wet!

References

Hendriks IE, Duarte CM, Heip CH (2006) Biodiversity research still grounded. *Science* **312**: 1715

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JB (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* **312**: 1806-1809

Maris E (2006) Drugs from the Deep. *Nature* **443**: 904-9054

Mora C, Andrèfouët S, Costello MJ, Kranenburg C, Rollo A, Veron J, Gaston KJ, Myers RA (2006) Coral reefs and the global network of Marine Protected Areas. *Science* **312**: 1750-1751

Myers RA, Worm B (2005) Extinction, survival or recovery of large predatory fishes. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* **360**:13-20

Web references

w1 – The Census of Marine Life is a worldwide project, with educational information and links to outreach programmes at www.coml.org

w2 – The International Census of Marine Microbes makes an inventory of the smallest life forms in our oceans, with a large database at http://icomm.mbl.edu/microbis/

The micro*scope site at http://starcentral.mbl.edu/microscope/portal.php and Microbial Life at http://serc.carleton.edu/microbelife/ are also useful sites for educators and their pupils.

w3 – Fish Online lists species that are fished responsibly: www.fishonline.org/advice/eat/

w4 – The EU Network of Excellence MarBEF (Marine Biodiversity and Ecosystem Functioning) has an outreach section with information for schools: www.marbef.org

Resources

The EurOcean website includes an overview of useful links: www.eurocean.org/categories.php?category_no=138

Image courtesy of Netherlands Institute of Ecology

Showing the diversity of marine life to people is very important

SeaOnScreen at www.seaonscreen.org (also ZeeInZicht at www.zeeinzicht.nl [in Dutch]), and Expeditie Zeeleeuw at www.expeditiezeeleeuw.be (to be replaced by Planeet Zee in 2008), are also useful.

The Marine Conservation Society is a UK charity dedicated to caring for our seas, shores and wildlife. It provides links to many useful sites, including marine societies and initiatives in other countries. See: www.mcsuk.org

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We would like to thank Froukje Rienks, science communicator at the Netherlands Institute of Ecology, for helping to write this article.

REVIEW

Although biodiversity is considered within many curricula, it is frequently restricted to the land. Oceanic biodiversity is much greater and yet less explored; some of the reasons for this are provided here.

This article can be used in class to stimulate thought and conversation, for example on the problems facing oceanic research, how over-fishing affects the environment, and how increasing sea temperatures affect habitats.

Shelley Goodman, UK

Fusion in the Universe: when a giant star dies...

Péter Székely from the University of Szeged, Hungary, and **Örs Benedekfi** from the European Fusion Development Agreement in Garching, Germany, investigate how a star dies and what a nearby supernova explosion would mean for us on Earth.

At 7:35 in the morning of 23 February 1987, a kilometre below the ground, the Japanese neutrino detector Kamiokande II registered 11 neutrinos in 15 seconds. This does not sound very dramatic, but neutrinos are hard to detect because they interact very weakly with matter. Normally, the detector registers only a couple of neutrinos per day from the Sun, so this indicated a spectacular event somewhere in the Universe: a giant star had died.

Size is everything

Probably the single most important property determining the fate of a star is its mass. As described earlier in this series (Boffin & Pierce-Price, 2007), stars with a similar mass to our own Sun die without any upheaval: they fuse helium into carbon and oxygen, then release their outer layers as a planetary nebula and over billions of years, the core cools down to form a white dwarf.

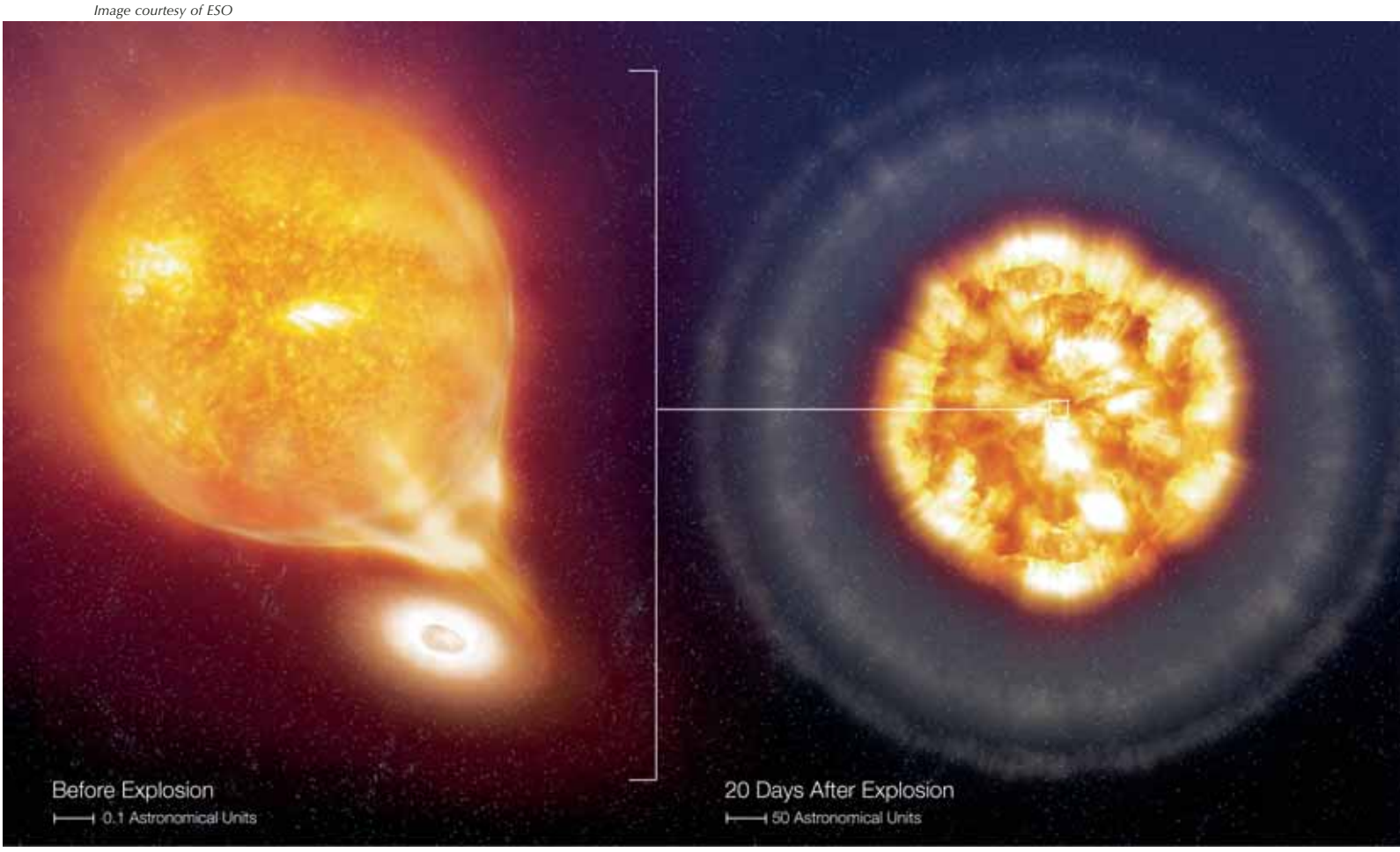
More massive stars have a shorter lifetime and more violent destiny. Whereas a star the size of our Sun can live for billions of years, stars that are eight to ten times the mass of our Sun last only millions of years because they rapidly run out of fuel. When this happens, the equilibrium is lost between two fundamental forces: gravity, which tends to contract the matter of the stars; and radiation pressure produced by nuclear fusion reactions in the core, which tends to expand the star. The core contracts to form a neutron star and the outer layers of the star fall inwards and rebound from the very dense core in a gigantic explosion: a Type II supernova.

Waves of particles, including neutrinos, leave the core, carrying the gravitational energy of the collapsing star. The infalling outer layers of the star absorb many of these neutrinos, giving rise to extremely high temperatures – hot enough to trigger the fusion of elements including gold and uranium (as described in Rebusco et al., 2007). A small proportion of these neutrinos, however, escapes the atmosphere of the dying star and can be detected on Earth, in the silence deep below the planet's surface.

A second type of stellar cataclysm occurs during the collision of a white dwarf and a much larger red giant with an expanded atmosphere (hundreds of millions of kilometres in diameter). If a white dwarf and a red giant orbit each other in a close relationship known as a binary star, the white dwarf can accrete material from its companion and increases in mass (see image). Once the white dwarf exceeds 1.44 times the mass of our Sun (the Chandrasekhar limit), it becomes unstable, fusion reactions produce heavy elements such as lanthanum and ruthenium, and the whole disintegrates in a giant explosion: a Type I supernova (see image).

Whether Type I or II, a supernova is one of the most powerful events in the Universe since the Big Bang. In the weeks after the explosion, the star and its remnants emit more energy than our Sun does over billions of years. This enormous explosion can outshine all other stars in its host

Image courtesy of ESO



An artist's impression of a white dwarf (bottom right) accreting material from a red giant star

Once the mass of the white dwarf has reached a critical limit, the star explodes as a Type Ia supernova

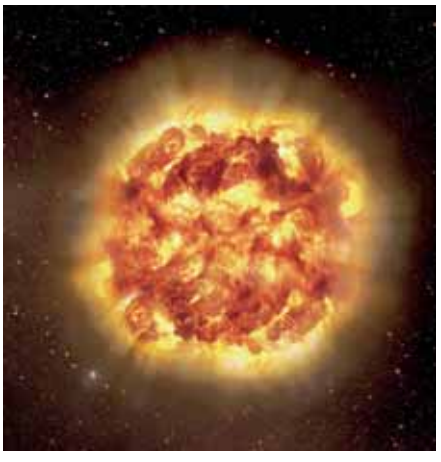
galaxy and the light can be detected from thousands of millions of light years away. Indeed, a supernova occurring anywhere in the Universe will probably be visible with a powerful telescope.

The remains of a star

So what remains after this violent and dramatic event? In the centre of the explosion of a star that is less than 20 solar masses is a newly formed neutron star, with the mass of the star packed into a sphere with a radius of only ten kilometres – unimaginably dense. The weight of one teaspoon of neutron star equals that of all the traffic vehicles (millions of cars, buses, trains) we have here on Earth (Swinton, 2006). Due to conservation of angular momentum (the smaller the radius, the faster the rotation), neutron stars often spin very rapidly (hundreds of revolutions per second); this may cause beams of radio waves emanating from the magnetic poles, in which case we describe the star as a pulsar.

An even more exotic kind of remnant than a neutron star or pulsar is a black hole, born when a star of at least 20 solar masses explodes in a Type II supernova. When such a massive star dies, the gravitational col-

Image courtesy of ESO



Artist's impression of a Type Ia supernova explosion

BACKGROUND

EFDA education and outreach

Many of the fusion research institutes in the European Fusion Development Agreement (EFDA) have their own outreach programmes, which often include lectures, and visits to schools and research facilities such as JET. Details of the individual research institutes are available on the EFDA website[w2]. Within the framework of EIROforum[w3], EFDA participates in *Science in School*, the Science on Stage[w4] festival and other outreach and education projects.

EFDA has produced a 60-page brochure for secondary schools, 'Energy, Powering Your World', giving a broad introduction to the world of energy. Topics include the ways we use energy in our daily lives, where it comes from, and how we will deal with our energy needs in the future.

To receive a free printed copy of the brochure, available in English, Dutch, Spanish, French, German or Italian, send an email to aline.duermaier@efda.org, including your name, postal address and the number of copies you would like (up to five). The brochure can also be downloaded from the EFDA website.

EFDA brochure for secondary schools

EFDA has a range of other educational materials available, such as a CD-ROM, 'Fusion, an energy option for the future', and a general poster on fusion, both of which can be requested via the EFDA website. The website also provides basic and more advanced information about fusion science.

lapse does not stop with the formation of a neutron star – instead, the infalling matter produces a very curious phenomenon with a theoretical volume of zero and infinite density. Nothing can leave the black hole or its close surroundings unless it exceeds the speed of light, but no light can escape the immense gravitational pull – hence the name.

As well as a neutron star or black hole, we can often observe the remnants of the star's gas clouds, which were blasted away by the supernova. One of these interesting objects is the Crab nebula: the remnant of the supernova that occurred around 5500 BC and was observed in 1054 by Chinese astronomers. Like the other remnants, it will disperse into the interstellar space over thousands of years.

Learning from supernovae

Even without the benefit of modern telescopes, a supernova in a nearby galaxy is hard to miss. The earliest observed supernova was recorded by Chinese astronomers in 185 AD. When the formation of the Crab nebula was detected in China some 800 years later, this 'guest star' was so bright that it could be seen in broad daylight for weeks.

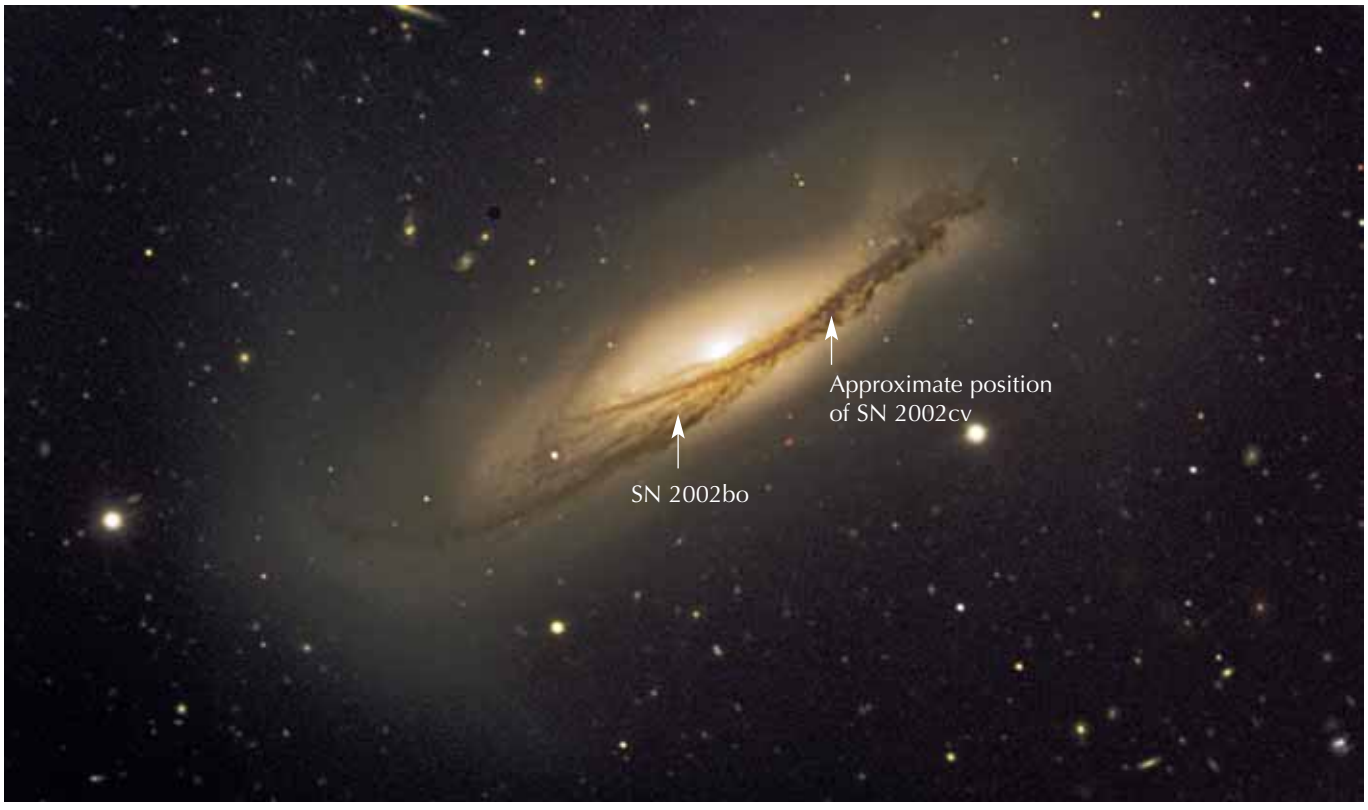
The maximum brightness of the individual supernovae explosions is very similar (we call them 'standard candles') because the exploding masses are similar. By comparing the expected brightness with the observable brightness, we can calculate how far away the host galaxy of the supernova is. This technique is very important in the 'cosmic distance ladder': it is so far the best method for measuring the distance of distant galaxies. And of course, it is one way to observe the early history of the Universe: by the time we see a distant cataclysm, the star itself has long since died.

Of course, astronomers not only want to know how far away a supernova's host galaxy is, but also want to characterise the individual supernova itself. They therefore use two indirect methods: photometry and spectroscopy. Photometry measures the diminishing brightness of the supernova over time and the maximum brightness: this is the technique used to calculate the distance of faraway galaxies. Spectroscopy allows the chemical elements in the supernova to be deduced on the basis of their characteristic wavelengths (as explained in Westra, 2007). Usually astronomers apply both methods to determine the physical properties of the dying star, such as its mass, temperature and luminosity.

Nearby supernovae?

So far, all observed supernovae have been a long way from Earth, but what would happen if a closer star became a supernova? Fortunately, supernovae are fairly rare, with only one supernova every 50 to 100 years

Image courtesy of ESO



The positions of SN 2002bo and SN 2002cv are marked in this picture of the spiral galaxy NGC 3190

in an ordinary spiral galaxy like the Milky Way. The last supernovae observed in the Milky Way were in 1572 and 1604, although vast and dense dust clouds could have hidden some explosions on the far side of our galaxy. The most recent and relatively close cataclysm was SN 1987A, which in 1987 ignited in the Large Magellanic Cloud, one of the smaller escort galaxies of the Milky Way, at a distance of around 160 000 light years (see image); this explosion was visible to the naked eye. Further afield, astronomers observe hundreds of supernovae explosions per year in other distant galaxies, sometimes two at the same time in the same galaxy[w1].

Fortunately, there is no star in our immediate neighbourhood (up to about 12 light years) that will turn into a supernova in the foreseeable future, although further away, astronomers have already identified some potential supernovae. Betelgeuse, the red supergiant at the left shoulder of the constellation Orion, is the best candidate, but this is around 450 light years from us. We think the safety zone is around 100 light years across: closer than this, and a supernova could seriously damage our planet. Of more concern is IK Pegasi – a binary star consisting of a white dwarf and an ageing normal star about 150 light years from us. Whereas Betelgeuse could blow up at any time from tomorrow to thousands of years hence, IK Pegasi will meet its fate sometime in the next few million years.

Effects on Earth

So what effects would a nearby supernova have on Earth? Supernovae produce vast amounts of gamma radiation and particles such as protons and electrons, all of which have very high energy and could destroy the Earth's atmosphere by degrading ozone and atomic oxygen. For example, gamma rays dissociate atmospheric nitrogen (N_2) into nitric oxide (NO) and other nitrogen oxides (NO_x) that catalyse the breakdown of ozone.

Without the protective ozone layer, ultraviolet rays from our own Sun would reach the Earth's surface unobstructed and destroy phytoplankton (microscopic plants that live in the water column). As phytoplankton form a fundamental component of the food chain, their loss would have a devastating effect on most other organisms. High-energy radiation would also damage living cells, causing cancer and genetic mutations: rather like a very heavy dose of X-rays. It is also possible that levels of radioactive elements in the atmosphere could increase, with harmful effects.

It may have been a supernova blast that caused the Ordovician-Silurian mass extinction approximately 450 million years ago. More than half of marine life forms were eradicated in

Image courtesy of ESO

SN 1987A in the Large Magellanic Cloud (marked with an arrow)

Image courtesy of ESO

This bright, compact nebula (SNR 0543-689) is the remnant of a recent supernova explosion

this event, believed to be the second largest extinction event on Earth in terms of the number of genera that died out. It is believed that the extinction was a result of both the destruction of phytoplankton and the reduction in global temperatures caused by the opacity of nitrogen dioxide (NO_2).

It is also possible that Earth suffered a close supernova explosion about 2.8 million years ago. During its explosion, a dying star unleashes a wave of radioactive elements which can be deposited on the surface of planets. Characteristic radioactive elements, for example iron-60, have been found when deep cores were drilled from the sea floor. These may be evidence of a supernova, but the debate is ongoing. More evidence of a recent and local supernova explosion is the Local Bubble, a cavity 300 light-years wide in the interstellar medium where our own Solar System is located. This bubble was created by various supernovae explosions, which pushed away the thin surrounding interstellar medium.

Our supernova origins

Fortunately those giant explosions have positive effects as well. We probably owe our existence to a nearby supernova. The shock wave from a supernova compresses the surrounding interstellar matter – a vast but thin cloud of dust, atomic and molecular gas – and triggers star formation. So perhaps a supernova caused the collapse of the enormous cloud from which the Solar System was born.

Furthermore, supernovae were the origin of everything we know: humans and everything from the smallest bacterium to the highest mountain are made from the ashes of stars. A normal star can produce lighter elements, but the fusion reactions forming heavier elements require the enormous temperatures and pressures prevailing in giant stars (for more details, see Boffin & Pierce-Price, 2007; Rebusco et al., 2007). These elements are formed and dispersed into interstellar space by supernovae, enriching the clouds of matter from which stars, planets and life arise. In a sense, we are children of supernovae.

Supernovae, therefore, have shaped our Universe and our history. They created the conditions for life on Earth by producing elements, they affected evolution by causing mass extinctions and now, by examining supernovae, we can learn a lot about the Universe and ourselves.

References

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

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

Swinton J (2007) The neutron teaspoon. *Science in School* **3**: 92. www.scienceinschool.org/2006/issue3/teaspoon

Westra MT (2007) A fresh look at light: build your own spectrometer. *Science in School* **4**: 30-34. www.scienceinschool.org/2007/issue4/spectrometer

Web references

w1 – To discover when and where the latest supernovae have detonated, see the Supernovae website, where scientists and amateurs hunt and register new supernova explosions: www.supernovae.net

w2 – The European Fusion Development Agreement (EFDA) website: www.efda.org

w3 – EIROforum website: www.eiroforum.org

w4 – Science on Stage website: www.scienceonstage.net

Small molecules make scents

Angelika Börsch-Haubold demonstrates the olfactory delights of organic chemistry.

Classroom activity: Experiment 1

Image courtesy of Angelika Börsch-Haubold

"Chemistry is all bangs and smells." Not all students of chemistry are drawn to the stenches and explosions in the laboratory. Fortunately, there are many organic molecules that actually smell nice. We experience these substances daily – using a perfumed shower gel, flavouring our meals with herbs, or burying our nose deep in a rose. Teaching the organic chemistry of natural scents should motivate even those who despise the toxic and dangerous side of chemistry to look at structural formulae and functionalities.

In order to be perceptible by our noses, chemicals need to be lipophilic, small (molecular weight < 300 Da) and volatile. Fragrant molecules escape from their fluid or even solid state into the air. The sensory tissue, called olfactory epithelium, is a mucous membrane which lies on the roof of the nasal cavity. Odorants reach this area (approximately 7 cm away from the nostrils) in the air we breathe; if something smells very faintly, we sniff two or three more times, forcing more air and fragrance towards the sensory membrane. There, the molecules dissolve in the mucus and then couple to smell receptors that are expressed on the

plasma membrane of sensory cells. The cells send nerve impulses to our brain, which learns to associate the smell with the original substance (such as a rose), lets us recognise it even when the object is hidden (such as when entering a house and knowing that a cake is in the oven) or classifies it as unknown (such as when we go to an exotic restaurant for the first time).

Similar chemical properties – similar smells

Arranging smells into a limited number of distinct classes is not as easy as defining the basic tastes (sweet, sour, salty, and bitter). Typical smell attributes are flowery (jasmine), spicy (ginger, pepper), fruity (ethyl acetate), resinous (resin smoke), foul (rotten egg), and burning (tar). Musk (muscone), camphor, rancid (isovaleric acid, butyric acid) and pungent (formic acid, acetic acid) are often added to this list. By concentrating more on chemical details, functional groups of fragrant molecules can be linked to characteristic odours (Table 1). The smells of *n*-aliphatic alcohols, for example, range from herbal, rose and woody to orange. By contrast, *n*-aliphatic acids smell fatty, sour, rancid or sweaty. Fruit scents are esters composed of short aliphatic organic acids with alcohols. Subtle differences in the chemical composition lead to distinct scents, such as the pineapple aroma of ethyl butyrate and the apricot aroma of pentyl butyrate. Vegetable smells often depend on organosulphur compounds. A ring structure with nitrogen might smell of roasted or fermented foodstuff, whereas aromatic alcohols (phenols) are components of smoked food.

Most of the examples in Table 1 are chosen from different types of food to make the odours easier to demonstrate. You could randomly distribute appropriate plant and food samples on a large surface, and ask students to group the exhibits according to their smell (you could help by providing the attributes 'floral', 'rancid', 'fruit', 'vegetable', 'spicy' and 'smoke'). When the students are done, let them compare their results with the chemical classification given in Table 1.

Bearing the structural characteristics in mind, the next question is how we use smell to distinguish between these differences in functional groups, sizes and overall shapes of molecules. In many physiological processes taking place at cell membranes, a recep-

Table 1: Classification of volatile organic compounds according to their functional groups and characteristic odours

Functional group	Source	Example	Smell
Alcohol **-OH**	Plants	Geraniol, linalool Menthol Aroma-active alcohols > c3	Fresh, floral Mint Sweet or pungent
Aldehyde; ketone **-CHO; >C=O**	Fat Milk products	Diacetyl	Like butter
Acid (C1-C12) **-COOH**	Cheese	Formic acid Capric acid	Pungent Like goats' milk
Ester, lactone **-COOR**	Solvent (these chemicals are used as solvents) Fruit	Ethyl acetate Methyl/ethyl butyrate Amyl/butyl acetate Pentyl butyrate	Glue Pineapple Banana Apricot
Pyrazine **aromatic =N-**	Roasted, cooked, fermented foods	2-isobutyl-3-methoxypyrazine 2-acetyl-tetrahydro-pyridine	Earth, spice, green pepper Popcorn
S-compounds: **aliphatic, aromatic**	Vegetables	Diallyldisulphide 1,2-dithiolane-4-carboxylic acid	Garlic Asparagus
Phenols (mono-, poly-)	Smoked food	Guaiacol Cresol	Wood smoke Tarry

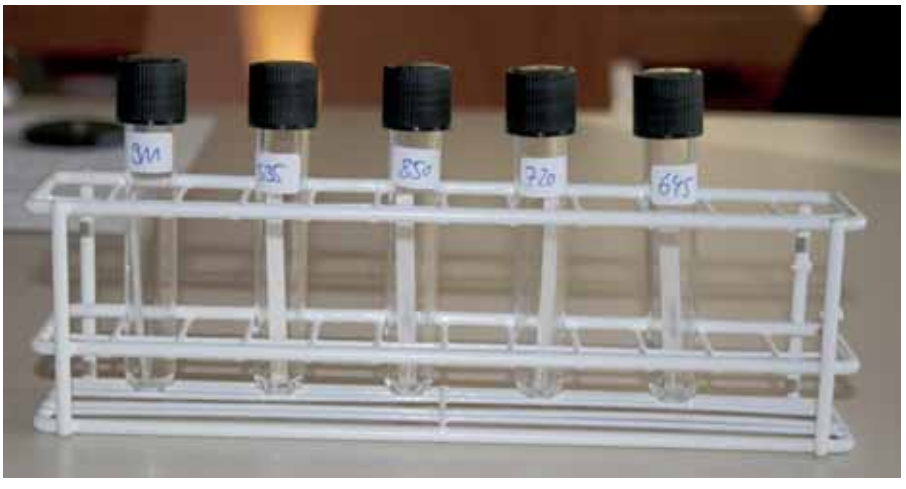
tor is activated after a ligand binds to its extracellular domain. This principle is often depicted as a key fitting into a lock – only the right key opens the corresponding lock – as the docking ligand has high specificity for its acceptor site on the receptor.

Odorant receptors

Some of the most fascinating features of the physiology of smell were discovered by the 2004 Nobel Prize winners Linda Buck and Richard Axel. In contrast to the simple but specific key-lock model that governs taste, smell is dictated by a whole set of sensory cells. One type of fragrant molecule interacts with more than one receptor type, so the overall sensation is created by the combination of activated receptors. When they tested a series of aliphatic *n*-alcohols on individual mouse neurons, Buck and co-workers found that clusters of olfactory neurons were activated. For example, pentanol weakly stimulated a receptor called S3; hexanol strongly activated S3 and S25; heptanol S3, S19 and S25; octanol S18, S19, S41 and S51; and nonanol S18, S19, S41, S51 and S83. Thus, a single odorant is recognised specifically by multiple odorant receptors working in combination.

Such a pattern of receptor activation creates a vast repertoire of perceivable odours. Indeed, it is estimated that we can remember about one thousand odours and distinguish between an order of magnitude more, depending on our age, experience and natural sensitivity. Our linguistic ability to name scents, however, lags far behind our nose's ability to discern them. The food industry trains experts to recognise subtle nuances of smells. For example, diluted essential oils or isolated compounds representing a certain aroma are applied onto a strip of odourless filter paper and placed into a screw-top glass vial (see right). You could offer your students oregano (1% carvacrol in propylene glycol), rose (1% essential oil in ethanol), lemon (10% essential oil in ethanol), cinnamon (5% cinnamaldehyde in propylene glycol), a fruit aroma (5% in propylene glycol) or bitter almonds (1% benzaldehyde in propylene glycol) in such an experiment. Either the student must choose from a list of about 20 odorants or he or she is asked to describe and name the scents without the help of given attributes (see Experiment 1 in the classroom activity[w1]).

An untrained person may correctly associate an odorant with its source or something that contains it, but still fail to identify the original substance. In a course on the sensory evaluation of food that I recently taught, only half of the students recognised the aroma of oregano; a quarter of them confused it with thyme or marjoram, which are closely related herbs; and others identified the scent as rosemary, basil and parsley, which are less closely related herbs with quite distinct flavours. However, some students correctly associated the odour with tomato soup, which may be flavoured with oregano. Two-thirds of the class recognised the smell of roses, some students associated it correctly with similar flowers such as lilac or melissa or with perfume, but others incorrectly suggested mint, medicine and spice. Almost all students recognised bitter almonds, mint and cinnamon, but failed to identify sage and coriander. When the solutions were revealed, everybody immediately recognised the smells that had previously eluded them, demonstrating that olfactory memory is far better than our ability to actually name a particular smell.



Sample presentation for a smell test. Glass vials contain filter paper strips that are soaked in diluted essential oil

Students identifying scents

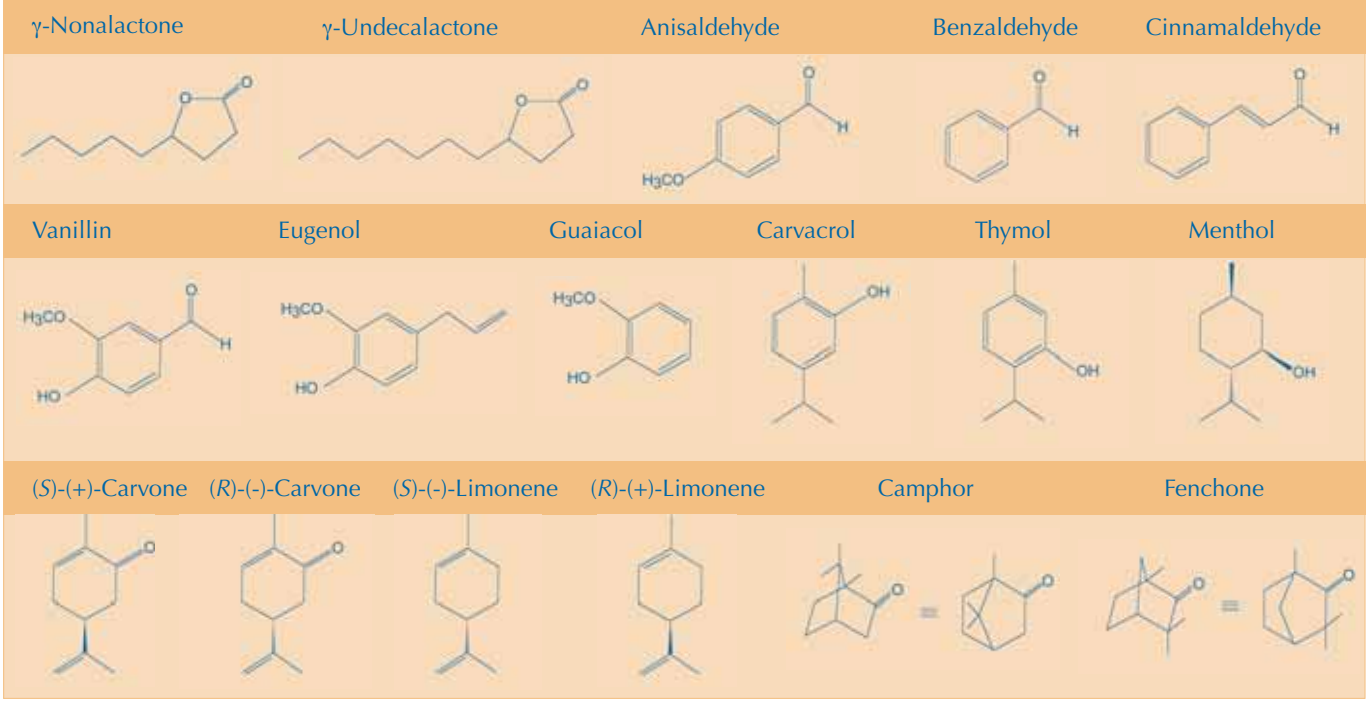
Images courtesy of Angelika Börsch-Haubold

Small changes in the chemical structure – distinct smells

The fine-tuning of our receptor machinery allows us to distinguish between chemically similar molecules. Many fragrances are derived from plants, and plant products can be used to demonstrate how small changes in the chemical structure of an odorant give rise to either completely different smells or at least distinguishable flavours (see illustrated structures). The examples are sorted by the following chemical principles:

1) Elongation of a carbon chain: adding two methyl groups ($-CH_2-CH_2-$) to the odorant of coconut, γ-nonalactone, gives the odorant of peach; inserting a vinyl moiety (-CH=CH-) into benzaldehyde (bitter almonds) yields cinnamaldehyde (cinnamon).
2) Exchange of a functional group: replacing the aldehyde group of the vanillin molecule with an allyl group ($-CH_2-CH=CH_2$) gives eugenol, the fragrance of cloves. The alcohol 1-butanol smells pungent whereas the corresponding carboxylic acid (butyric acid) smells like rancid butter or vomit.
3) Addition of a functional group: adding a methoxyl group to benzaldehyde changes its smell from bitter almonds to aniseed.
4) Position of the functional group: carvacrol, which has an -OH group next to a $-CH_3$ group, smells like oregano, whereas thymol, which has an -OH group next to a $-CH(CH_3)_2$ group, smells like thyme; 1-propanol smells ethanol-like, whereas 2-propanol smells sweet (the numbers reflect the position of the -OH group).

Images courtesy of Angelike Börsch-Haubold



Chemically similar compounds smell different

Image courtesy of Angelika Börsch-Haubold

Lavender

Image courtesy of Angelika Börsch-Haubold

Aniseed

5) Exchange of aliphatic and aromatic rings: replacing the benzene ring of thymol with cyclohexane produces menthol which smells completely different.
6) Stereochemical differences: usually, one enantiomer of a chiral flavour molecule elicits a strong odour whereas the other is weak. Notable exceptions are (*S*)-(+)-carvone (the aromatic ingredient of caraway seeds) and (*R*)-(-)-carvone (spearmint). (*S*)-(-)-limonene smells like turpentine (pine) but (*R*)-(+)-limonene has the odour of oranges.

However, there are compounds that are structurally unrelated but smell similar. Cyclooctane, camphor and 1,8-cineol all have a camphoric odour, although cyclooctane consists of an all-carbon single ring structure (C_8H_{16}) whereas camphor and 1,8-cineol are both bicyclic molecules with a functional group containing oxygen . The so-called 'green note' of unripe fruit and vegetables, which is added to cosmetics for a scent of 'freshness', comes from a group of closely related C6 aldehyde compounds (*cis*-3-hexenal: fresh tomatoes; *cis*-2-hexenal: green apples; *trans*-2-hexenal: green and black tea, fresh tomatoes). Similarly, the alcohol *cis*-3-hexenol (freshly cut grass), the C9 aldehyde 2-*trans*-6-*cis*-nonadienal (cucumber peel), an aldehyde attached to a ring structure (the grassy-smelling ligustral) and even some pyrazines (2-propyl-3-methoxypyrazine: bell peppers) have this 'green note'.

Plants are nature's perfume factory

By using the wide range of odorants contained in plants, you can combine organic chemistry with the physiology of smell to demonstrate how well we understand our environment without being fully aware of it. If you want to focus on training the sense of smell, you could ask your students to sort different dilutions of one odorant by increasing intensity (see Experiment 2 in the classroom activity[w2]). These two activities[w1, w2] should stimulate students to link everyday situations with chemistry and make them curious about the description of our world in terms of chemical compounds.

Acknowledgements

I would like to thank the students from the sensory training course (Fachhochschule Weihenstephan, Winter semester 2006/07) for the preparation of odorant samples and for stimulating discussion.

Web references

w1 – Experiment 1: Test your sense of smell. The experimental protocol, including the necessary worksheets, can be downloaded here: www.scienceinschool.org/2007/issue6/scent/

w2 – Experiment 2: Sort a dilution series of an essential oil. The experimental protocol, including the necessary worksheets, can be downloaded here: www.scienceinschool.org/2007/issue6/scent/

Resources

Buck LB (2004) Unraveling the Sense of Smell. Nobel Lecture, 8 Dec, Stockholm, Sweden. http://nobelprize.org/nobel_prizes/medicine/laureates/2004/buck-lecture.html

REVIEW

Students may be pleasantly surprised to discover that chemicals not only are responsible for potentially dangerous and/or unpleasant effects but also give rise to delightful odours and tastes. The activities that Angelika Börsch-Haubold presents here may be used to demonstrate that the realm of smell resides in chemistry and that our noses are exquisitely sensitive chemical sensors, able to detect subtle variations in molecular structure.

The article is applicable to organic chemistry in general, with specific relevance to food technology. It could be linked to a discussion of the use of (unnatural) food additives or of genetic modification of food crops. It would also be useful background reading for teaching lessons on the senses.

Matthew Fletcher, UK

Busch-Stockfisch M (ed; 2005) *Praxishandbuch Sensorik in der Produktentwicklung und Qualitätssicherung*. Hamburg, Germany: Behr's Verlag

Malnic B, Godfrey PA, Buck LB (2004) The human olfactory receptor gene family. *Proceedings of the National Academy of Sciences USA* **101**: 2584-2589

Malnic B, Hirono J, Sato T, Buck LB (1999) Combinatorial receptor codes for odors. *Cell* **96**: 713-723

Steinegger E, Hänsel R (1988) *Lehrbuch der Pharmakognosie und Phytopharmazie*. 4th Ed. Berlin, Germany: Springer-Verlag

Dr Angelika Börsch-Haubold, who is a trained pharmacist and pharmacologist, teaches regularly at the Fachhochschule Weihenstephan in Freising, Germany.

Nicky Mulder

Image courtesy of the EMBL Photolab

Scientist profile: Nicky Mulder, bioinformatician

Have you ever wondered what bioinformatics is? Or what a bioinformatician does? **Sai Pathmanathan** and **Eleanor Hayes** talk to Nicky Mulder, a bioinformatician at the European Bioinformatics Institute in Cambridge, UK.

The European Bioinformatics Institute

Image courtesy of the EMBL Photolab

Recent advances in molecular biology mean that we can now analyse DNA sequences easily and quickly, performing – in a matter of days – analyses that, not so long ago, would have taken years to carry out. The result is an explosion in the amount of biological data available, but data alone do not confer knowledge: we need ways to interpret it. That is precisely the purpose of bioinformatics: the application of computer technology to the management and analysis of biological data.

That may not sound very exciting, but bioinformatics is in fact an important and interdisciplinary research area at the interface of the biological and computational sciences. The ultimate goal of bioinformatics is to uncover the wealth of biological information hidden in the mass of data, to help us understand the fundamental biology of organisms and to use this information to benefit humankind. The results of bioinformatics research could assist fields as varied as human health, agriculture, environmental protection, energy technology and biotechnology.

In molecular medicine, bioinformatics is already used to produce better and more customised medicines. In the field of environmental science, it

Image courtesy of the EMBL Photolab

The European Bioinformatics Institute

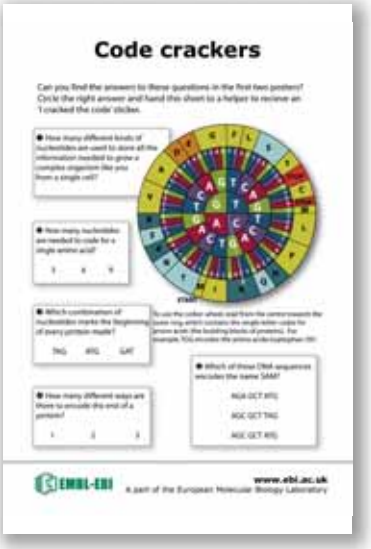
is used to identify bacteria that are capable of cleaning up polluted areas (bio-remediation) and in agriculture it can be used to develop high-yield, low-maintenance crops. These are just a few of the many benefits of bioinformatics, now and in the future.

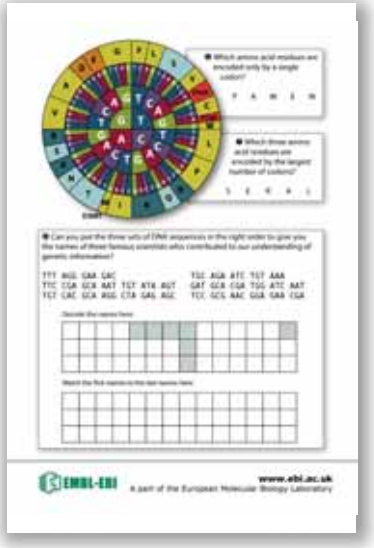
But surely Nicky didn't know all that when she was at school in South Africa? Of course not! In fact, she had planned to become a graphic designer, but always enjoyed science, even though she didn't study biology at school. "Towards the end of my final year, our school guidance counsellor told me about the Bachelor of Science at university," says Nicky, "and all the subjects sounded so interesting that I decided to do it!" She specialised in microbiology and chemistry and then went on to do a PhD in medical microbiology.

So how did she get involved in bioinformatics? "During my PhD, after doing lots of bench work [experiments], I had to do some data analysis on the computer. I found this part interesting and was amazed to see how much you can find out about a gene through computational tools." This technological side of the biological sciences had grabbed Nicky's attention. Following her PhD she dived straight in and began work at the European Bioinformatics Institute (EBI) in Cambridge, UK. One advantage for Nicky was the lack of laboratory work, because she was uncomfortable experimenting on animals .

Nicky's job has two different aspects. One involves providing a database and computational tools to scientists all over the world. It is a real challenge to keep up with user demands but it proves to be greatly rewarding too. "So many people access, use and quote the resource from all over the world for their research." The second part of her job involves infectious diseases. Nicky is currently using computational tools to analyse the genome sequences of pathogens such as *Mycobacterium tuberculosis* (the bacterium that causes tuberculosis) to better understand how the pathogens work. "We still do not know the function of so many genes in this organism, but among them there may be some that are important in causing the disease and therefore have potential applications in drug or vaccine design."

By comparing the sequence of 'unknown' genes with the sequence of genes in other organisms for which the function is already known, bioinformaticians can gather information about the possible function of genes. This method is known as comparative genomics. The data come from public databases that store genome sequence information; Nicky and her colleagues take these data and perform their own data manipulations and comparisons to try and make biological sense





Code crackers – teaching materials from the European Bioinformatics Institute

Images courtesy of the European Bioinformatics Institute

of it. "So far we have found that some genes that are known to cause disease in other pathogens can also be found in *M. tuberculosis*, so we can investigate these further. We have also found some genes that are unique to *M. tuberculosis* that may be required for its survival in the host, and we can now study these further in collaboration with colleagues in the laboratory."

Nicky finds science exciting, as it deals with important problems. "For everything I do, I can see a real-life example or application of my work, so my results have the potential to affect other people and potentially help in the medical field." What about the drawbacks? "There is constant pressure to publish results, and scientists often compete rather than collaborate. You can work on a problem for ages only to find suddenly that someone else has published it before you!"

Are there other challenges? "The challenges are mostly in keeping up to date with the current literature and finding an appropriate research post," says Nicky. "Another challenge is the constant need to find funding for research."

Being promoted to team leader at the EBI was a particularly memorable moment in Nicky's career. "I had been running a project at the EBI for a few years but didn't officially receive credit for it until I was promoted to team leader of the project." She is now responsible for day-to-day management of the team as well as for strategic decision-making on the direction and goals of the project. "It has also been rewarding for me as a woman, as the majority of team and group leaders at the institute are male. I hope this encourages other women in science to be ambitious."

We asked Nicky what advice she would give to someone who wants to do bioinformatics. "Try to get a good basic grounding in both biology and computer science, then apply for a position or studentship in the field – the best way to learn is on the job." Nicky is keen to encourage young people to think about a career in science, and has visited several schools to speak about career opportunities in bioinformatics.

In the future, Nicky would like to focus a bit more on research. "Until now, my main responsibilities have been to keep the database and service running efficiently for the public. I would like to have time to use all the important data we store and generate, to answer interesting biological questions such as those in our research project on *M. tuberculosis*."

Resources

The European Bioinformatics Institute provides a range of teaching materials in bioinformatics, including a DNA code-cracking quiz. You can also try translating your name into DNA code and searching for proteins with your name in them! See www.ebi.ac.uk/training/schools/

The EBI also hosts the 2CAN portal, which introduces bioinformatics and demonstrates how to perform bioinformatics analyses using EBI tools: www.ebi.ac.uk/2can/

The EBI, as part of the European Molecular Biology Laboratory, offers workshops for teachers at the European Learning Laboratory for the Life Sciences: www.embl.org/ells/

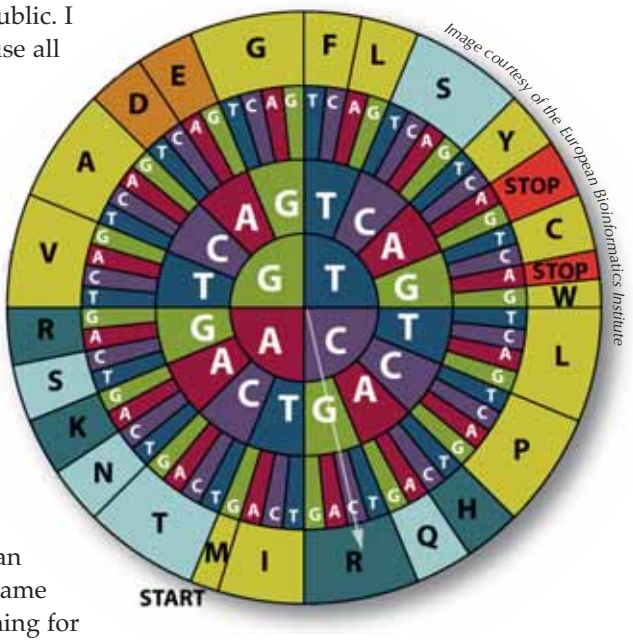


Image courtesy of the European Bioinformatics Institute

Teaching on ice: an educational expedition to Antarctica

Are there days when you long to get right away from the classroom? How far would you be willing to go? **Eleanor Hayes** talks to Phil Avery, one of four teachers who are taking a break from school to journey to the Antarctic.

Image courtesy of Steve Bull (expedition leader)

The team training in the Lake District: left to right: Ian, Phil, Zoe (reserve), Ruth, Amy, Richard (reserve guide)

On 3 November 2007, four teachers from the UK will head to the Ellsworth Mountains of Antarctica to camp for four weeks. The aim of the expedition is to inspire geography and science students with live reports from the ice and to conduct research projects, the results of which will be turned into exciting and innovative teaching resources.

The expedition is organised by the Fuchs Foundation[w1], founded in honour of Sir Vivian Fuchs, the Antarctic scientist who completed the first-ever crossing of the continent in 1957/58. The Foundation's aim is to inspire teachers to change students' lives, challenging the idea that science and geography are dull, and awakening a sense of excitement, adventure and the thirst for knowledge. By targeting teachers, they hope to reach millions of students, working on the principle that each teacher will influence 10 000 students over the course of their career.

Research on ice

All four of the teachers have their own projects, which they will then

convert into exciting lessons for their students within the framework of the national curriculum. For example, Phil Avery, a geography teacher at Oxted School in the UK, is working with the University of Portsmouth, UK, to discover how humans cope physiologically and psychologically with extreme cold. Before and after the expedition, the four teachers and two guides will undergo fitness tests, anthropometric profiling (which examines body shape) and psychological questionnaires.

Amongst other activities, they will be cycling inside a walk-in freezer (-20ºC) wearing swimming costumes! The point is to see at what core body temperature they start to sweat and then, once they have stopped cycling, shiver. The results will be compared before and after the expedition to see if they are due to the harsh conditions experienced (temperatures in Antarctica will be around -30ºC plus wind chill).

The selected teachers are neither research scientists nor explorers and have never done anything like this before. And they have only just met in training. All this adds a whole new, 'Big Brother'-style dimension. How will they cope with the stress? Will they argue? Will they (or the ice) crack up? This is one of the reasons that the University of Portsmouth were so keen to test them mentally as well as physically.

BACKGROUND

Funding

Half of the expedition costs are covered by the Fuchs Foundation but each participating teacher must raise £10 000 with the support of their schools, friends and others. Additional donors and sponsors are very welcome[w2]!

Phil explains one of the positive side-effects of fund-raising: "I now know a lot about the romantic nature of my school, after I ran a service with which members of the school could send flowers to each other. Year 8 [ages 13-14] are the most romantic year (about half of the students sent flowers) and teachers are the least romantic (obviously not all that staff-room gossip is true!). Year-8 students are also the 'most desirable' year (receiving the most flowers) with teachers being the 'least desirable'."

Image courtesy of Phil Avery

Phil in the freezer getting cold (he's not swearing, he's got a thermistor on his finger!)

Image courtesy of Phil Avery

Phil undergoing a maximum oxygen uptake test (he has excellent endurance and lactic acid threshold)

Training

The teachers have already completed two training trips in northern England, focusing on how to camp in a cold environment and how to move on ice. All went well, except for when they left their stoves behind…if they repeat this mistake in Antarctica, they will die! Fortunately, training ensures that the teachers can learn from their mistakes before the real expedition begins.

And of course, there are other types of training course, explains Phil. "I spent one weekend contemplating bones poking through legs, guts on the outside, scratched retinas, rotten toes, dislocated elbows, lacerations, collapsed lungs, swelling brains, heart attacks, spinal injuries and diarrhoea. This wasn't TV – I was on a medical course for people who are going to be more than 24 hours from professional help. The list of injuries sustained while on expeditions made me wonder if this expedition was a sensible idea!"

To check that they are ready for the rigours of the expedition, the teachers are currently undergoing tests to see how well adapted they are to the cold. Exactly how much fat do they have and where is it? How quickly do

Image courtesy of Phil Avery

Phil practising rescuing himself from a crevasse

Image courtesy of Phil Avery

The team trying on their kit. Phil is in the foreground with his arms out

they start sweating and how much sweat do they produce? How fit are they? What happens if they are submersed in cold water? How well do their hands work in the cold? "It could be quite demoralising," worries Phil. "What if they say 'you are scrawny, unfit and incapable of operating in the cold…enjoy the Antarctic!'?"

As we go to press, the crucial training trip is still to come: in August 2007, they will head for a week to Norway to camp on a glacier, complete crevasse rescue drills and learn to cross-country ski while pulling sledges loaded with equipment.

Applications at school

When the teachers return from Antarctica, they will use their experiences and the results of their experiments to produce valuable resources for schools, available on the Fuchs Foundation website[w1]. The advantage of sending teachers on an expedition instead of the more usual research scientists is that they have the experience and opportunity to really bring the Antarctic to life in the classroom.

The subject of the Antarctic lends itself not only to biology lessons on physiology, geography lessons about climate, or physics lessons about state change, but also to a wide variety of interdisciplinary topics. For example, Antarctic tourism could be discussed within the English geography syllabus, travel and tourism syllabus or citizenship syllabus (see Phil's blog[w2] for more details); and the history of Antarctica spans geography, history and food technology (explorers' diets).

Although the expedition hasn't yet begun, Phil is already using it to excite his students. In a recent school assembly, he held 2200 secondary-school students spellbound with his description of a vast continent on the other side of the planet, the extreme conditions, and the expedition itself: its educational aims, the idea of untrained teachers pulling a sledge across the snowy expanses and the very real danger involved.

"With so much administration in education," he muses, "have we forgotten that possibly the best teaching tool is great stories – and giving teachers time to research them and tell them well?"

CLASSROOM ACTIVITY

Competition

Here is your chance to get answers to questions you have about Antarctica, the effects of cold on humans or other related topics. Send us your ideas for simple experiments to be performed during the expedition; Phil and his companions will choose and carry out the best one. They will send back the results live from Antarctica, for publication on the *Science in School* website.

Entries are welcome from science teachers across Europe and should reach us (editor@scienceinschool.org) by 30 September 2007. Please include your school, country and the subjects you teach.

To get you thinking, here's one of the questions sent in so far: Does your saliva freeze before it hits the ground?

Image courtesy of Phil Avery

Phil being dragged by Ian and Zoe as they practise using a pulley system to rescue team members from crevasses

Phil is also keen to get younger children thinking about the Antarctic and what we can learn from such a harsh environment. With some help from teachers who contacted him via his website[w2], he is planning several workshops with local primary schools.

- Penguin huddling. One of the ways penguins respond to the harsh conditions of Antarctica is by grouping together. "After showing the children lots of great pictures of Antarctic wildlife, I am going to take the children outside, huddle them together and get them to measure temperatures on the outside and inside of the group to see the difference that body heat makes."
- Kit lists. By considering what equipment they would take on an expedition to Antarctica, the children will start thinking about the conditions they would face. "To get them started, I will bring along some mountaineering equipment, and talk about old kit and modern kit. We can also have a scenario in which we get too tired and weak to pull the heavily loaded sledges; the children should then consider which pieces of kit are most essential."

Phil had to consider many of these points himself recently, when buying kit for the expedition.

"Do I really need this item, or will it just be extra weight to carry around? What sort of spoon shall I buy? A metal one would freeze to my lips, but a plastic spoon will become brittle – I'd better get a wooden one. Is my knife sharp enough to cut ropes easily and free me from my sledge if I fall down a crevasse? Is my first-aid kit able to support an injured person who might not be rescued for days?"

Other teachers are also keen to hear about the expedition and its results. In particular, they are interested in how it could be included in climate-change projects, science careers evenings and a consideration of extreme environments. If you have further ideas, why not check Phil's blog[w2] and leave comments.

When they return

When the teachers return at the end of the year, they will be busy producing teaching materials to share their experiences with colleagues around the world. But we hope they will have time to talk to *Science in School* so that we can let you know how the expedition went.

REVIEW

Many European countries are suffering from a lack of scientific vocations which might soon become a fundamental problem. A common explanation is that the effort to become a scientist is not rewarded with social or economic success. However, the best reward in science is always the sense of adventure that any research involves.

Phil Avery's project brings into the classroom the importance of effort and risk that is involved in any research, and is a good tool to motivate students to explore the world of scientific research.

As a possible application of the article, teachers could encourage their students to design a research project for an expedition to a national or European region. The students could use this article as a guide to design the training and equipment necessary, and how to use their results

Juan de Dios Centeno Carrillo, Spain

Web references

w1 – The Fuchs Foundation website, including blogs: www.fuchsfoundation.org

w2 – Phil Avery's website, including a blog, photos and an online donation form: www.antarctic-teacher.co.uk

w3 – Phil Avery's blog plus videos, podcasts and other materials on the website of Teaching Expertise, one of the expedition's sponsors: www.teachingexpertise.com/blog/teachingonice

The Talking Ape: How Language Evolved

By Robbins Burling

Reviewed by Bernhard Haubold, Fachhochschule Weihenstephan, Germany

Everyone does it everywhere all the time. I am not talking about Germans smoking, Americans eating burgers, or adults having sex – although the latter gets us thinking in the right direction. But nothing beats talking as a universal human activity. We do it incessantly, whereas no other animal engages in anything remotely resembling our logomania. This begs the question posed by the American linguist Robbins Burling in his book *The Talking Ape*: "How did we get from an ordinary primate that could not talk to the strange human primate that can't shut up?"

This question alone is quite unusual in linguistics. In spite of the fact that William Jones discovered the relatedness of what became known as the Indo-European languages more than half a century before Charles Darwin published *The Origin of Species*, linguists have traditionally avoided the subject of how human language evolved. The reason for this is simple: our present linguistic prowess is estimated to be at least 35 000 years old, whereas script was invented in the late fourth millennium BC. In contrast to animals and plants, for which we have a rich record of fossils documenting earlier forms, there is absolutely no record of early language.

In spite of this rather dire dearth of data, Burling has a lot of very interesting things to say about how language might have evolved. His historical scenarios are based on insights into the acquisition and evolution of modern languages.

Burling starts his exploration with a simple but illuminating fact about the nature of our linguistic abilities: we tend to understand more than we can say. This is particularly true of small children, who go through a phase in which they can understand quite complex sentences, yet utter nothing beyond exploratory babble. From extrapolating this insight into the evolutionary past, Burling concludes that it must have been comprehension rather than production that drove the evolution of language. It then becomes quite plausible that language evolved gradually from primitive early stages to the splendor of Shakespearian rhapsody.

But why is our language as complex as it is, with its intricate syntax and its vocabulary of many thousands of words? The traditional explanation for language evolution is that it gave early speakers an edge in the struggle for subsistence. Hunters needed to coordinate their actions and language certainly helped. Yet this account is not as convincing when we remember that wolves and lions are expert hunters without any language. The whole idea that language drove technology is suspect because the invention of language predates the invention of, say, agriculture, by many millennia. Conversely, societies with a low level of technology have languages that are every bit as intricate and subtle as English.

Sexual selection is the evolutionary pressure that is usually invoked to explain the emergence of traits that do not contribute to subsistence. The classic example is the peacock's tail. A male peacock might escape predation more easily with a scruffy tail, but if females prefer showy-tailed mates, he won't leave any offspring throughout his long life.

In the context of language, sexual selection amounts to a 'chatting up' theory of evolution. Yet in contrast to birds' plumages, which in many cases are markedly flashier in males than in females, men and women have equal linguistic abilities. Burling argues that this unusual symmetry in a trait under sexual selection suggests a corresponding symmetry in choosing: males consider their choice of mate as carefully as females do. Such a scenario implies that some form of long-term partnership between parents has been the rule among humans for a very long time.

Burling writes lucidly for the lay reader and since we are all expert speakers of our native tongues, his essay on the origin of this most human of traits will resonate with anyone who has ever wondered why it is often so difficult to get a word in edgeways in class.

Details

Publisher: Oxford University Press
Publication year: 2007
ISBN: 9780199214037

Experimental Design for the Life Sciences (2nd Edition)

By Graeme D. Ruxton and Nick Colegrave

Reviewed by Mark Langford, UK

Rather than being a book in which one dips to search for the answer to a particular question or for a desired fact, *Experimental Design for the Life Sciences* is a book to read through in its entirety: the student begins at the beginning and works through, learning how to design a good experiment in the life sciences.

Although it is black and white throughout (something that is now almost unheard of in high-school texts), the book is clear and accessible. It is well written and uses unadulterated language to explain each point, and the authors make no assumptions about the knowledge of the reader. In particular, they do not assume that the student is a mathematician. The common-sense approach addresses many of the mistakes we have all made (for example, "Keep more than one copy of your data"!).

The book's main focus is on experimental design with living subjects, be they mice, people or cabbages. There are more examples that use animals than plants, but the emphasis is on the methodology involved in acquiring data and its treatment. The authors discuss experiments in controlled environments, such as labs, and examples from the field, such as vets gathering data about pet diets or samples collected from the wild.

One of the key points that the authors are keen to put across is that numbers – and statistics – are not everything. Just because you have lots of bits of information and a pretty graph does not mean you have performed a useful or valid experiment. A well-designed experiment will actually reduce the need for statistical analysis.

This is a good point for two reasons: it reduces the work that needs to be done to reach a useful conclusion, and it reduces the strain on the organisms being investigated. To enhance the text, several tactics are used: key points are highlighted and repeated, and extra details are outlined in boxes. I found two parts of the book particularly useful.

First, throughout the text, the learning experience is enhanced by carefully crafted questions. Referred to as 'self-test' questions, they would also provide perfect stimuli for discussion and debate in small groups, or form the basis of essay topics. Answers are provided, but they are sometimes deliberately vague, and, in one case, the authors admit *we don't know*. There is plenty of scope for students to go into greater detail, or even produce a completely different answer that can also be correct.

Second, the idea of ethics is repeatedly brought to the fore. Life sciences invariably involve living organisms, and they are often capable of suffering. The suffering that experiments cause – either directly or indirectly – was not something that required much thought when I was at school in the early 1980s, but is now something that, quite rightly, should be considered. The authors introduce questions of balance that could cause a lot of discussion amongst suitably motivated students (such as, should a small number of animals be treated several times, to reduce the total number that suffer, or should a large number be treated once per animal, to reduce the amount of discomfort that each animal experiences?).

The book would be as useful to students studying solely vegetable or microbial subjects as to those permitted to perform tests on animal or human subjects.

Would I use this book? Yes. It would certainly be useful to A-level classes (ages 16-18) and undergraduate students in the life sciences, even if it is not on their official reading lists. I would even consider using it to extend more able GCSE classes (ages 14-16).

Details

Publisher: Oxford University Press

Publication year: 2006 (2nd Edition)

ISBN: 019928511X (paperback)

Exploring the Living Cell DVD

By Véronique Kleiner and Christian Sardet

Reviewed by Friedlinde Krotschek, Internationale Gesamtschule Heidelberg, Germany

The *Exploring the Living Cell* DVD includes a wide range of films about the cell, covering many topics and providing background information for lessons: the history of the discovery of the cell, ethical debates about stem cells and evolution/creationism, and current research in cell biology. For the school curriculum, however, the most useful part of the DVD is certainly the film *Voyage Inside the Cell*.

This animation is breathtaking for two reasons. First, it includes excellent colourful representations of cell structures and a detailed close-up picture produced by an electron microscope, giving the viewer the feeling of being in the middle of the action. Second, the film's underlying explanations are so fast that one starts to gasp for air, glued to the fast-changing scenery while still absorbing the information.

Older school students with a good knowledge of cell biology will find the animation very useful for reviewing what they have already learned and will enjoy the perfect visualisation. In teacher-training institutes, this film and the rest of the DVD would be perfect for providing a wider and updated perspective on teaching biology and cytology.

For teaching the structure and function of the cell to less advanced students, there is a slower version of the animated film[w1]. This could be used as a self-teaching tool for all levels of students across Europe – and should be mandatory for bilingual schools!

The related Bioclips website[w2], which includes many of the animations found on the DVD, is also a very useful teaching tool. It offers a diversity of 'real-life' videos, short enough to repeat and discuss in the classroom whenever related topics come up. Watching these prize-winning movies is very motivating, and makes the science of cell interaction more fun to study. The whole webpage should win a prize!

Web references

w1 – A slower version of the *Voyage Inside the Cell* film can be purchased ($24.95) here: www.sinauer.com/voyage/video.php

w2 – On the Bioclips website, 90 sequences of cells from the *Exploring the Living Cell* DVD are made freely available: www.bioclips.com/dvd/

Full contents

- The story of the discovery of the cell: 1 film
- Evolution and diversity of cells, stem cells, debates: 4 films
- The world of biologists, laboratories and cells: 13 films
- Voyage inside the cell: 1 computer-animated film
- Explanatory notes, links to websites

Details

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1 place Aristide Briand
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France
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Fax: +33 (0)1 45 07 58 60
Email: videotheque.vente@cnrs-bellevue.fr
Website: www.cnrs.fr/cnrs-images/

Fossils: A Very Short Introduction[*] and *Dinosaurs: A Very Short Introduction*[+]

[*]By Keith Thomson

[+]By David Norman

Reviewed by Eric Demoncheaux, Battle Abbey School, UK

Fossils: A Very Short Introduction and *Dinosaurs: A Very Short Introduction* are both real tours de force and very engaging books. Their small size makes them easy to pack and take away to read during any spare moments.

How did Darwin use fossils to support his theory of evolution? This is one of the fascinating questions that Keith Thomson has ventured to answer in his book. He deals with issues surrounding fossils and more particularly addresses some of the uncertainties that scientists faced when trying to understand their origins. He successfully highlights the impact of fossils on mythology, history and philosophy while keeping the reader grounded by tackling their important role in our concept of time and popular culture in a manner that is easy to understand. The book contains ten chapters, a short introduction and a final summary entitled 'Back to the future'. This all-encompassing explanation of fossils gives the reader a remarkable overview of the field. Keith Thomson is Professor Emeritus of Natural History at the University of Oxford, UK.

Dinosaurs: A Very Short Introduction was written by David Norman, who is Director of the Sedgwick Museum of Earth Sciences in Cambridge, UK, and who was the advisor for David Attenborough's *Lost Worlds Vanished Lives*, and *Walking with Dinosaurs* programmes for the BBC, and *Dinosaur!* for Granada TV/AE Network. His book is more akin to a scientific investigation in which the reader is taken through anatomy, genetics, forensics and engineering design to build a picture of what dinosaurs looked like. It also tackles their place in evolutionary history with a chapter describing how animal life evolved on Earth. The book contains eight chapters and concludes with an insightful discussion of the future of research on the past. For all of us who are fans of the film *Jurassic Park*, this book should provide some definitive answers about the appearance and whereabouts of dinosaurs.

Both books are well-written, contain a wealth of information and include many (black and white) illustrations. Although non-native English speakers may struggle with the complicated language, they will find the definitions of keywords helpful. The books were not designed to be used as teaching aids but could be useful for secondary-school teachers and a helpful addition to a secondary-school library. They could also be used as a resource for self-motivated students aged 14 and above, or for bright younger students.

Details

Fossils: A Very Short Introduction
Publisher: Oxford University Press
Publication year: 2005
ISBN: 9780192805041

Dinosaurs: A Very Short Introduction
Publisher: Oxford University Press
Publication year: 2005
ISBN: 9780192804198

The March of Unreason: Science, Democracy, and the New Fundamentalism

By Dick Taverne

Reviewed by Alexandre Lewalle, King's College, London, UK

The foundations of democratic western civilisation are under threat, argues Dick Taverne. Since the Enlightenment, material and social progress in our society has relied to a large extent on the achievements of science and on the freedom of scientists to question and experiment, free from dogma and ideologies; it is also this freedom to think and to challenge that has allowed democracy to flourish. Yet, some increasingly influential groups are only too happy to discard the scientific method and evidence-based arguments to further their own goals. Animal-rights activists force universities to shut down laboratories that do crucial research. Self-righteous 'eco-warriors' indiscriminately boycott genetically modified (GM) crops. Alternative medicine becomes established alongside scientific medicine. Many people not only do not know about scientific evidence, but also do not want to know or are even proud not to know. What causes this distrust of science and scientists? How serious are its consequences?

The March of Unreason is Taverne's war cry against what he calls 'anti-science', the systematic and deliberate avoidance of evidence-based knowledge in dealing with science-related issues in society. As a politician, he understands government policy making first-hand. He considers in turn the rise of pseudo-medicines, the opposition to GM crops, the fashion for organic products and the critiques of globalisation, lays bare the unscientific arguments (and sometimes even factual untruths) used by the more vociferous activists, non-governmental organisations and media, and denounces their growing influence.

Their basic concerns may well be legitimate and their intentions laudable, but these 'new fundamentalists' are uncompromising and dogmatic. They demonise scientists as profit-oriented and materialistic, feeding their arguments on the fears and ignorance of the public. Driven by self-righteous moral heroism, their belief is that "nature always knows best". Need we be so alarmed by some people's choice to use anodyne homeopathic remedies, even if their benefits are clinically unproven? Probably not, but the rejection of proper medicine is a slippery slope that leads to aberrations such as the denial by South African president Thabo Mbeki of the sexual transmissibility of HIV/AIDS. The refusal by some parents to give their child the measles/mumps/rubella vaccine, in the face of evidence of harm, has produced a health risk for society as a whole. Likewise, the adamant opponents of GM farming and globalisation sometimes fail to appreciate all the adverse consequences of their campaigns.

You might wonder, however, whether Taverne himself is guilty of 'unreason'. His statements are bold and his tone is passionate, and he occasionally lacks the restraint necessary to preach beyond the converted. His attempt at a philosophical argument is surely too brief to be entirely convincing and his summary dismissal of the Enlightenment philosopher Jean-Jacques Rousseau as "the enemy of reason who proved to be the inspiration of the reign of terror" begs for moderation. The book deals not so much with the technical correctness of scientific knowledge as with the interface between science and ethics, and in this realm reason alone cannot provide a recipe for truth. Unavoidably, the book invites controversy and many of Taverne's assertions read like debatable personal opinions rather than objective truths derived from reason.

All in all, *The March of Unreason* is a stimulating and accessible read, comfortably within the reach of secondary-school students. The issues it raises should be the concerns of any well-rounded citizen. Its central thesis – that science is not only a body of technical knowledge but, perhaps more importantly, a method of inquiry – certainly has the power to inspire. Irritation caused by the forthrightness and subjectivity of Taverne's opinions results only from the reader being

Science Magic: in the Kitchen and *Science Magic: in the Bathroom*

By Richard Robinson

Reviewed by Mark Robertson, UK

challenged to define his or her own stance on the issues discussed. But this is probably the very kind of engagement that Taverne is at pains to encourage.

Details

Publisher: Oxford University Press
Publication year: 2005
ISBN: 9780192804853

The *Science Magic* books are part of a series of home-based practical science books that take as their unusual theme the use of items typically found in particular rooms of the house. These titles both seem to be aimed primarily at parents who wish to discover science with their children but can be used by teachers to gain ideas for classwork or even to set as practical homework. They are probably best suited to the later years of primary school or the earlier years of secondary school.

As the title suggests, *Science Magic: in the Kitchen* introduces experiments that use either everyday kitchen utensils or food. The experiments range from standard bicarbonate/vinegar neutralisations, to heating plastic bottles to observe the effects of air pressure, to observing the decomposition of organic waste. The book provides good coverage of the three main sciences taught in most schools.

Science Magic: in the Bathroom moves the focus of the experiments to the bathroom with many of the experiments involving water. In this book, it seems that physics is the main source of inspiration with experiments investigating surface tension, refraction and sound.

Many of the experiments described are well known but there are some that, although not original in their basic idea, have interesting approaches that may interest the more advanced students with a keen interest in science. As such, both books are good value for money (£3.99 each) and would be a worthwhile addition to a class/science-club library.

Details

Science Magic: in the Bathroom
Publisher: Oxford University Press
Publication year: 2003
ISBN: 9780199111534

Science Magic: in the Kitchen
Publisher: Oxford University Press
Publication year: 2003
ISBN: 9780199111541

Resources on the web: 'Ask a scientist' websites

Halina Stanley from the American School in Grenoble, France, reviews some of her favourite 'ask a scientist' websites in English and French. Thanks to the help of many readers throughout Europe, we can also draw your attention to sites in Croat, Danish, Finnish, Hungarian, Norwegian, Portuguese, Russian and Serbian.

There is a surprisingly large number of 'ask a scientist' websites that rely on experts to answer scientific questions submitted by students or teachers. These are a very useful resource for project work when you don't want to reinvent the wheel, but like much technology, they need to be used correctly. Teachers are generally unimpressed by (and wise to) assignments cut-and-pasted from the worldwide web (or worse, pages printed off in their entirety) and getting expert replies to some homework questions could easily be construed as cheating. Some websites even refuse to answer questions on subjects commonly covered in general reference books or textbooks.

Asking a scientist should be a last, rather than a first, resort. This is for your own benefit as much as for reasons of principle. A website may receive a few hundred or more questions a day, so not all are answered, and, as with the web in general, the standard of the answers can be very variable. Although most of the expert replies I have seen are excellent, some answers can be oversimplified to the point of being misleading, while others are so technically difficult that you need to be an undergraduate in the subject to understand them.

There is now a tremendous amount of information readily available on the web and so when most people fail to find the information they need it is because they don't know how to use a search engine properly. The choice of keywords is crucial. Google's website on basic use of search engines[w1] is definitely worth consulting before you fire off your question.

If your best search efforts and Wikipedia fail you, choose your 'ask a scientist' website carefully, checking that it answers questions in your subject area of interest. The best websites give a list of instructions for those wishing to submit questions – read these carefully. Think hard about the question you want to ask. If your question is long, rambling or unclear, you are unlikely to get the answer you want. Specific questions like 'How are cirrus clouds formed?' are much more likely to be answered than 'How do you prepare a sample for electron microscopy?' To maximise your chances of receiving an answer at the level you need, include information about what you already know and where you are unclear, and state who you are (teacher, or for students, age or grade level). Finally, consider approaching someone at your local university or technical college rather than an anonymous, remote website. Many research scientists are only too happy to help science teachers or students, so you may find a very useful contact closer to home. University websites detail research areas and often list email addresses.

My favourite 'ask a scientist' websites are those run by government agencies or universities. There are also sites associated with scientific publications and companies. Here are a few examples.

English websites

The website run by Argonne National Laboratory answers questions on subjects ranging from astronomy to zoology. Its expert scientists are volunteers from around the world who are registered with the site. It is aimed mainly at high-school children (ages 16-18) and their teachers. See: www.newton.dep.anl.gov/archive.htm

NASA runs a number of websites that answer astronomy and space-related questions: http://science.msfc.nasa.gov/faq/ask-a-scientist.htm

NASA's Goddard Space Flight Center answers questions relating to astrophysics: http://imagine.gsfc.nasa.gov/docs/ask_astro/ask_an_astronomer.html

The European Space Agency runs a similar site: www.esa.int/esaCP/SEMGMZUZJND_index_0.html

Scientific American has an 'ask a scientist' service: www.sciam.com/page.cfm?section=expertform. You can find answers to how GPS devices work or why it feels good to scratch an itch here: www.sciam.com/askexpert_directory.cfm. As you would expect from a professional popular journal, their answers are both expert and well written.

For biology questions, you can try the Howard Hughes Medical Institute: www.hhmi.org/askascientist/

Arizona State University's 'Ask a Biology' site is aimed specifically at biology teachers of students aged 3-18: http://askabiologist.asu.edu/

The Cornell Center for Materials Research also answers everyday scientific questions. The answers are provided by many different experts (ranging from a Nobel prize winner to young research associates) so their quality varies. See: www.ccmr.cornell.edu/education/ask/about.html

Cornell University also hosts the 'Ask an Astronomer' website, where questions are answered by graduate students in astronomy. The website particularly encourages teachers and students to send in questions. See: http://curious.astro.cornell.edu

The Canadian science.ca site answers questions on virtually any scientific subject and answers are helpfully organised in different categories. There are some very interesting profiles of scientists too. See: www.science.ca

The Ask an Expert website forwards questions to experts in a wide range of subjects – and also has links to many other websites where answers may already be posted. See: www.askanexpert.com

CERN, the world's largest particle physics laboratory, invites questions about particle physics from the general public: http://public.web.cern.ch/Public/Content/Chapters/AskAnExpert/AskAnExpert-en.html

French websites

La main à la pâte is a website for primary-school teachers: www.inrp.fr/lamap/?Page_Id=31

Another site that is good for younger children is archi7.net, run by a science journalist with a PhD in physics. The explanations are clear, but you may be lucky to get an answer as there appears to be only one person working on the site. See: http://archi7.ouvaton.org/phys/

Excellent sites for secondary-school project work are run by the prestigious Ecole Normale Supérieure in Lyon, in collaboration with a great many registered professional research scientists.

- For life sciences, see Planet-Terre: www.ens-lyon.fr/Planet Terre/Site/Commun/Utilitaires/POSERQUESTION.html.
- For physics, see CultureSciences Physique: http://culturesciencesphysique.ens-lyon.fr/ and http://culturesciencesphysique.ens-lyon.fr/contactez-nous

The Espace Jeunes of the CNRS (French national research organisation) also aims to help high-school students with their projects: www2.cnrs.fr/jeunes/222.htm

The French physical society has a team of professional scientists who answer physics questions at any level: www.sfpnet.fr/front_office/index.php?rubrique=point_science

Meteo France does the same: www.meteo.fr/meteonet/decouvr/education/doctpe.htm

For chemistry questions, there is a chemistry resource centre designed specifically for teachers, which has answers to a great many frequently asked questions. See: http://culturesciences.chimie.ens.fr/index.html

The Université Pierre et Marie Curie has a website aimed mainly at helping teachers of life sciences. Questions are answered by a team of professors. See: www.snv.jussieu.fr/vie/faq/1faq.htm

Croatian websites

All 'e-school' projects by the Croatian Natural Science Association offer a range of 'ask a scientist' websites aimed principally at school students. Questions are answered by university professors or scientists from science institutes.

- Biology: www.biol.pmf.hr/e-skola/
- Astronomy: http://hpd.botanic.hr/ast/eastro.htm
- Physics: http://eskola.hfd.hr/
- Chemistry: http://eskola.chem.pmf.hr/

Danish websites

Dansk Naturvidenskabsformidling enables teachers, school students and others to direct their questions to a panel of science experts. Users can search through all previous questions and answers: www.formidling.dk

Spoergolivia (Ask Olivia) is a virtual girl who answers questions from children on all topics, including science. The answers are provided by a panel of experts, as well as librarians from children's libraries throughout Denmark: www.spoergolivia.dk

Finnish websites

The Bioteknologia Info website answers questions about biotechnology: www.bioteknologia.info

Tiede, a popular science magazine in Finland, answers questions from the public: www.tiede.fi/kysyasiantuntijalta/

Hungarian websites

The Hungarian science journal *Természet Világa* (*World of Nature*) enables university or high-school students to write in with questions which are answered by high-school teachers or university scientists: www.chemonet.hu/hun/teazo/miert/

For those interested in astronomy, the following website offers the public the chance to have their questions answered by a scientist or amateur astronomer: http://hirek.csillagaszat.hu/olvasoink_kerdeztek.html

Norwegian websites

A number of 'ask an expert' websites in Norway are aimed at the general public, including school students. Many of the experts work for Norwegian universities.

- Ask a biologist: www.bio.no/bio/enbiolog/
- Ask an energy adviser: www.miljolare.no/tema/energi/sporsmal/
- Ask a meteorologist: www.miljolare.no/tema/luftkvalitet/kampanjer/regnsjekken/sporsmal/
- Ask an ornithologist: www.miljolare.no/fuglevennen/sporsmal/
- Ask a meteorologist and oceanographer: http://web.gfi.uib.no/faq/

Portuguese websites

These three sites are well suited for the general public, although the third example is dedicated more to children and to experiments that they can easily do at home, or to in-house phenomena like what soap is made of.

- Via the Ciência Hoje website, members of the public can have their questions about science and medicine answered by university professors and other research scientists: www.cienciahoje.pt
- Researchers at the Lisbon Astronomical Observatory (Observatório Astronómico de Lisboa) answer astronomical questions from the public: www.oal.ul.pt
- Particularly suitable for children is the Ciência em Casa (Science At Home) website, which answers questions about simple experiments to do at home, domestic phenomena, the constituents of soap and other everyday questions in its Eureka section: http://cienciaemcasa.cienciaviva.pt/

Russian websites

The Russian version of *Scientific American* includes a section where the general public can have their questions answered by experts, mostly university scientists. Only the most interesting questions are answered and published: www.sciam.ru

Serbian websites

Via the Serbian journal *Mladi fizicar* (*Young Physicist*), scientists answer questions from the public: http://mf.dfs.org.yu/arhiva/modules.php?name=Feedback

Web references

w1 – The Essentials of Google Search: www.google.com/help/basics.html

Results of the cover competition

By Alina Postu (aged 18)

By Raluca Barza (aged 13)

By Anca Gabriela Banea (aged 17)

In Issue 4, we challenged you and your students to design the cover for *Science in School* and were very impressed by the quality of the entries. Despite gloomy studies about decreasing interest in the sciences, there are clearly a lot of very enthusiastic and artistically gifted young scientists in Europe, supported by inspiring science teachers.

Selecting the winners from among such talented artists was not easy. Congratulations to 13-year-old Raluca Barza, the winner of the 10-14 age category. Judging the 15-19 age category was even more difficult. After much thought, we chose as our cover picture *Chemistry is where life starts* by Elena Pascal, aged 18. We also liked Alina Postu and Anca Gabriela Banea's striking pictures.

Particular congratulations are due to Lidia Minza from Romania, who encouraged her students to submit many very beautiful pictures.

Sadly, we had only one entry in the teacher category. If we run this competition again, we hope more of you will find the time to put pencil (paint, crayon, whatever) to paper and demonstrate your talents.

Congratulations to all the entrants. We enjoyed judging the competition and I am sure our readers will enjoy the pictures we chose.

About *Science in School*

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

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

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

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

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