

SCIENCE in SCHOOL

In this issue:

Car racing in the physics classroom

Also:

Life savers in the sky:
flying doctors



Highlighting the best in science teaching and research

Welcome to the sixteenth issue of *Science in School*



Progress in science can be sporadic. For nearly 40 years, no human has visited the Moon, but interest in lunar exploration is now growing, as Adam Baker reports (page 10). If a trip to the Moon sounds daunting, why not take a deep breath and explore the deep seas instead: hydrothermal vents (page 14) and cold seeps (page 60)?

The more we find out about these and other marine environments, the clearer it becomes that they are extremely vulnerable, as Jean-Luc Solandt explains (online). The damage that we can cause to our oceans has become all too obvious, as specialists battle with the oil spill in the Gulf of Mexico. With some of the activities described by Astrid Kaiser (page 45), primary-school children too can investigate how best to treat oil spills.

This and all our other articles are intended to be used by our readers – so we were delighted to hear about a teaching unit based on our article about a potential treatment for obesity (page 19).

Before they reach the market, however, all medical treatments need to be thoroughly tested in clinical trials, as Sarah Garner and Rachel Thomas explain (page 54). Of the many therapies tested, cancer treatments seem to get the most headlines – but how much do we really know about this disease? Over the past few years, it has become clear that genes play a significant role in the development and growth of many tumours. Now, with the aid of some real genomic data, your students can search for mutations that can cause cancer (page 39).

After someone is diagnosed with cancer, fast action is crucial – as it is for the victims of accidents. Anne Weaver, a flying doctor with London's Air Ambulance, knows that only too well, as she describes in our feature article (page 6).

Louis Palmer is also no stranger to speed; the organiser of the Zero Emissions Race was the first person to tour the world in a solar car (page 50). Cars can provide inspiration closer to home, too: Nick Poynter's students learned to think scientifically as they competed to build the fastest car (page 33), whereas Rudolf Ziegelbecker's students designed an award-winning gyro-car (online).

As a teacher, you will have your own ideas about what works well in the classroom – so why not join our referee panel, helping us decide which articles to publish? We welcome the involvement of both primary- and secondary-school teachers in Europe; see: www.scienceinschool.org/submissions/panel

Finally, don't forget to visit our website and browse the online-only articles, the events list, and our new 'science in the media' section. For details of these and many other features, see our online help page: www.scienceinschool.org/help and remember – your feedback is important to us!

Eleanor Hayes

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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.

The journal 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 earth sciences, engineering and medicine, focusing on interdisciplinary work.

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

Science in School is published quarterly, both online and in print. The website is freely available, with articles in many European languages. The English-language print version is distributed free of charge within Europe.

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See: www.scienceinschool.org/2010/issue16

Events calendar: www.scienceinschool.org/events

The launch of the publication *Teaching Science in Europe 3: what European teachers can learn from each other*

Science on Stage: sharing teaching ideas across Europe



Image courtesy of Science on Stage Germany

Originally, Science on Stage was the brainchild of EIROforum^{w1}, the publisher of *Science in School*. Since then, the commitment of the national organisers has enabled this network of local, national and international events for teachers to grow and grow. **Eleanor Hayes** reviews some of the latest activities.

How to demonstrate Light and shade to kindergarten and primary school children – a project by Werner Stetzenbach

Image courtesy of Science on Stage, Germany



Searching for the best teachers in Europe

In April 2011, about 400 science teachers from across Europe will meet in Copenhagen, Denmark, to share ideas and inspiration in a dizzying whirl of workshops, lectures and dramatic presentations at the international Science on Stage teaching festival. The search for the lucky 400 teachers is still continuing.

In a series of national events, enthusiastic and inspiring teachers are competing to represent their countries in Copenhagen. Austria, Belgium, Canada, the Czech Republic, France, Ireland and the Slovak Republic have

Images courtesy of Science on Stage Germany

Can a sparkler burn underwater?



It takes only a few chemicals and tricks to be a magician, as stand-up chemist Joachim Hecker demonstrated at the launch of the publication *Teaching Science in Europe 3: what European teachers can learn from each other*



Why does money not burn? This and many other tricks were part of stand-up chemist Joachim Hecker's performance at the launch of the publication *Teaching Science in Europe 3: what European teachers can learn from each other*

already selected their winners. The national representatives of Bulgaria, Germany, Greece, Hungary, Italy, Malta, Poland, Portugal and Spain have yet to be selected.

To find out more, and – if it is not too late – apply to take part in your national event, visit the Science on Stage Europe website^{w2}.

Inspiring ideas for teachers

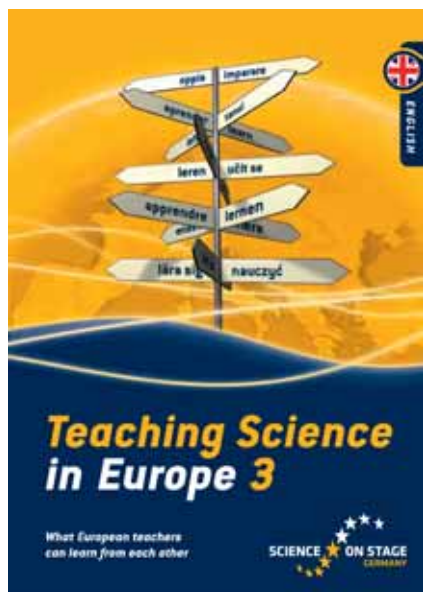
In 2008, the Science on Stage festival in Berlin, Germany, brought together teachers from across Europe in several discussion workshops. Over the course of two years, 55 science teachers from 12 countries continued three

of these discussions under the guidance of Science on Stage Germany. The outcome is the publication *Teaching Science in Europe 3: what European teachers can learn from each other*, divided into three sections.

1. How is a shadow cast? How are colours formed? What causes day and night? How can we tell the time from the Sun? These are just some of the investigations to encourage young children to look at the world in a new way. There is also a discussion of how science education can be used to improve not only the children's knowledge of science but also their language skills.

2. Five examples are used to illustrate the benefits of non-formal education initiatives: a science learning centre in Zurich, Switzerland; a web-based learning platform hosted by the European Space Agency^{w3}; a travelling exhibition based in

Images courtesy of Science on Stage Germany



Front cover of the publication *Teaching Science in Europe 3: what European teachers can learn from each other*

Werner Stetzenbach demonstrates how light and shade can be explained to children in kindergarten and primary school



Stand-up chemist Joachim Hecker melting a yoghurt cup

Nuremberg, Germany; a science museum in Barcelona, Spain; and a science competition run from Czosnow in Poland.

3. Terraforming Mars – the spectral analysis of light and protein biosynthesis. These and other teaching units address the role of the teacher, and how to find the balance between moderating the students' learning and merely instructing them.

The publication (in English or German) can be ordered by email (info@science-on-stage.de) or downloaded from the website of Science on Stage Germany^{w4}.

Teacher training

Science on Stage Germany has not only been active at a European level – it also caters for teachers closer to home. On 18 June, physics teachers from in and around Berlin took part in a workshop organised by Science

on Stage Germany to share some of the ideas that have come out of the national and international Science on Stage events.

In the German part of the workshop, 'Nanotechnology and school', teacher Walter Stein demonstrated the experiments he had done with his 16-year-old students to produce single-wall nanotubes out of carbon, a field-effect transistor out of graphene, and low-cost and colourful photonic crystals out of latex spheres.

The Austrian project, 'The latex motor', investigated the conversion and conservation of energy via four experiments using latex. A latex glove was used to convert thermal energy into potential energy, lifting a weight when heated; the heating and cooling of condoms was used to create a motor driven by heat from a spotlight; the same latex motor was reversed to demonstrate that kinetic energy can be transformed into ther-

mal energy; refrigeration was demonstrated with a latex loop that is cooled on one side (relaxed) and heated on the other (expanded). To learn more about the latex motor, see Eidenberger et al. (2009).

Reference

Eidenberger L et al. (2009) The latex motor. *Science in School* 13: 34-38. www.scienceinschool.org/2009/issue13/latex

Web references

w1 – EIROforum – the publisher of *Science in School* – is a partnership of seven European inter-governmental research organisations. For more information, see: www.eiroforum.org

w2 – The national Science on Stage events culminate in a European teaching festival every two years; the next one is in Copenhagen, Denmark, from 16-19 April 2011. To

How can I hear without using my ears?



Image courtesy of Science on Stage Germany

learn more about Science on Stage and find your national contact, see the Science on Stage Europe website: www.science-on-stage.eu

w3 – To find out more about the European Space Agency, see: www.esa.int

For details of the education materials produced by ESA, see the ESA Education website (www.esa.int/education) and the ESA Human Spaceflight Education website (www.esa.int/esaHS/education.html).

w4 – To learn more about Science on Stage Germany, to download the publication *Teaching Science in Europe 3: what European teachers can learn from each other* or to find out about the teacher training on offer, visit www.science-on-stage.de

Resources

To learn more about how Science on Stage was established, see:

Hayes E (2009) Science on Stage: heading for a country near you. *Science in School* 13: 2-3. www.scienceinschool.org/2009/issue13/sons

All previous *Science in School* articles about the Science on Stage activities can be viewed here:

www.scienceinschool.org/sons

Werner Stetzenbach not only contributed primary-school and kindergarten activities to the publication *Teaching Science in Europe 3: what European teachers can learn from each other* but also shared some of his other ideas with the readers of *Science in School*:

Stetzenbach W, Stetzenbach G (2010) Physics in kindergarten and primary school. *Science in School* 14: 48-53.

www.scienceinschool.org/2010/issue14/kindergarten

Dr Eleanor Hayes is the editor-in-chief of *Science in School*. She studied zoology at the University of Oxford, UK, and completed a PhD in insect ecology. Eleanor then spent some time working in university administration before moving to Germany and into science publishing, initially for a bioinformatics company and then for a learned society. In 2005, she moved to the European Molecular Biology Laboratory to launch *Science in School*.



Life savers in the sky: flying doctors

Anne Weaver, lead clinician for London's Air Ambulance, tells **Marie Mangan** about her job: saving lives.

Anne Weaver
at work



Image courtesy of Iain Crockart, www.iaincrockart.com

Anne Weaver regularly sees Lucy, 14, at fundraising events for London's Air Ambulance^{w1} in the UK. What is remarkable is that seven years ago, Lucy almost died from massive multiple injuries after she was hit by a jeep while running across the road to go to the park. She had head and facial injuries so severe that blood pumped into her airway and stopped her breathing.

Anne, a doctor with London's Air Ambulance, recalls: "We were on scene in nine minutes. There was a doctor desperately trying to manage Lucy's airway, with the help of the ambulance crew, but there was so much blood it was impossible to control. She wasn't breathing. We gave her an emergency anaesthetic, released the pressure in her collapsed and bruised lungs with surgical holes in the chest cavity, packed her face and then flew her back to hospital."

There, Lucy had almost 12 hours of surgery to reconstruct her face, followed by three months in intensive care. "This was the moment that made it totally clear to me why we do this job," Anne says. "I now see a girl who is enjoying being a teenager but I know that she was snatched from death by the quick work of the doctor in the park and then our critical interventions at the scene and in hospital."

Anne has been the lead clinician for London's Air Ambulance since 2007. The service, now more than 20 years old, pioneered the concept of trauma-trained doctors and paramedics treating critically injured patients at the scene and taking them to a hospital that specialises in trauma.

"When I started with London's Air Ambulance, it felt a bit like trying to pass your driving test: there were so many things to consider. I remember thinking I was never going to manage it all. You are the only doctor on the scene and making the right decisions rests on your shoulders. That's why the training is so thorough. The doctors we recruit are always senior doc-

Image courtesy of Iain Crockett, www.iaincrockett.com



tors and they spend the first month of their six-month placement working alongside one of the existing doctors who will be training them, de-briefing them after every mission, challenging, questioning, supporting them.

"As lead clinician, I am responsible for the day-to-day running of the service, making sure the doctors and paramedics are trained, maintain their skills and are supported. I run twice-weekly case review sessions with the whole team where we challenge and learn from each other.

"When they are on duty, team members can call day or night for guidance or to discuss the best course of action for a patient. The service has a good reputation internationally and I need to ensure we not only maintain our high standards but also stay ahead of the game using cutting-edge technology and techniques. It's a challenging role and there are never enough hours in the day!"

One day that is still clearly imprinted in Anne's memory is 7 July 2005, the day that suicide bombers attacked four locations on London's tube and bus networks.

"It was so surreal," Anne says. "I was in a meeting with 16 past and present air ambulance doctors, something we do once a month. The chief pilot must somehow have been aware



- ✓ General science
- ✓ Ages 9-19

This is an inspiring story describing a profession that combines some truly wonderful traits: medical service, emergency treatment, dedication to helping people in need, and flying. Anne Weaver, the clinician being interviewed, is enthusiastic about her job and through some of her memories, she passes this enthusiasm on to the reader.

The article is very interesting and easy to read. It could be read in any classroom (science or not) and at any level (even elementary school). It is not an article to teach with but one to inform and inspire – and not only at school. Perhaps policy makers in other cities and countries that do not have similar flying doctor programmes should read it and think about adopting such practices.

*Michalis Hadjimarou,
Cyprus*

REVIEW

of something awry and said that we should all get our flight suits on. It seemed ridiculous at the time for 16 of us to get ready when normally only one doctor is on duty, but minutes later a major incident was declared.”

The helicopter and cars ferried the medical teams to the four London locations – Aldgate, King’s Cross, Edgware Road and Tavistock Square.

Anne, as lead clinician, was responsible for organising the effort.

“I remember standing in the operations room on the helipad, looking over London and feeling sick and guilty that I was sending my friends and colleagues out into dangerous situations.

“I thought I was going to get a call to say that a doctor or paramedic had been killed if another device detonat-

ed. I knew that if I hadn’t done the organisation at the start, we wouldn’t have had people in the right places. But it was a relief to then go to King’s Cross myself and do what I felt I was meant to do in this situation: be a doctor. Later that day, the chief executive gathered 400 staff from the hospital and air ambulance service together to de-brief. It was an amazing feeling of camaraderie. Everyone had pulled together and we felt very emotional about the events. We knew we had provided a good service for patients that day.”

So how did Anne’s interest in medicine start? It was sparked in the last two years of school, when she attended a course at the Queen’s Medical Centre, where the University of Nottingham’s^{w2} medical school is based.

“The medical school was an integral part of the hospital and had a really clinical feel. Unlike other medical schools where you spend your first two years in lectures, from week one you were allowed to see patients. Being in a medical environment, surrounded by doctors who were constantly inspiring you, you were reminded of why you were doing so many exams!

“I remember my first day at university so clearly. I really enjoyed meeting people from different courses; on my floor in the hall of residence, we had art history, theology, philosophy and engineering students. We became like a little family. When I was revising for medical exams, they made me tea at three in the morning.

“So many of my tutors inspired me. Seeing one of them, Dr Demas Esberger, in action just weeks after I started at university was a landmark moment. It was 5 November 1990 and I was in the accident and emergency department. Two boys, both very badly injured in a car accident, were brought in. I was shaking and thinking I was so glad I was not qualified, as I would have had no idea where to start.

Image courtesy of Iain Crockett, www.iaincrockett.com



“I was in awe of Dr Esberger and the team and from that moment, I wanted to be able to do what they did. Officially, you only did two weeks in accident and emergency as a medical student but I think I spent every available waking moment there. They couldn’t get rid of me! Later in my training, I made sure I chose placements that would enable me to help these patients.” One of those placements was a six-month stint with London’s Air Ambulance, which sowed the seeds of Anne’s future career.

Today, Anne juggles her air ambulance responsibilities with being a senior doctor (consultant) in accident and emergency. She also finds time to be a trustee of the air ambulance’s charity. The service is partly funded by the UK National Health Service and corporate sponsors but still has to find £1.2 million a year from charitable donations. “We are feeling the impact of the recession. We now have to have contingencies to reduce the service when what we really want to do is increase it. It’s frustrating.”

Current challenges aside, Anne does not take her achievements for granted. “It is a great privilege to head the service that is on call for 11 million people in London.”

London’s Air
Ambulance

Acknowledgement

The original version of this article was published in *Alumni Exchange*^{w4}, the alumni magazine of the University of Nottingham, UK.

Web references

w1 – To learn more about London’s Air Ambulance, see:
www.londonsairambulance.com

w2 – For more information about Nottingham University, see:
www.nottingham.ac.uk

w3 – Barts and The London NHS Trust manages three leading London hospitals: St Bartholomew’s (Barts) in the City, The Royal London in Whitechapel and The London Chest in Bethnal Green. To learn more, visit:
www.bartsandthelondon.nhs.uk

w4 – *Alumni Exchange*, the alumni magazine of the University of Nottingham, is freely available to download. See:
www.alumni.nottingham.ac.uk

Resources

If you enjoyed this article, you might like to browse the other feature articles published in *Science in School*:
www.scienceinschool.org/features

For a list of all medicine-related articles published in *Science in School*, see:
www.scienceinschool.org/medicine

Marie Mangan is a fellow alumna of the University of Nottingham and former head of media at Barts and The London NHS Trust^{w3}.

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Image courtesy of Iain Crockett, www.iamcrockett.com

image courtesy of Luc Viatour; image source Wikimedia Commons

Space exploration: the return to the Moon

Have you ever looked up at the Moon in a clear night sky and wondered about the very few people who have walked on its surface? What did we learn, and what are we still unsure about? When might humans return to the Moon? **Adam Baker** investigates.

In 1969, Neil Armstrong and Buzz Aldrin became the first humans to walk on the surface of another astronomical body: the Moon. Over the next three years, ten more American astronauts landed on the Moon as part of the USA's Apollo programme. Since then – nearly 40 years ago – there have been no further manned missions to the Moon. Why is that? And when might people return to the Moon?

In the 1960s and 70s, the Apollo programme and the unmanned Russian Luna and US Surveyor missions concentrated on the surface of the near side of the Moon and left many key questions unanswered, in particular:

- The age of the Moon and how this is linked to the age of the rest of the Solar System. The rocky surface of the Moon is key to this research:

although we can study the Earth more easily, its surface has been altered by weathering, whereas the surface of the Moon has remained more or less unchanged since its formation.

- The overall chemical composition and internal structure of the Moon. This will start to tell us how the Moon originated, and whether it formed from bits of Earth debris, as some theories claim.
- Whether resources such as water are available on the Moon, which would enable astronauts to use the Moon as a base for exploring other planets.

Today, space technology is seen as mostly addressing problems on Earth, such as climate change; the European Space Agency (ESA), for example, has launched many satellites to observe the Earth's atmosphere, oceans and



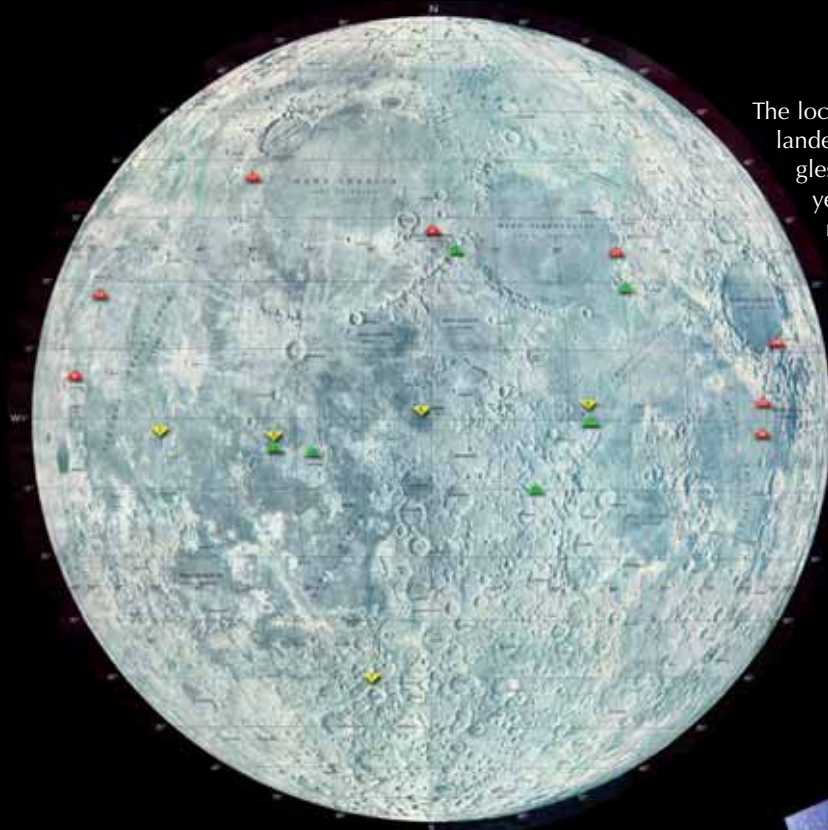
General science

The space exploration race of the 1960s was a very exciting period and important in the development of a number of technologies; the Moon landings were a major highlight. After a gap of several decades, people are again planning to explore the Moon – this article considers how and why.

The article could be used as the starting point of discussions in science or technology lessons, for example on the history of science. It could also be used in science clubs or similar activities.

Eric Deeson, UK

REVIEW



The locations of spacecraft that have landed on the moon. Green triangles represent Apollo missions, yellow are NASA Surveyor missions, and red are Russian Luna spacecraft



Smart-1, ESA's lunar orbiter mission

Image courtesy of National Space Science Data Center / NASA's Goddard Space Flight Center

Image courtesy of ESA

ice caps^{w1}. Nonetheless, after years of inaction in lunar exploration, the past decade has again seen many countries sending missions to the Moon.

In 2003, ESA sent the robotic (unmanned) Smart-1 mission^{w2} to orbit the Moon, to test technology for sending missions accurately beyond Earth's orbit, and to conduct basic science such as X-ray observations of the Moon. Shortly afterwards, ESA also launched the Mars Express mission, its first mission to orbit another planet, with a package of scientific instruments. These missions marked the reawakening of interest in space exploration.

In the USA in 2004, President George W. Bush directed NASA to return to the Moon and build a long-term outpost on the lunar surface as part of his vision for space exploration^{w3}. Subsequently, a global exploration

strategy^{w4} was agreed between 14 space agencies and organisations, encompassing the US vision, as well as space exploration plans from other countries such as the UK^{w5}.

September 2007 saw the launch of the Japanese Kaguya orbiter mission (originally known as Selene). While orbiting the Moon's surface, it searched (unsuccessfully) for water on the lunar surface, measured the strength of the lunar gravitational field using a small satellite, and studied the chemistry of the lunar surface. Kaguya also imaged the lunar surface in visible wavelengths, generated maps of much of the surface, and measured the radiation in orbit to assess the risk to future astronauts.

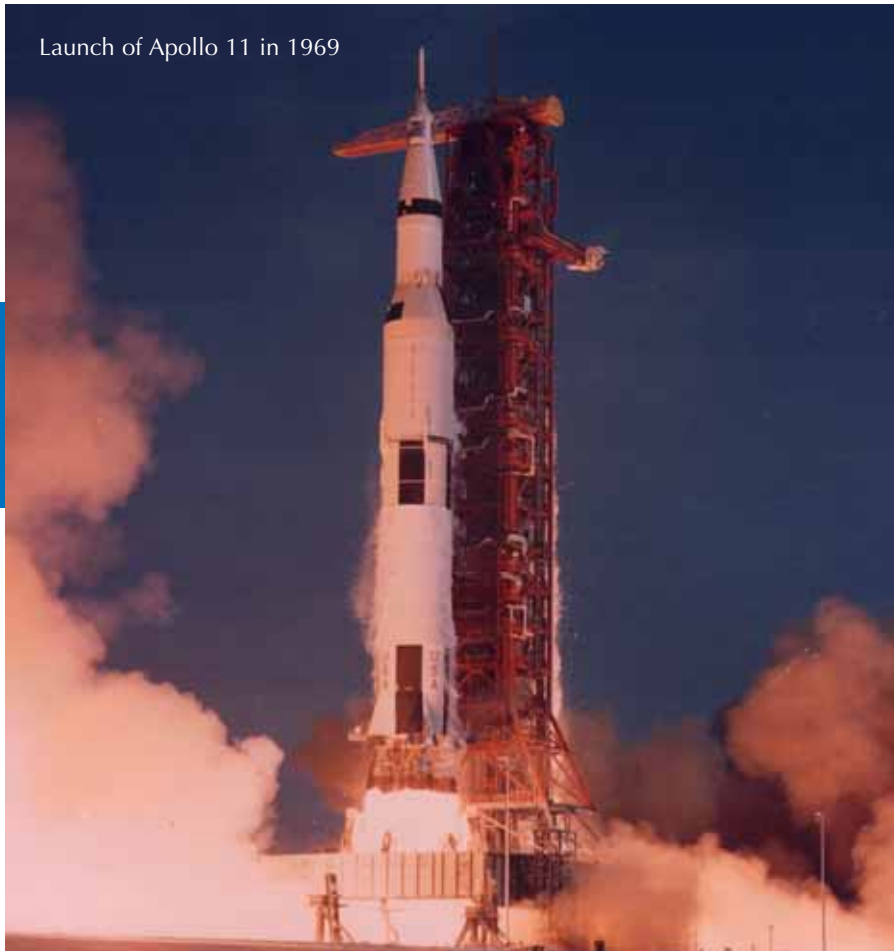
The Chinese orbiter Chang'e-1, launched a month later, also studied the topography and chemistry of the lunar surface and searched for water.

Little data from Chang'e-1 has been released to the international community, however.

In April 2008, the Indian Chandrayaan-1 orbiter was launched to address many of the same questions as the Kaguya orbiter. Additionally, Chandrayaan-1 carried a radar instrument, allowing scientists to peer into dark craters near the lunar poles for the first time. These radar measurements suggested that water ice was present at the lunar south pole. This was confirmed in 2009 when the US LRO orbiter fired a rocket, the LCROSS impactor, into a south pole crater: instruments on the orbiter detected evidence of water ice in the particles that were thrown into space by the crash^{w6, w7}. Data from the LRO orbiter even showed where – 37 years before – a Russian lunar rover had come to rest^{w8}.

Image courtesy of NASA Kennedy Space Center (NASA-KSC)

Launch of Apollo 11 in 1969



These recent missions, therefore, have gone some way to addressing the questions left unanswered in the 1970s, providing information about the chemical composition of more of the Moon's surface, and hinting at the presence of water and other resources that might be found at the cold, dark south pole (below 100 K). More information is still to come – some of the extensive maps generated by Japanese, Chinese, Indian and American orbiters are still being processed.

However, to fully understand the nature of the Moon and its environment – and potentially to prepare for people to visit and stay safely on the Moon for long periods, making astronomical observations, investigating the lunar geology, preparing for more distant space exploration or even mining lunar resources – we need information that even these recent

missions, orbiting far above the Moon's surface, cannot answer. What, for example, is the effect of lunar dust on people, vehicles and telescopes? Can we survive on the Moon for periods as long as several weeks? What new technology, such as power sources and thermal insulation, is needed to help astronauts survive comfortably when working in the dark, extremely cold lunar polar craters?

The answers to these questions will require landers – robots to land on the surface of the Moon and directly measure the properties of dust, rock and the lunar environment (such as moonquakes) over extended periods. Unlike the unmanned missions of the 1960s and 70s, future lander missions would need to investigate the entire lunar surface, carrying out scientific studies, seeking the best places to

Image courtesy of NASA



This is one of the few photographs showing Neil Armstrong on the Moon (he carried the camera most of the time). He is reflected in Buzz Aldrin's visor

build bases and transmitting the data directly back to Earth via radio links.

Already, such missions are being planned. China and India intend to follow their recent orbiter missions with robotic landers (Chang'e-2 and Chandrayaan-2, respectively). To build on these and other lunar missions and to cover a larger portion of the unexplored lunar surface, the UK is developing small, low-cost spacecraft. With their automated guidance systems and miniaturised instruments, these spacecraft would enable regular, inexpensive, small missions to the Moon – starting as early as 2014. With the support of ESA, other European nations are also studying advanced lunar landers⁹⁹. These will carry a wide range of technologies and can test systems suitable for carrying astronauts and for future Mars expeditions, but will be larger and more costly, and are not fully funded yet.

Although the US vision for space exploration – with a manned lunar base by 2020 – sounds exciting, NASA and the US government have recently decided that their plans are unaffordable. Instead, it will be robotic lunar missions that characterise the lunar environment and map available resources, providing a logical, faster and more affordable route to a sustained presence on our nearest neighbour. Although it will probably be

Image courtesy of NASA Jet Propulsion Laboratory (NASA-JPL)



The far side of the Moon, a view of the lunar surface not possible from Earth, taken from the Galileo spacecraft in 1990

Image courtesy of SSTL



The UK's planned MoonLITE orbiter has four penetrators – small daughter spacecraft to be fired into the Moon's surface

Image courtesy of SSTL



The UK's planned MoonRaker lander would give accurate indications of the age of the Moon, sampling regions which no mission has yet visited

some time before the 13th human lands on the Moon, robotic missions are key to bringing that day ever closer. This is a lasting legacy of Apollo.

Reference

Hodge R (2006) The sky's the limit. *Science in School* 1: 70-71. www.scienceinschool.org/2006/issue1/baker

Web references

- w1 – To learn more about the European Space Agency's earth observation programme, including the CryoSat-2 ice satellite to study the effects of global warming, see: www.esa.int/esaEO
- w2 – To learn more about ESA's Smart-1 mission, see: www.esa.int/SPECIALS/SMART-1
- w3 – To learn more about the US vision for space exploration, see: <http://history.nasa.gov/sep.htm>
- w4 – For more information about the global exploration strategy, see: www.globalspaceexploration.org
- w5 – The 2007 report of the UK space exploration working group can be downloaded from the UK Space Agency website (www.bnsc.gov.uk) or via the direct link: <http://tinyurl.com/3xe8vr7>
- w6 – To read the article 'NASA 'ecstatic' after LCROSS impact reveals

water on moon', see *The Guardian* website (www.guardian.co.uk) or use the direct link: <http://tinyurl.com/ylmb6pm>

- w7 – For more information about the LRO mission, see: <http://lunar.gsfc.nasa.gov>
- w8 – To learn more about the recently discovered Russian lunar rover, see the Science Daily website (www.sciencedaily.com) or use the direct link: <http://tinyurl.com/yfbzjcv>
- w9 – ESA is inviting industry to submit proposals for a lunar lander mission. For more details, see the ESA website (www.esa.int) or use the direct link: <http://tinyurl.com/2utzaq7>
- w10 – Surrey Satellite Technology specialises in designing, building and launching small satellites. See: www.sstl.co.uk

Resources

For more information about the Apollo programme, see: Flightglobal's website devoted to Apollo missions: www.flightglobal.com/page/Apollo-40th-Anniversary
A video commemorating the 40th anniversary of the first walk on the Moon: www.youtube.com/

[watch?v=oXxGE4tBBEA](http://www.youtube.com/watch?v=oXxGE4tBBEA)

NASA's archive for lunar mission data: <http://nssdc.gsfc.nasa.gov/planetary/lunar>

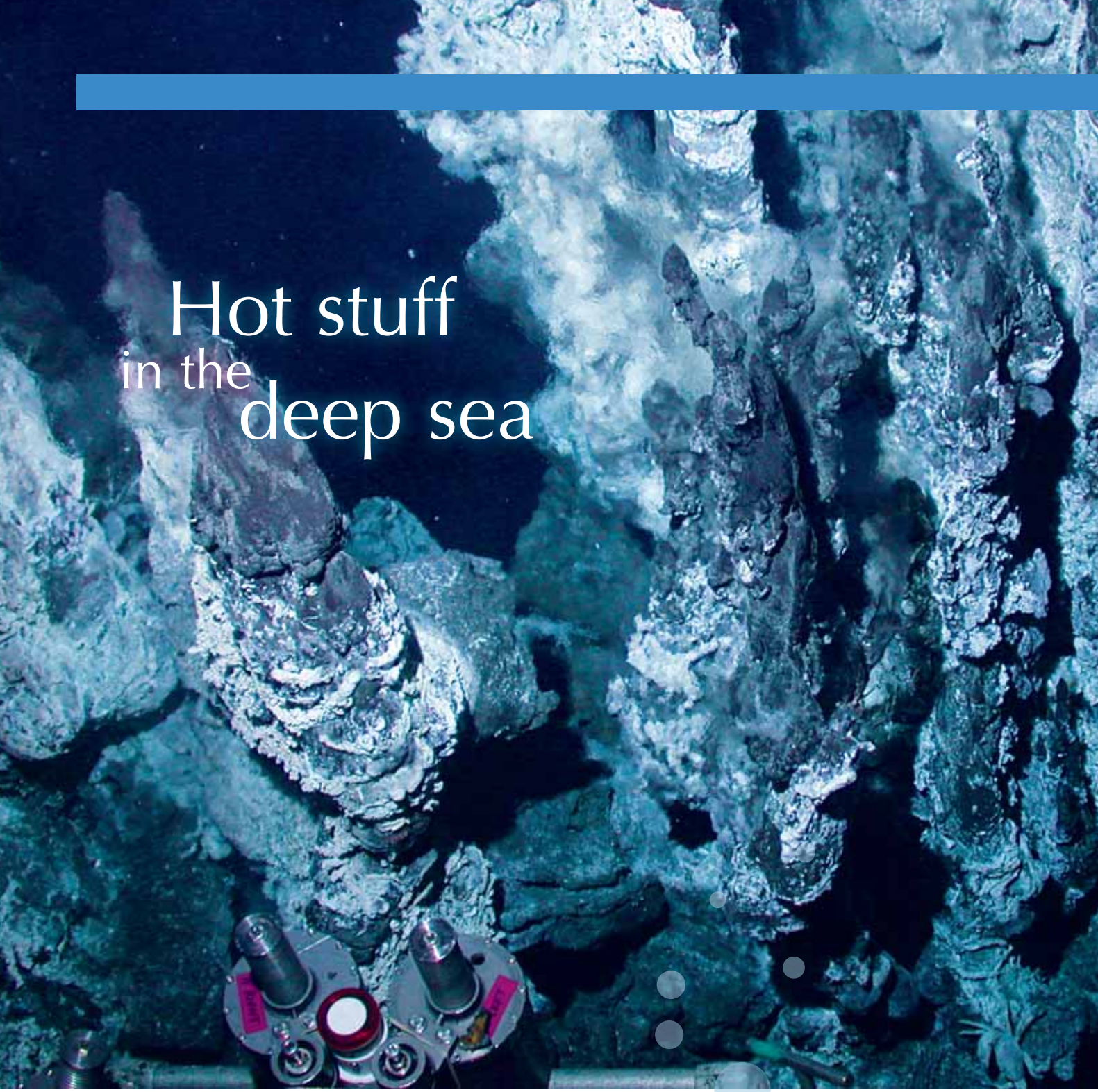
To mark the 40th anniversary of the Moon landings, BBC Radio 4 presented the story of the British MoonLITE project and the lunar ambitions and achievements of the other space-exploring nations. See: www.bbc.co.uk/programmes/b00lnycv

If you enjoyed this article, you might like to browse all the *Science in School* articles about space science. See: www.scienceinschool.org/space

Adam Baker works for Virgin Galactic as their safety manager, in charge of assessing and ensuring the safety of future sub-orbital passenger flights. He wrote this article while working at Surrey Satellite Technology^{w10}, which defined the MoonLITE and MoonRaker missions.

Adam studied materials science at the University of Oxford, UK, where he then completed a PhD on composite materials for jet engines. During his PhD, he built rocket engines as a hobby, which is how he came to work for Surrey Satellite Technology and then Virgin Galactic. For more information about Adam, see Hodge (2006).





Hot stuff in the deep sea

How do fossils form around hydrothermal vents? **Crispin Little** describes how he and his team found out – by making their own fossils.

Research on the deep-sea floor is a serious undertaking. It requires specialised equipment like the famous manned submersible *Alvin* and very expensive oceanographic vessels capable of operating far from land for a long time. Potential problems are not only technical – ships' engines malfunctioning or submersible cables tangling, for example – but can also be due to factors beyond anyone's control: bad weather has scuppered many a well-planned research cruise.



Hydrothermal vent chimneys are formed mainly of sulphide minerals

Image courtesy of Crispin Little

Working on the mid-ocean ridges is even harder, because these are among the most geologically active areas on the planet. Here, new ocean crust is being formed as lava erupts onto the sea floor, accompanied by strong earthquakes (see Searle, 2009). Not only that, but the ridges are also sites of intense hydrothermal activity, with highly acidic vent fluids at 370 °C gushing out of towering mineral chimneys on the sea floor. At these depths, the high pressure raises the boiling point of water enough for it to stay

Images courtesy of Crispin Little



Some of the dominant animals found at vent sites on the East Pacific Rise: vestimentiferan tube worms, vent fish and vent crabs. The shimmery water towards the top of the image is diffuse flow hydrothermal fluid



Collecting vent mussels and crabs using one of *Alvin's* manipulators (left)



- ✓ Biology
- ✓ Evolution
- ✓ Ages 12 to 18

This is a superb article that describes the process of scientific investigations in the extreme environmental conditions of hydrothermal vents. Suitable for students aged 12 to 18, it could be used in lessons on biology in extreme environments, adaptation, life in space or mineral resources. For example, it could be used to discuss the probability of life on other planets.

Suitable comprehension questions include:

1. What kinds of organisms are found near deep-sea vents?
2. How can organisms survive at these depths without sunlight?
3. What do these organisms eat?
4. What sorts of minerals are found near the hydrothermal vents?

The multidisciplinary aspect of this research makes the article very useful when discussing how science really works.

Eric Demoncheaux, UK

REVIEW

liquid even at these temperatures.

This challenging environment was the setting for our project to study fossilisation in deep-sea hydrothermal vents. Indeed, these challenges were confirmed when we lost an entire set of experimental devices to a major sea-floor volcanic eruption early on in the experiment.

Presumably our cages are still there, but covered by several metres of basalt!

Why are we interested in fossilisation at deep-sea hydrothermal vents? The aim of the study was to better understand the evolutionary history of the extraordinary communities of animals that live only at hydrothermal vents. First discovered in 1979 on the Galapagos Rise, these communities have radically changed our view of the diversity of life in the deep sea, partly because their primary energy source is not sunlight, but geochemi-

Image courtesy of Dr Peter Auster, NOAA / OAR / OER / Mountains in the Sea Expedition 2003



Alvin being launched from the research vessel Atlantis

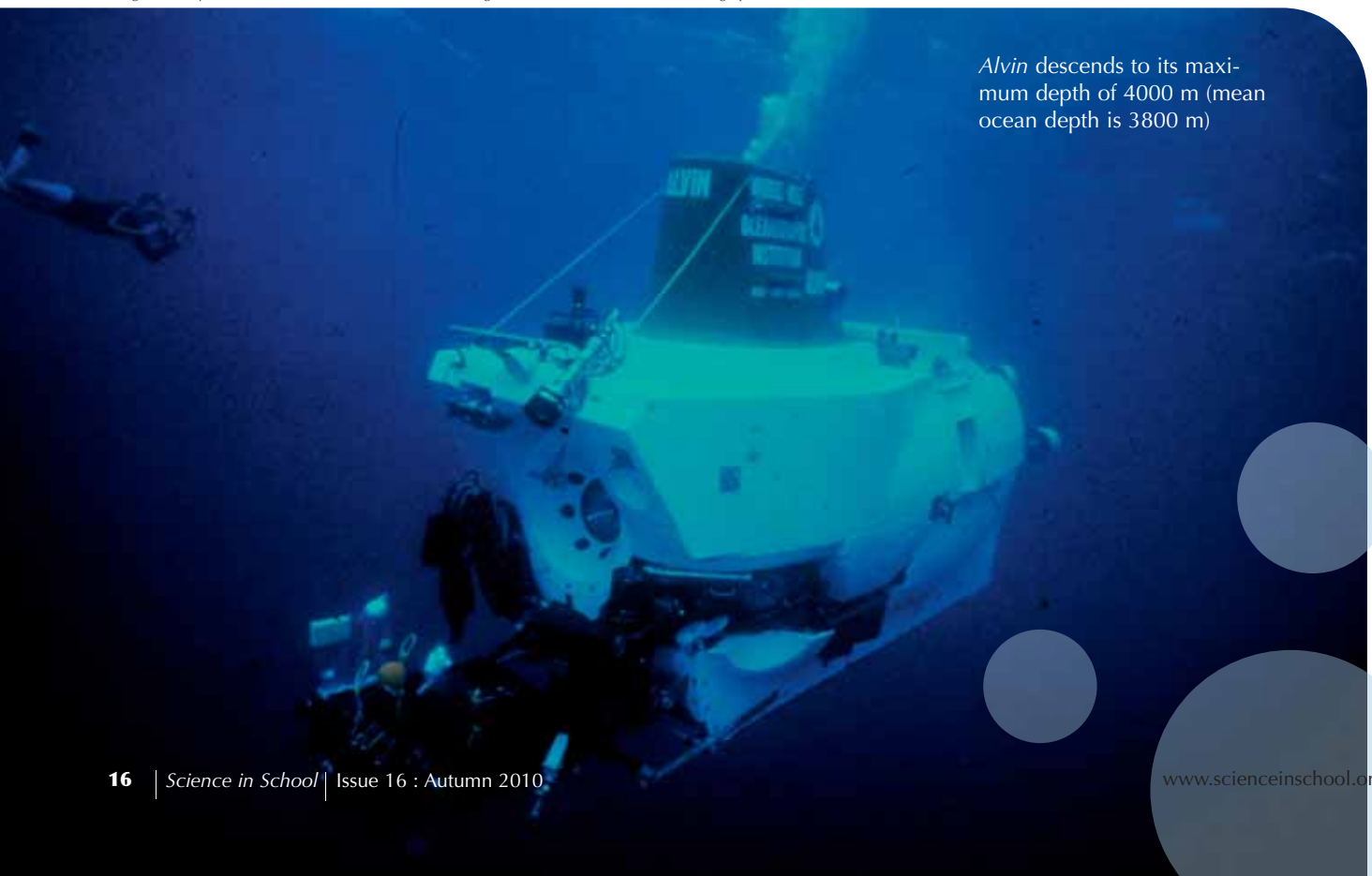
cal energy from hot rocks. The most important compound in vent fluid is hydrogen sulphide, and many vent animals, including giant tube worms (vestimentiferans), vent mussels and clams, depend for food on symbiotic bacteria that live by oxidising this sulphide.

This dependence on geochemical rather than solar energy may have shielded vent communities from

major environmental events, like the mass extinctions and global climate change that affected contemporary photosynthesis-based ecosystems. Thus, the evolutionary history of vent fauna is probably very different from that of other marine biotas.

The only direct evidence for this history comes from the fossil record. But at present this is sparse, with only 25 examples known from the past 550

Image courtesy of OAR / National Undersea Research Program (NURP); Woods Hole Oceanographic Institution



Alvin descends to its maximum depth of 4000 m (mean ocean depth is 3800 m)

million years, and there are fundamental questions about why this is. For example, why do some ancient vent deposits contain fossils, while others in the same state of preservation don't? There are also significant groups of animals, such as crabs and shrimps, that are abundant at modern vents but which do not appear in the vent fossil record. Why should this be? Is it a case of imperfect preservation, or were these groups not present at vent sites in the past?

To find out, we decided to investigate how modern deep-sea hydrothermal vent animals (molluscs, crustaceans and tube worms – both vestimentiferans and polychaetes) become fossilised at vents. To do this we chose an area on the East Pacific Rise, 500 nautical miles south of Mexico, where scientists have been studying vents for two decades.

In partnership with colleagues at Woods Hole Oceanographic Institution and the University of New Hampshire, USA, the plan was to use *Alvin* to deploy specially designed duplicate sets of experimental materials at different hydrothermal vents in three different micro-habitats: the high temperature 'black smoker' hydrothermal fluid habitat (up to 370 °C), 'diffuse flow' sites where hot fluid and seawater mix (at 10-40 °C, this is where the majority of animals live), and a control site away from active venting (3 °C).

We'd then recover these experimental materials at roughly yearly intervals for transport back to the UK and investigation. The experimental devices consisted of identical titanium mesh cages, inside which were wired a variety of control materials and biological substrates: dried vestimentiferan tubes, vent mussel and clam shells, periwinkle shells and tiger prawn carapaces.

We deployed the first fossilisation cages at two vent sites in May 2005. Unfortunately, our hard work came to nothing – the cages (together with all

the other research groups' scientific equipment) were destroyed by a major submarine volcanic event in the area late in 2005, in which an estimated 22 million cubic meters of lava erupted. Presumably our cages are still there, but covered by several metres of basalt!

We had to restart the project, building new cages and negotiating ship time with our American colleagues. Happily, we have since enjoyed great success. We deployed new sets of fossilisation cages at two different vent sites in November 2006 and December 2007, and recovered them after 373 days and 319 days, respectively. The results are very interesting, and go a long way towards answering many of our questions about fossilisation at hydrothermal vents. For example, we now know that fossilisation is very dependent on exactly where the remains are located around the vent.

In our experiment, fossilisation by the growth of sulphide minerals on the biological materials (vestimen-



Image courtesy of Crispin Little

Crispin Little back on the deck of the research vessel *Atlantis* after his first dive in *Alvin* in December 2007. Being doused with cold seawater is traditional. During the dive, he and his colleagues deployed a new set of fossilisation cages at a vent site; they were subsequently recovered around a year later

tiferan tubes, periwinkle, mussel and clam shells) only occurred in the high-temperature areas of the vent sites, or where the vent changed over time – for example, where a diffuse flow vent turned into a black smoker during the experiment. Sulphide mineralisation did not generally occur at



Image courtesy of Crispin Little

Crispin Little extracting a pair of fossilisation cages from *Alvin*'s collection basket (*Alvin*'s claw can be seen on the right), recovered from 2.5 km down on the sea floor. After around a year in the high-temperature vent fluid, the cages have a pyrite chimney growing through them

Image courtesy of OAR / National Undersea Research Program (NURP); Woods Hole Oceanographic Institution



Alvin in 1978, a year after first exploring hydrothermal vents

Image courtesy of OAR / National Undersea Research Program (NURP)



Alvin hovering above deck before diving to 4000 m

diffuse flow sites, although mollusc shells suffered considerable dissolution here, or at control areas away from active venting. The implication is that the fossils found in ancient vent deposits reflect only the parts of those communities that lived at the higher-temperature areas around the vents.

We found that the mollusc shells and tubes acted as simple substrates for the growth of pyrite (iron sulphide), with mineralisation occurring on both shells and tubes. This is exactly what we might expect from the preservation of vent fossils in ancient vent deposits.

We also discovered that the apparent bias towards the fossilisation of worm tubes and mollusc shells is a real phenomenon and reflects how well the various biological substrates resist chemical dissolution in the vent environment, which puts them under high pressure due to depth and exposes them to hot, acidic vent fluid. Thus, no shrimp carapaces remained in any of the ten cages, including those from the control sites away from active venting. Vestimentiferan tubes, by contrast, proved resistant enough to decay to become fossilised.

The organic coating of mollusc

shells, called the periostracum, protects them to some extent from dissolution and makes it more likely that shells with thick periostracal layers will be preserved as vent fossils, particularly as the periostracum on its own can be mineralised. The implication is that crustaceans such as crabs and shrimps were present at hydrothermal vents in the past, but were just not preserved.

Our results are consistent with observations from ancient vent sites and let us better interpret the fossil record of vent communities. From this, we now know more of how vent fauna evolved, because we now understand how organisms are preserved in these environments, including the extremely rapid pathway to fossilisation – less than a year.

However, because fossilisation at vent sites happens so quickly, we still don't fully understand the very early stages of mineralisation of shells and tubes by pyrite, and future experiments should have shorter durations – in the order of a few months. Ship time and submersible seats, anyone?

Acknowledgement

This article was first published in *Planet Earth*, a free magazine about

natural and environmental science, published by the UK's Natural Environment Research Council. See Little (2009).

To subscribe to *Planet Earth*, email requests@nerc.ac.uk.

References

- Little C (2009) Hot stuff in the deep sea. *Planet Earth Winter*, 18-19. <http://planetearth.nerc.ac.uk/features/story.aspx?id=576>
- Searle R (2009) Holes in the crust. *Planet Earth Autumn*, 28-29. <http://planetearth.nerc.ac.uk/features/story.aspx?id=511>

Resources

If you enjoyed reading this article, you might like to browse the other *Science in School* articles on biological topics. See: www.scienceinschool.org/biology

Dr Crispin Little is a senior lecturer in the School of Earth and Environment at the University of Leeds, UK.



Using cutting-edge science within the curriculum: balancing body weight

Friedlinde Krotscheck



Friedlinde Krotscheck describes how she used a cutting-edge science article from *Science in School* as the main focus of a teaching unit on the human body.



- ✓ Biology
- ✓ Medicine
- ✓ Mathematics
- ✓ Health
- ✓ Human body
- ✓ Metabolism
- ✓ Obesity
- ✓ Ages 15+

When students are actively involved in their lessons, they always both enjoy and learn more. This article shows how this can be achieved using a cutting-edge science article from *Science in School* that can be used to cover a whole topic of the curriculum.

The work is involved and will challenge many students with mathematics, biology and discussions on health and well-being. The students must feel secure in the classroom before they begin to discuss weight issues and it may be a good idea to mention that personal issues are confidential and should not be discussed outside the room.

The issue of drugs to control weight and promote weight loss is an interesting topic and could be extended to include herbal and over-the-counter products. Students could discuss the social, commercial and ethical issues of weight-loss products and promotions. It should be a fun and interesting way of studying a topic by making it relevant to the students' own lives.

Shelley Goodman, UK

REVIEW



For teenagers, school lessons can be of secondary importance. Many students are interested principally in their appearance, their partners and having a good time outside school; they are also very sensitive to the opinions of their peers. When I reviewed an article for *Science in School* about a new potential hormone therapy for obesity (Wynne & Bloom, 2007), therefore, I wondered whether I could use the article and the concerns of teenagers to get my Year 10 students (ages 15-16) more involved in their biology lessons.

The first semester of Year 10 is dedicated to 'the human body'; this is the first and only time the students look at the topic in depth. Over three months, I devoted all 24 biology lessons (45 minutes each) to the sub-topic of 'homeostasis and the human body', focusing on the *Science in School* article, supplemented with video clips from *The Science of Fat* lectures (Evans & Friedman, 2004).

I began by asking my students if they would like to try a different teaching approach, based on a folder I had prepared containing worksheets and tables. The students would work independently and in groups to develop their own portfolios of information (notes, diagrams and essays), present their results to the others and take part in class debates. The students responded enthusiastically to the idea.

During the next three months, the students' enthusiasm for both the topic and the teaching approach continued. They were motivated to study the organ systems, grasp the principle of homeostasis and critically analyse their own lifestyles. I was impressed at how hard they worked on their portfolios – also outside lessons – and at their eagerness to learn more about the science involved, to influence the direction of the teaching unit, to teach each other and to discuss the ethical issues involved.

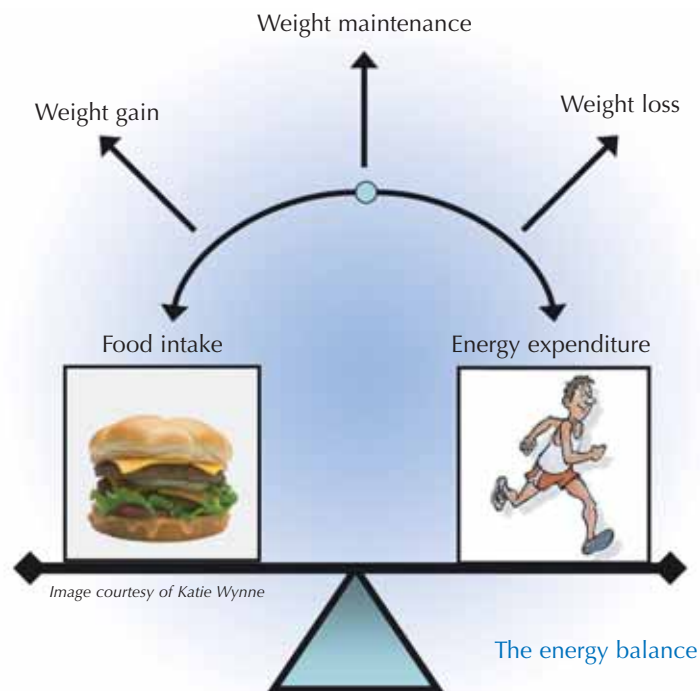
Of course, when addressing the topic of obesity, one concern is how to deal sensitively with any overweight or obese students in the class. Because the teaching unit began with a fairly lengthy consideration of homeostasis and metabolism, the students were quite relaxed by the time we discussed body mass index – and of course the students' individual data were not made public. Once we started discussing obesity and the research article, my two overweight students were elated, realising that their condition was not necessarily their fault – and began to discuss their eating habits openly in class. Other students talked openly about other weight problems, including anorexia and bulimia.

Below are guidelines for reproducing the teaching unit. I used it to introduce (with the students' agreement) a different approach to biology lessons, similar to the way scientists work. It also made my students realise that basic factual knowledge is important for understanding cutting-edge research.

If you are not able to devote such a long time to the topic, you could just use small parts of the project, or individual worksheets.

1) The daily life of a student

Start the first lesson with the simple question "How are you?" Discussing the students' answers and separating them into polite answers and honest reflections of their current state of



	Food intake		Energy expenditure		
Day	Food description	ml or g	Activity	Time	Distance

Table 1: Food intake and energy expenditure. Each day, record what you eat, how much you eat, what type of physical activity you do and for how long



BACKGROUND

Editor's note

If you have used one of our science articles in your lessons, please tell us how. Contact: editor@scienceinschool.org

emotions (e.g. sad, happy, tired, bored) should lead to factors that influenced their answers, for example:

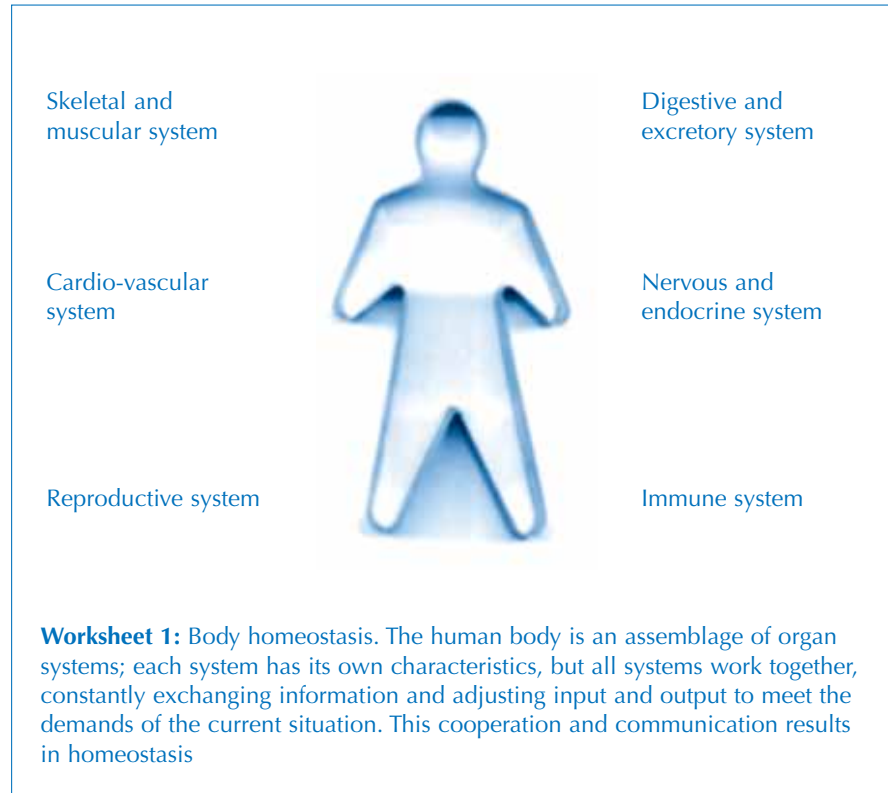
- Whether they like school
- Whether they are hungry or thirsty
- How much food or what type of food they have eaten
- How much sleep they have had.

From there, lead the discussion on to human metabolism and one of the diagrams (the energy balance, left) from Wynne & Bloom (2007). As homework, the students should complete Table 1 each day for a week, listing what they eat and what exercise they take. All tables and worksheets needed for the unit can be downloaded from the *Science in School* website^{w1}.

2) The organ systems

To address the topic of metabolism, the students need to understand the organ systems of the body and how they work together to maintain homeostasis. Over the course of the whole unit, the students should gather a portfolio of information about the diverse functions of the organ systems, working either in groups or individually, in the classroom or at home. It is important that the teacher is only the provider of materials (textbooks, websites, models, diagrams and other information

Image courtesy of Friedlinde Krotscheck



about the different organ systems); the students should gather the facts by themselves. I gave my students very little guidance about which facts to collect – providing support mostly for the weaker students. Other teachers may prefer to provide more structure.

Each group of students could concentrate on one organ system and

then give a 15 minute presentation, providing their audience with a quiz to complete.

Once they have collected information about all the organ systems, the students should use Worksheet 1 to:

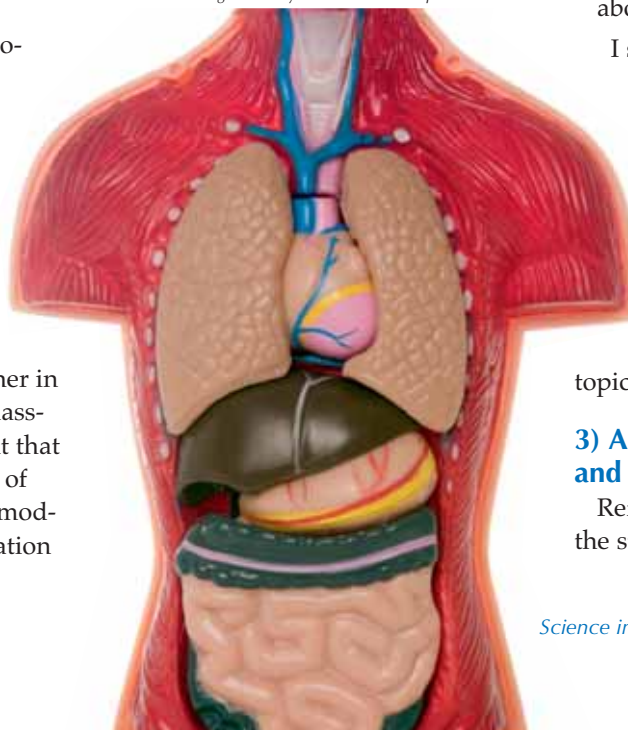
1. Describe the functions of each system and name the organs belonging to it.
2. Use arrows and labels to describe the influence that the organ systems above have on each other.

I spent 12 lessons on the first two parts of the teaching unit, after which my students had a basic understanding of the organ systems, how they depend on each other and what homeostasis is. The only teacher lecture I gave was about the central nervous system; otherwise all the topics were student-led.

3) An evaluation of food intake and activity

Referring to their data in Table 1, the students should each state a

Image courtesy of scol22 / iStockphoto



Food intake minus energy expenditure			
Day	+ kJ (food intake)	- kJ (energy expenditure)	Energy balance

Table 2: Food intake and energy expenditure balance

hypothesis about their own energy balance (e.g. weight loss or weight gain). They should then consider how their results can be compared quantitatively to those of their classmates – and arrive at the idea of using the body mass index (BMI).

$$\text{BMI} = \frac{\text{body mass (kg)}}{(\text{height (m)})^2}$$

Using the equation or an online BMI calculator^{w2}, each student should calculate his or her own BMI. The first of *The Science of Fat* holiday lectures ('Deconstructing obesity' by Jeffrey M Friedman) can be used to introduce some of the limitations of BMI, in particular that it does not apply equally well to everybody.

Then, using Table 2 and the data from Table 1, each student should calculate his or her energy balance each day and average the data over the week to see in which direction his or her energy balance tips. To do this, the students will need the teacher's guidance to convert the data in Table 1 into kilojoules. There are also many websites that do the calculations or provide the necessary information^{w3}.

The calculated energy balance will vary from student to student – and may differ from the hypotheses made at the beginning of this section. On the 'energy balance' diagram (see page 20), fill in the energy balance (in kJ) calculated for each student and discuss the results. The students will realise that total energy expenditure can be divided into the energy that the body uses for metabolic processes when at rest (our basal metabolic rate)

and the energy used during activity. However, Table 2 only includes the energy expenditure during activity – and the basal metabolic rate will vary from student to student.

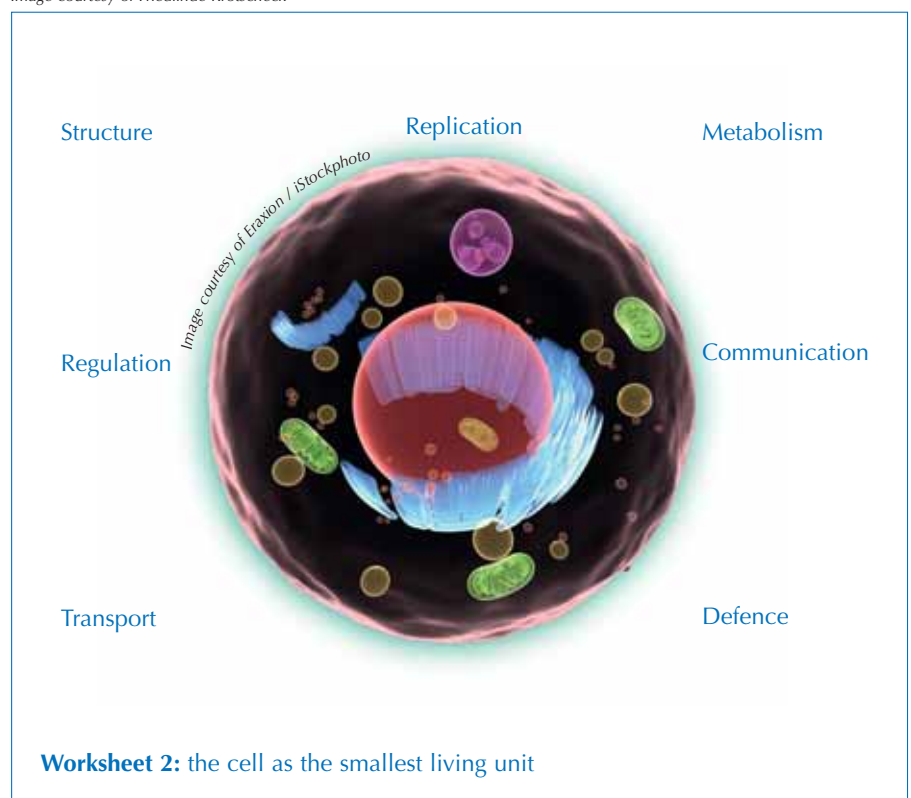
Our metabolic energy expenditure can be estimated, based on our height, weight, sex and age^{w4, w5}. The students could estimate their basal metabolic rate and include it in the calculation of their energy balance in Table 2. How does this change the students' positions on the 'energy balance' diagram (see page 20)?

At this point, metabolism at the level of the cell can be introduced using Worksheet 2. The students should use their textbooks to answer the following questions, making the connection between our own energy balance and the activities of the cells, tissues and organs.

1. List the cell structures and organelles involved in each of the functions in the diagram.
2. In Worksheet 2, use arrows to show the interdependency of these functions.
3. Compare your knowledge about cell functions with the homeostasis of the human body. Describe any parallels you see.

Among my students, this led to a discussion of the fact that our phenotype – for example, whether we are tall or whether we are fat – is affected by how the cells in our organs function. Sometimes these cells are present but they do not function properly. My students then concluded that home-

Image courtesy of Friedlinde Krotscheck



ostasis happens at all levels – between cells and between organs – and that homeostasis (balance) is necessary for a healthy body.

4) Introducing the *Science in School* article

Even if the variation in metabolic energy expenditure were taken into account, not all the students would have an energy balance of close to 0; instead, some of them clearly consume more (or less) energy than they expend. Why? The discussion should lead to the concept of satiety: the feeling of having eaten enough.

Introduce a second diagram (below, right) from Wynne & Bloom (2007) – but without labels^{w1}. Describe the research reported in the article and explain the signalling involved in appetite, eating and satiety. In particular, the role of the L cell can be researched and discussed, drawing on the students' knowledge of cell functions within our organ systems.

The students should label the diagram accordingly.

Since the students are now familiar with the concept of BMI and the definition of obesity, get them to discuss in small groups the problems of obesity and the necessity for help, with the aid of Worksheet 3^{w1}.

Ask the students to imagine they were obese and answer the following questions:

1. Which one of the disadvantages associated with obesity (see Worksheet 3) would you like to address first?
2. How would you do it?
3. Would you ask for help? If so, from whom?
4. Make a list of small steps to reach your goal.
5. How do the disadvantages of obesity relate to each other? What could these disadvantages lead to?
6. Do you think that obesity is something that could happen to you? Explain.

The discussion should lead the

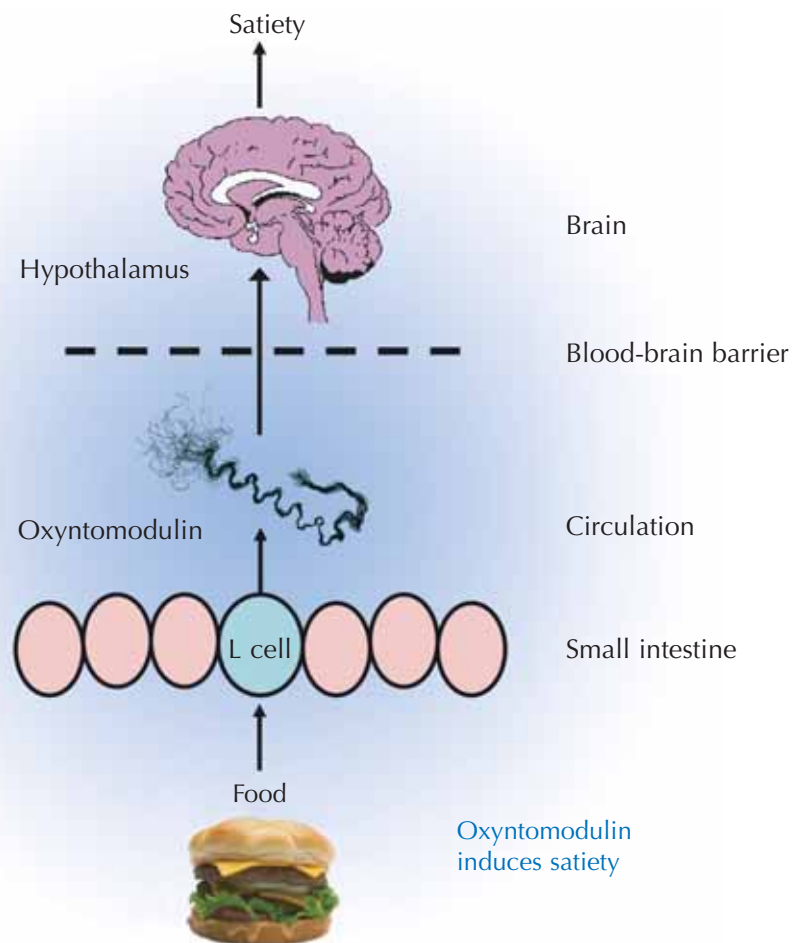


Image courtesy of Katie Wynne

Image courtesy of Friedlinde Krotscheck



drug trials (right) to show that before drugs are licensed, they go through many stages of testing to identify and minimise side effects.

The following questions may arise or could be posed:

1. What effect does injected oxyntomodulin have on the receptors in the brain?
2. What effect did oxyntomodulin have on the volunteers in the study, other than triggering satiety?
3. Could the injected hormone disturb the production of oxyntomodulin by the body (substrate-induced inhibition)? State a hypothesis.

Concluding the topic

Ask the students to write a short essay – either a creative story or a factual discussion – about the possible impact of using oxyntomodulin to treat obesity.

Finally, the students could discuss whether this type of research should be funded at all. Why? Why not? With my students, this led to a lively debate, including the point that many more people starve to death around the world than die of obesity-related problems.

By the end of the unit, the students should have understood that our organ systems depend on and influence each other, and that if one parameter is changed there will be a chain of changes elsewhere in the system. This is true of any disturbance of body homeostasis, whether overeating, starvation or even drug abuse.

References

Evans RM, Friedman JM (2004) Howard Hughes Medical Institute holiday lectures: *The Science of Fat*.

In these lectures for secondary school, leading scientists discuss how the body regulates weight by carefully controlling the storage and burning of fat – and how a better understanding of these complex metabolic systems could lead

Image courtesy of egal / iStockphoto



students to the conclusion that obesity is a sign of disturbed homeostasis, when some individuals do not recognise satiety because their L cells may not function properly. Treatment with oxyntomodulin has the potential to cause weight loss by correcting the body's energy balance, enabling a healthy weight to be maintained.

5) Outlook of the treatment

Before oxyntomodulin can be used widely to treat obesity, further study is necessary. From Wynne & Bloom (2007), use the box about clinical



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 of 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.

	Phase			
	I	II	III	IV
Number	124	259	169	55

Table 3: Potential obesity drugs entering each phase of clinical trials in 1994-2007. Although many potential drugs are investigated, few reach the market: only two are currently licensed in the USA.

BACKGROUND

researchers to treatments that curb obesity and improve public health.

Lecture 1: Deconstructing obesity, by Jeffrey M Friedman, MD, PhD

Lecture 2: Understanding fat: syndrome x and beyond, by Ronald M Evans, PhD

Lecture 3: Balancing the fat equation, by Ronald M Evans, PhD

Lecture 4: Exploring obesity: from the depths of the brain to the far Pacific, by Jeffrey M Friedman, MD, PhD

These and all other lectures in the Howard Hughes Medical Institute holiday lecture series can be viewed online or ordered free on DVD. The transcripts of the lectures are available to download. See www.hhmi.org/biointeractive/obesity

To learn more about some of the Howard Hughes Medical Institute holiday lectures, see the following reviews:

Hadjimarcou M (2006) Review of *Learning from Patients: the Science of Medicine*. *Science in School* 2: 83.

www.scienceinschool.org/2006/issue2/patients

Hadjimarcou M (2007) Review of *Clockwork Genes: Discoveries in Biological Time and Evolution: Constant Change and Common Threads*. *Science in School* 7: 66-67.

www.scienceinschool.org/2007/issue7/clockwork

Hadjimarcou M (2009) Review of *Potent Biology: Stem Cells, Cloning, and Regeneration*. *Science in School* 11: 92.

www.scienceinschool.org/2009/issue11/potentbiology

Wynne K, Bloom S (2007)

Oxyntomodulin: a new therapy for obesity? *Science in School* 6: 25-29.

www.scienceinschool.org/2007/issue6/oxyntomodulin

Web references

w1 – The necessary tables and worksheets for this activity can be downloaded from the *Science in School* website:

www.scienceinschool.org/2010/issue16/obesity#resources

w2 – Body mass index can be calculated using online tools such as:

www.nhlbisupport.com/bmi/bmi-m.htm and

www.bmi-calculator.net (in either metric or imperial measures).

w3 – To calculate their energy intake in kJ, the students might find the search function on the Nutrition Data website helpful. See:

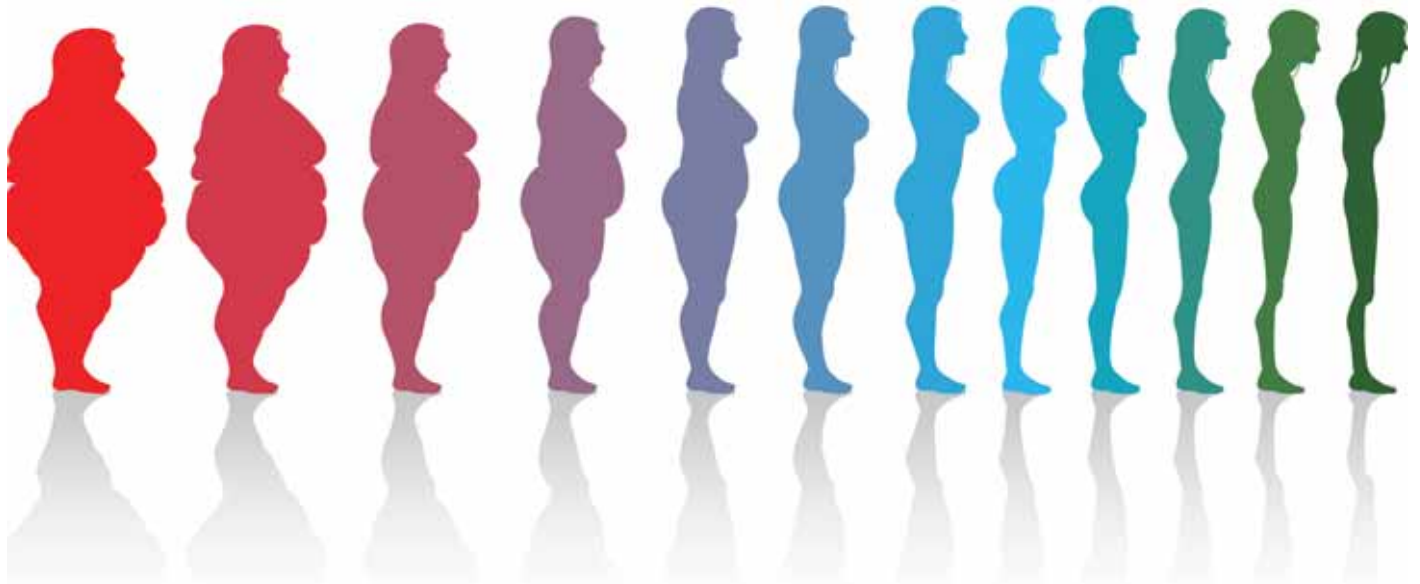
www.nutritiondata.com

To calculate their energy expenditure in kJ, they could use the information on Answers.com:

www.answers.com/topic/average-energy-expenditure-of-various-activities-and-sports

w4 – To calculate their own basal metabolic rates, the students could use the following website:

www.bmi-calculator.net



w5 – A useful slideshow presentation about basal metabolic rates is available here:

www.slideshare.net/Meggib/energy-expenditure-presentation-703878

w6 – To learn more about the European Molecular Biology Laboratory (EMBL), see:

www.embl.org

For more information about the European Learning Laboratory for the Life Sciences, EMBL's science-education facility to bring secondary-school teachers in contact with EMBL's scientific environment, see: www.embl.org/ells

w7 – Science on Stage is a network of local, national and international events for teachers. National Science on Stage events culminate in a European teaching festival every two years, the next one being in Copenhagen, Denmark, from 16-19 April 2011.

To learn more about Science on Stage and find your national contact, see the Science on Stage Europe website:

www.science-on-stage.eu

To find out more about Science on

Stage Austria, see:

www.scienceonstage.at

To read about the Science on Stage Austria national event in February 2010, see:

Hayes E (2010) Science on Stage: gathering momentum. *Science in School* 15: 2-3.

www.scienceinschool.org/2010/issue15/sons

Resources

To learn more about clinical trials, see:

Garner S, Thomas R (2010) Evaluating a medical treatment. *Science in School* 16: 54-59.

www.scienceinschool.org/2010/issue16/clinical

To browse all medicine-related articles in *Science in School*, see:

www.scienceinschool.org/medicine

Friedlinde Krotscheck has taught for a total of 25 years. After qualifying as a teacher, she taught both biology and sports at secondary schools in Hamburg and Heidelberg, Germany.

In 1988, she and her family moved to Texas, USA, where she taught science for six years, and organised the annual science and mathematics day at the school. After summer courses on biotechnology and gene technology, she became a biotechnology ambassador, teaching the subjects to US high-school teachers.

Returning to her old school in Heidelberg (the Internationale Gesamtschule) in 1995, Friedlinde became involved with the education activities at the European Molecular Biology Laboratory^{w6}, visiting the laboratory with her students and taking part in teacher-training courses. These emphasised the importance of 'real' science in science teaching – planning and doing experiments and understanding the process of scientific discovery.

Since moving to Austria after her retirement in 2008, Friedlinde has continued to review articles and resources for *Science in School*, and to chair Science on Stage Austria^{w7}.



Microscale chemistry: experiments for schools

Elias Kalogirou and **Eleni Nicas** introduce a selection of very small-scale chemistry experiments for school.



- ✓ Chemistry
- ✓ Ages 11-19

An important part of the job of a science teacher is to teach not only scientific theory but also experimental skills. For this reason, traditional practical work cannot and should not be replaced. However, considerations such as economic factors and environmental awareness and protection are also valuable in this age of 'green chemistry'. Integrating some microscale chemistry into traditional laboratory practical work will help develop these ideas. Working with microscale quantities is also appropriate for younger children.

Marie Walsh, Republic of Ireland

REVIEW



Image courtesy of tap10 / iStockphoto

By industrial standards, all school chemistry is small-scale – 50 ml here, 1 g there. For the past three years, however, we have been doing *microscale* chemistry experiments at our school – using one or two drops of each reagent.

Working at this scale has many advantages. Using smaller amounts of reagent reduces the time, cost and waste involved, and encourages stu-

dents to think about environmental protection. Although safety precautions are still necessary, the risk involved is lower with smaller volumes – and the students had no difficulties manipulating such

Image courtesy of Kraska / iStockphoto

small quantities. At this scale, the experiments do not need normal laboratory glassware but can be performed using simple household materials such as chewing-gum packets; these are cheap, can be reused several times and require little storage space.

Below are instructions for some microscale experiments that we perform with 14- to 15-year-old students. Our students carried out the experiments in groups of four. Alternatively, the teacher could demonstrate the experiments by placing the apparatus on an overhead projector.

The reactions are part of the usual Greek education curriculum for this age of students, but would normally be studied on a larger scale.

Experiments

Rather than using normal, full-scale laboratory equipment, these experiments are carried out in a chewing-gum blister packet, from which the foil and the gum have been removed (see image). Tablet packets would be fine too, if the tablets were large enough. Each experiment takes place in a separate well of the packet.

Image courtesy of Elias Kalogirou and Eleni Nicas



Our reaction vessel: a chewing-gum packet

Safety notes:

- Hydrochloric acid and sodium hydroxide, required for the majority of the experiments described in this article, should be used only when wearing gloves and safety glasses.
- With such small quantities and low concentrations, any remaining reagents can simply be washed down the sink.

The tables (experimental procedures and results) for all the experiments can be downloaded as a Word® document from the *Science in School* website^{w1}.

Preparation

To prepare the red cabbage indicator, cover 10 g fresh, chopped red cabbage leaves with 200 ml distilled water and bring to the boil. Boil until the liquid turns light purple. Leave it to cool and strain off the liquid, which is the indicator solution.

To prepare the sodium hydroxide (NaOH) solution, dissolve 0.4 g sodium hydroxide in 100 ml water.

To prepare the limewater (saturated calcium hydroxide solution), fill a 500 ml beaker one-third full with calcium hydroxide [Ca(OH)₂] and add distilled water up to the 400 ml mark. Stir the mixture well and leave the resulting suspension to settle for several hours. The colourless, saturated solution (limewater) should be poured into a dropping bottle, taking care not to disturb the sediment.

Hydrochloric acid solution (15% w/w) can be bought in the supermarket in some countries. Alternatively, make a 1 M solution (approximately) in the laboratory.

(Note that the hydrochloric acid solution used is more concentrated than the sodium hydroxide solution, to ensure that the acid reactions can be observed with the naked eye, while the base reactions do not waste reagents.)

For the experiments, each of the solutions should be placed in a dropping bottle.

Aims

The purpose of Experiment 1 is for the students to realise both that acids and bases change the colour of pH indicators, and that the colour change is different between acids and bases.

In Experiment 2, the students observe how acids react with metals. They should observe the production of bubbles (effervescence) and also that magnesium reacts more strongly (producing more heat and more bubbles) with acid than iron does – although less acid is used. We explain to our students that the gas produced is hydrogen.

In Experiment 3, the students observe how acids react with carbonates. They should observe the production of bubbles (effervescence). We explain that the gas in the bubbles is carbon dioxide.

Experiment 4 gives the students the opportunity to practise using pH indicator paper. They should learn that the pH of a solution can be determined with indicator paper and the solutions classified as either acid or base.

In Experiment 5, the students investigate the conductivity of distilled water, hydrochloric acid and sodium hydroxide solution. They should learn that whereas distilled water does not conduct electricity, both acid and base solutions do.

Red cabbage



Experiment 1: Colour change of indicators

Equipment

- Chewing-gum blister packet (see image on page 28)
- Drinking straws, cut diagonally (see images, right)
- Scissors
- Disposable gloves
- Safety glasses

Materials

- Hydrochloric acid solution (15% w/w or 1 M)
- Ammonia-containing household solution (e.g. Ajax® window cleaner)
- Sodium hydroxide solution (0.1 M, for preparation, see page 28)
- Limewater (see page 28)
- Red cabbage indicator (see page 28)
- Litmus indicator solution
- Phenolphthalein indicator solution
- Lemon juice
- Crushed aspirin tablet
- Distilled water

Image courtesy of Elias Kalogirou and Eleni Nicas



Cut the drinking straw diagonally, so that it can be used to measure out small quantities of powder



One drinking-straw tip of iron powder

1. Referring to Table 1, add a test solution (e.g. lemon juice) and a pH indicator (e.g. litmus indicator solution) to each well.

Method

Well 1 <ul style="list-style-type: none"> • 10 drops of lemon juice • 2 drops of red cabbage indicator 	Well 2 <ul style="list-style-type: none"> • 10 drops of limewater • 2 drops red cabbage indicator
Well 3 <ul style="list-style-type: none"> • 1 drinking-straw tip of aspirin powder (see image above) • 10 drops of water • 2 drops litmus indicator solution Stir the mixture	Well 4 <ul style="list-style-type: none"> • 10 drops household ammonia solution • 2 drops litmus indicator solution
Well 5 <ul style="list-style-type: none"> • 10 drops hydrochloric acid solution • 2 drops of phenolphthalein 	Well 6 <ul style="list-style-type: none"> • 10 drops of sodium hydroxide solution • 1 drop of phenolphthalein

Table 1: Procedure for Experiment 1

2. Using Table 2, record the observed colour changes.
3. What can you conclude from your results?

Indicator	Original colour of indicator	Colour after acid is added	Colour after base is added
Red cabbage		Well 1:	Well 2:
Litmus indicator solution		Well 3:	Well 4:
Phenolphthalein		Well 5:	Well 6:

Table 2: Results for Experiment 1

Experiment 2: Effect of acids on metals

Equipment

- Chewing-gum blister packet
- Drinking straws, cut diagonally
- Scissors
- Disposable gloves
- Safety glasses

Materials

- Iron (Fe) powder
- Magnesium (Mg) powder
- Hydrochloric acid solution (15% w/w or 1 M)

Method

1. Referring to Table 3, add a metal powder (e.g. iron) and an acid solution (hydrochloric acid) to each well.
2. What do you observe when hydrochloric acid is added to the iron powder?
3. How does this differ from the effect of the acid on magnesium?
4. Can you explain the reason behind the difference?

Experiment 3: Effect of acids on carbonates

Equipment

- Chewing-gum blister packet
- Drinking straws, cut diagonally
- Scissors
- Disposable gloves
- Safety glasses

Materials

- Powdered chalk (CaCO_3)
- Sodium bicarbonate (NaHCO_3)
- Hydrochloric acid solution (15% w/w or 1 M)

Method

1. Referring to Table 4, add a carbonate (e.g. powdered

Well 1	Well 2
<ul style="list-style-type: none"> • 1 drinking-straw tip of iron powder • 10 drops hydrochloric acid solution 	<ul style="list-style-type: none"> • 1 drinking-straw tip of magnesium powder • 2 drops of hydrochloric acid solution

Table 3: Procedure for Experiment 2

chalk) and an acid solution (hydrochloric acid) to each well.

2. What do you observe when the acid is added to the carbonate?

Experiment 4: Using pH indicator paper

Equipment

- Paper towels
- A4 white paper
- Scissors
- Disposable gloves
- Safety glasses
- pH indicator paper or universal indicator strips

Materials

- Vinegar
- Hydrochloric acid solution (15% w/w or 1 M)
- Ammonia-containing household solution (e.g. Ajax window cleaner)
- Limewater
- Distilled water

Method

1. Place a layer of paper towels on the table and lay an A4 sheet of paper on top of it.
2. Cut five 4 cm strips of pH indicator paper and lay them, well spaced out, on the white sheet. (Alternatively, use five universal indicator strips.)
3. Onto each strip, pour two drops of a different test solution (e.g. vinegar or limewater).
4. Once the strips have changed colour, compare the colour to the colour chart for the indicator paper and determine the pH.
5. Using Table 5, record the pH of each solution and decide whether it is an acid or a base.

Well 1	Well 2
<ul style="list-style-type: none"> • 1 drinking-straw tip of chalk powder • 5 drops of hydrochloric acid solution 	<ul style="list-style-type: none"> • 1 drinking-straw tip of sodium bicarbonate • 5 drops of hydrochloric acid solution

Table 4: Procedure for Experiment 3

Solution	Vinegar	Hydrochloric acid	Ammonia	Limewater	Distilled water
pH					
Acid or base					

Table 5: Results of Experiment 4



Image courtesy of Diffydave / iStockphoto

Image courtesy of Jobalou / iStockphoto

Experiment 5: Conductivity of distilled water, acid and base solutions

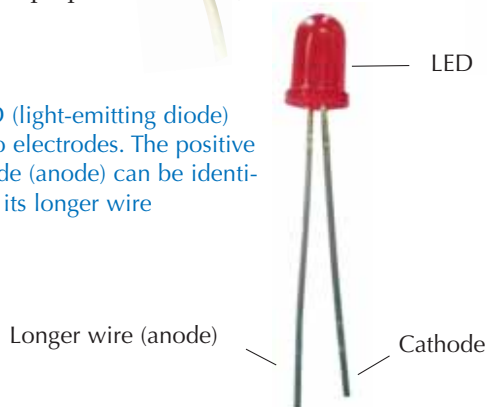
Equipment

- Chewing-gum blister packet
- Scissors
- Disposable gloves
- Safety glasses
- Aluminium foil
- 3 connecting cables with crocodile clips
- Sticky tape
- 4.5 V battery
- LED (5 mm in diameter)

Materials

- Distilled water
- Hydrochloric acid solution (15% w/w or 1 M)
- Sodium hydroxide solution (0.1 M, prepared as above)

An LED (light-emitting diode) has two electrodes. The positive electrode (anode) can be identified by its longer wire



Method

1. Cut four strips of aluminium foil, each 6 cm x 0.5 cm.
2. To form the electrodes, bend two strips of foil into Well 1 of the blister packet, then use sticky tape to attach the strips to the table to prevent them from moving (see image, below).



Attaching the electrodes

The next step is to construct the electric circuit (see image, below).

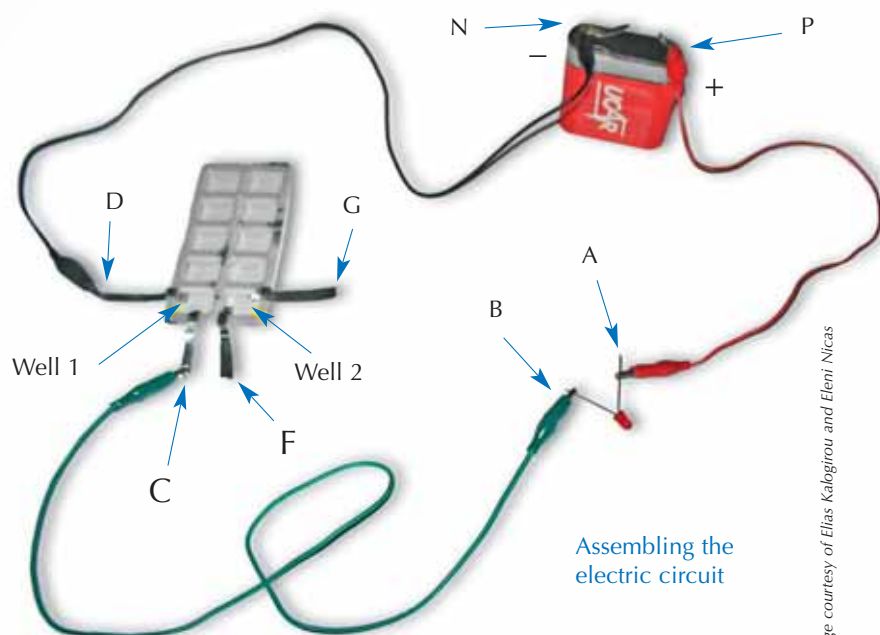


Image courtesy of Elias Kalogirou and Eleni Nicas

Image courtesy of Elias Kalogirou and Eleni Nicas

3. Using one of the cables, connect the positive terminal of the battery (P) with the anode of the LED (A). With a second cable, connect the LED's cathode (B) to one of the aluminium foil strips (C). Via a third cable, connect the other strip of foil (D) to the negative terminal of the battery (N).
4. Half-fill Well 1 with distilled water. This forms a complete circuit.

Does the LED light up?
What can you conclude? Does distilled water conduct electricity?
5. Add 3 drops of hydrochloric acid to Well 1.

Does the LED light up now?
What can you conclude? Does hydrochloric acid solution conduct electricity?
6. Disconnect the cables from the two strips.
7. Bend two new strips into Well 2 and attach them to the table (as in step 2).
8. Connect the cables to the ends of the new strips (F and G).
9. Drop by drop, add sodium hydroxide solution to Well 2 until the ends of the aluminium strips are covered (we needed six drops).

Does the LED light up?
What can you conclude? Does sodium hydroxide solution conduct electricity?

Acknowledgement

The authors would like to thank Penelope Galanopoulou, who teaches English at the 3rd Pyrgos Lyceum Pierre de Coubertin, for translating this article from Greek into English.

Web references

w1 – The tables (experimental procedures and results) for all the experiments can be downloaded as a Word document from the *Science in School* website:
www.scienceinschool.org/2010/issue16/microscale#resources

Resources

Williams KL, Little JG (1997)

Microscale Experiments for General Chemistry. Boston, MA, USA: Houghton Mifflin. ISBN: 9780669416060

Zubrick JW (2003) *The Organic Chem Lab Survival Manual: A Student's Guide to Techniques* 6th edition. New York, NY, USA: John Wiley & Sons. ISBN: 9780471215202

Skinner J (1998) *Microscale Chemistry: Experiments in Miniature*. Cambridge, UK: Royal Society of Chemistry. ISBN: 9781870343497

Greek speakers may find the following book useful:

Κ. Γιούρη & Τσοχατζή (2003) *Σχολικά Πειράματα Χημείας, Από τη Μακρο- στη Μικροκλίμακα*. Θεσσαλονίκη, Ελλάδα: Εκδόσεις Ζήτη ISBN: 9604318608

For another activity using red cabbage indicator, see:

Lorenc A (2008) Investigating the action of urease. *Science in School* 9: 39-44.
www.scienceinschool.org/2008/issue9/urease

If you enjoyed this article, you might like to browse all the other teaching activities that have been published in *Science in School*. See:
www.scienceinschool.org/teaching

To view all chemistry-related articles in *Science in School*, see:
www.scienceinschool.org/chemistry

Elias Kalogirou is a secondary-school science teacher. He is responsible for the Laboratory Centre of Physical Sciences, which works with secondary-school science teachers to promote the use of experimental work in science teaching. In particular, he encourages the use of microscale experiments at school.

Eleni Nicas trained as a biologist and for the past six years has taught biology, chemistry and physics at middle school (ages 13-15), currently at the 4th Junior High School of Pyrgos. For the last three years, she has used microscale experiments in her chemistry lessons, in collaboration with the regional Laboratory Centre of Physical Sciences. She is currently studying for a postgraduate degree in physics education.

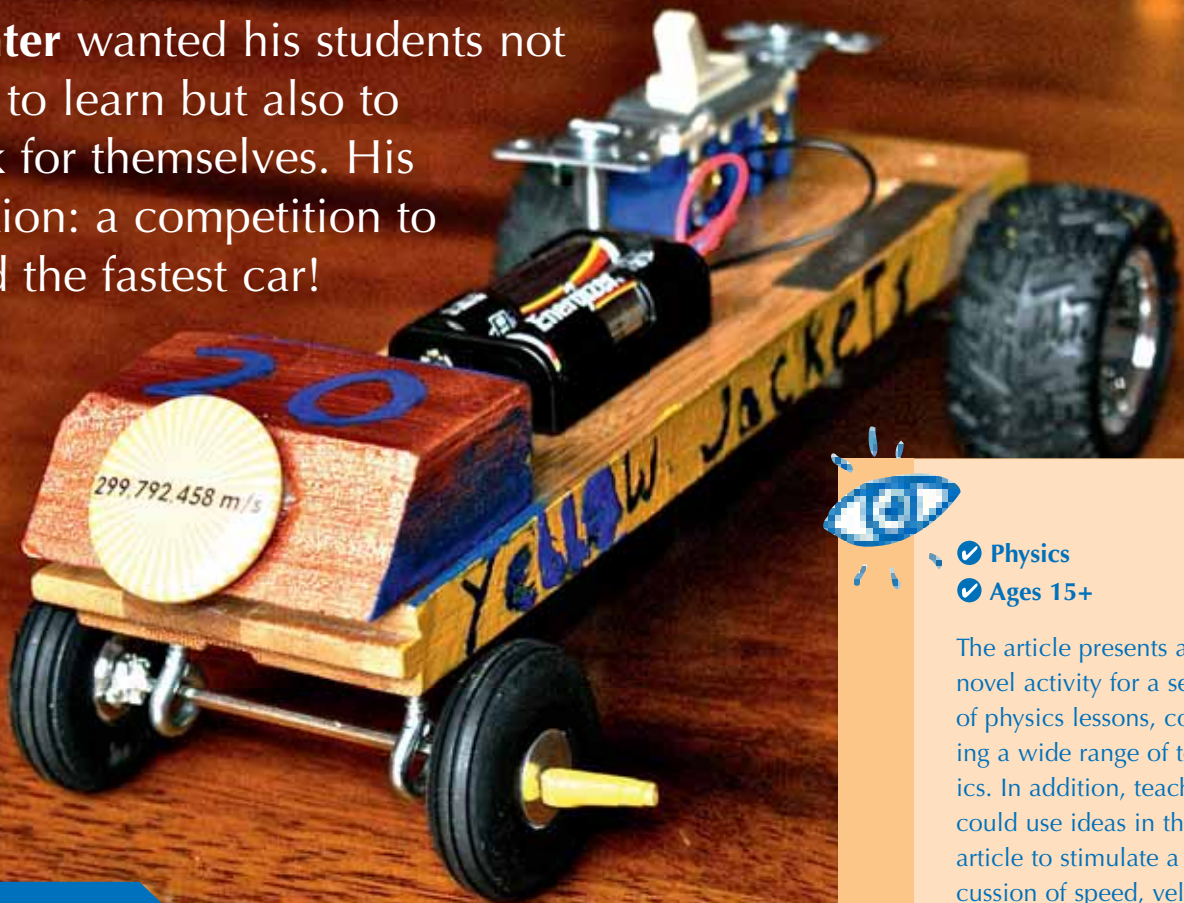


Image courtesy of DCCornell / iStockphoto

Car racing in the physics classroom

Image courtesy of Nicolas Poynter

Physical science teacher **Nicolas Poynter** wanted his students not only to learn but also to think for themselves. His solution: a competition to build the fastest car!



The car prototype

To motivate my students and teach them about simple machines, electricity, experimental variables, the laws of motion and the scientific method, I developed a car-racing project, spanning the topics of the entire first block of a standard textbook for ninth-grade (aged 15) physical science in the USA (Hsu, 2005). Teams should compete to construct the fastest car, using the

knowledge gained in lessons. I felt that the usual textbook activities were too constrained: the students followed instructions as if baking a cake. I wanted to make them reason and think. The project was a complete success: not only did the students gain a deep understanding of the subjects, but their enthusiasm was strong and infectious.



- ✓ Physics
- ✓ Ages 15+

The article presents a novel activity for a series of physics lessons, covering a wide range of topics. In addition, teachers could use ideas in the article to stimulate a discussion of speed, velocity and acceleration or of different types of energy (e.g. kinetic and electrical).

Comprehension questions arising from the article include:

- What are gear ratios?
- How can you calculate power of a circuit?
- What is the relationship between mass, acceleration and work done?

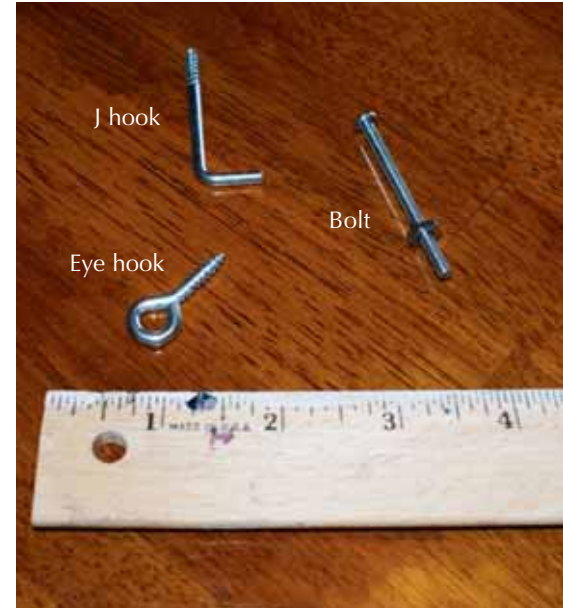
Eric Demoncheaux, UK

REVIEW

Image courtesy of Nicolas Poynter



Image courtesy of Nicolas Poynter



The activity

Timing: Each section described below takes approximately 80 minutes: 20 minutes for the introduction, and an hour for practical work. Before starting, students should know about measurements, unit conversions and the scientific method.

I taught the class every day of the week, alternating between introductory laboratory activities and the car project: e.g. after two days of simple circuit construction, we would advance to building a circuit from scratch for the project.

Rules: In addition to a gearbox, each car should have a wooden chassis, be powered by two 1.5 volt batteries, and have a switch included in the design of the circuit.

Car components

Each group of students needs:

- A gearbox and motor (identical for each team). I used a three-speed gearbox with a 3 V motor from Tamiya^{w1} (item #70093), but any will do
- A battery holder
- A standard switch
- A pine, bamboo or oak board (7.5 cm x 25 cm x 2 cm) for the chassis

- A set of three or four tyres (a selection for the students to choose from).

I bought old remote-controlled cars cheaply and then pulled wheels, axles and motors off for parts. However, anything that rolls, such as screen-door castors, can be used as wheels; many cheap, acceptable items can be found in any hardware store or on the Internet.

Hardware and supplies

- 1.2 cm screws (suitable for wood)
- 5 cm bolts with washers and nuts
- 0.8 mm thick wire
- Eye hooks and J hooks
- Solder
- Electrical tape
- Glue suitable for metal, wood and plastic – the stronger the better
- Paint and brushes
- 3 mm diameter aluminium rod (for the front axles), approximately 3 cm per car. The Tamiya gearbox kit comes with a spare axle that can also be used for the front.
- Coarse sandpaper
- Pencils
- Grease (from the gearbox kit)

Tools

- A soldering iron
- A box saw
- Wire cutters
- Small screw drivers
- A small carpenter's square
- A drill and small drill bit
- Weighing scales

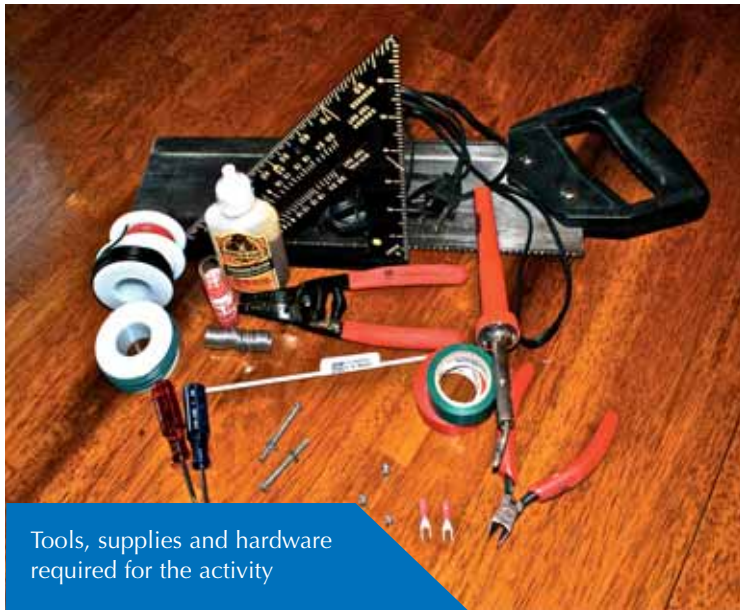
Additional materials

- Two prototype cars, one set on high speed (low torque), the other set on low speed (high torque). These will take about one afternoon to build. It is vital for the students to be able to continually refer to a working model, even though they may greatly deviate from it in their own design.
- Optional: a bicycle with gears
- Optional: a NERFTM toy gun (a type of childproof plastic gun) with styrofoam bullets, sticky tape
- Two photogates and a 10 m phone cord (to time the car race)

Assembling the gearboxes: gears and sliding friction

Students should learn the function of gearing as they construct the gearbox for their car, and understand the parallels with the gears in a real car

Image courtesy of Nicolas Poynter



Tools, supplies and hardware required for the activity

Image courtesy of Nicolas Poynter

Demonstrating Newton's second law of motion with a NERF gun, styrofoam bullets and tape



and bicycle. Newton's laws and gears should be covered before you start.

1. Introduce the two prototype cars. Demonstrate that one is faster on an even surface, but unable to climb steep gradients (>45 degrees) while the other, low-speed, high-torque car can handle these easily (see image on page 37).
2. Optionally, you may mount a bicycle on the desk to show the students that at the lowest gear ratio, the tyre spins most per turn of the pedals. At the highest gear ratio, the tyre does the fewest revolutions per turn of the pedals, reducing the force necessary to pedal (as when climbing a hill). Thus, when it is easiest to pedal, the speed is smallest. This really helped my students understand the purpose of gearing.
3. Give each team of two to four students one of the identical gearboxes.
4. Tell the students that their cars will race on level ground.

From the very beginning of the project, I told them the precise length of the race and the track: 10 m on a waxed floor. It is important that they know the distance they are aiming for: some cars run straight for 5 m and then fly off course.

5. Ask the students to select a gear ratio (16.6:1, 58.2:1 or 203.7:1) and assemble the gearbox, following the supplier's directions. They should choose the high-speed setting (16.6:1). If they choose incorrectly, they won't realise this until they test the cars and will then have to reassemble their gearbox – quite a lot of work. The two prototypes help them decide correctly and minimise this extra work.
6. Place the leads across a battery to check that the motor is operating properly and that the axle is spinning.
7. Apply grease to the gears to reduce friction, increasing speed. The results are minor, so many teams forget to grease their gears later on. The important thing is for them to understand that sliding friction means lower efficiency. This is an opportunity to explain that the standard automobile (internal combustion engine) is less than 25% efficient because of all the moving parts – all the sliding friction.

Designing the chassis: Newton's second law of motion and air resistance

The students should understand Newton's second law of motion, and

air resistance (drag), and translate what they have learned to the design of their car chassis.

1. Introduce Newton's second law of motion, and the concept of air resistance. I used a simple NERF gun which fires toy foam bullets with the same force every time. I wrapped sticky tape around some bullets to increase their mass, and had students weigh them (for some reason, it makes all the difference whether they weigh them or the teacher does). Then I asked my students how far the bullets would fly: if a bullet had twice the mass of another, it would go half as far. The law is fundamentally simple, but it is also vital to winning this car race.
2. Show the students the prototype cars. Mine had a 7.5 cm x 25 cm x 2 cm wooden chassis made from bamboo.
3. Ask each team to choose the material (a board cut to similar proportions) for their chassis.

I gave students the choice of oak, pine or bamboo, with pine being the lightest. Balsa would also be possible, and is even lighter. I chose bamboo, the densest and

Image courtesy of Nicolas Poynter

Draw a perfectly perpendicular line to mount the gearbox on the chassis



Image courtesy of Nicolas Poynter



A selection of tyres to choose from

least efficient, for the prototype, in order to reward teams that selected the lightest wood, rather than those that simply copied the prototype. Weighing scales were available in the classroom. I guided the students as little as possible, but answered all their questions and ensured that they all had a choice between heavy and light wood. When the finished cars were weighed several lessons later, I explained why pine was the best choice.

4. Ask the students to draw their design on the wood for further cutting. The teacher should do the cutting with a box saw.
5. Let the students sand the chassis.
6. Paint and number the cars.

Students should attempt to make their cars lighter by choosing the right wood, cutting pieces away, and sanding their cars into more aerodynamic shapes.

Wiring the chassis: simple electric circuits and motors

Students should learn about simple electric circuits and electric motors. They should have been instructed on voltage, current and resistance, as well as simple circuits.

1. Each team already has its own gearbox with an axle and motor. Give each team a battery holder and a switch.
2. Be sure to draw a perfectly perpendicular pencil line on the chassis for the gearbox, using a carpenter's square, and mount the gearbox carefully on that line, setting the axle and tyres at right angles to the chassis later on – otherwise the car will not run straight.
3. Secure the battery holder and gearbox to the chassis using wood screws, and attach the switch using bolts, nuts and washers. Most teams copied the prototype, though they could attach these components where they wished.
4. Connect the components in a simple circuit using 0.8 mm thick wire. Be sure to check for loose connections. Drilling a hole through the centre of the board allows wiring to travel from the top to the bottom of the car more efficiently than looping over the sides.
5. Optionally, students may solder their finished connections with a soldering gun, under the teacher's supervision. This is not a necessary step, but students derive a great

deal of satisfaction from these 'real' tasks.

6. Break open one of the electric motors, and show the students the copper coils and magnets inside to demonstrate electromagnets.

Choosing tyres: friction

Students are again taught about friction. Although air resistance and sliding friction are detrimental to their cars' speed, some rolling friction is essential for the cars to move forward at all. The goal is for the students to comprehend the balance between beneficial and detrimental friction: a paved highway is better than a gravel road because there is less friction, but if ice coats the road, the cars will not be able to function without using chains to bring back some friction.

The students should choose between tyres that supply a great deal of friction and tyres that supply very little. By pure chance, each group of my students chose a different type of tyre. Unfortunately, their cars also differed in many other ways, so it was impossible to tell precisely which tyres were best. Ideally, a smaller

Image courtesy of Nicolas Poynter



Low speed, high torque

selection of tyres might be used, and they could be tested beforehand under controlled conditions.

For us, it was obvious which tyres did not work, but not so clear which ones worked best. Smooth tyres spun a little whereas tyres with very deep treads grabbed the road too much. Wider tyres seemed to be better, but if they were too wide, their mass became an issue. The students who picked first chose abnormally large tyres with large masses. The cars with these tyres were horribly slow, so the tyres had to be exchanged. Still, the entire class learned something from watching this happen, and such mistakes can help everyone examine the science involved. The teams were allowed to change tyres at any point.

1. Cut a 3 cm length of aluminium rod for the front axle using the wire cutters. It can be mounted using eye hooks (see images on pages 33 and 34). For a three-wheeled car, a J hook can be used.
2. The gearbox axle will go in the rear.
3. Allow the students to select from a variety of tyres. Depending on where they mount the gearbox (it can be mounted on top of the chassis, but seems to do better if

mounted on the bottom), different cars will need different tyre diameters for ground clearance.

4. Use strong glue, solder or sticky tape to secure the tyres to the axles.

Racing

1. Let the teams test their functional cars to evaluate and modify them. The most common problem was cars that ran off-course and had to have their gearboxes realigned to be square with the chassis. Slow cars often needed the screws of the gearbox to be tightened properly. A small grub screw locks the gearbox axle into place, spinning it. It readily works itself loose and must be tightened with a hex wrench, included in the gearbox kit.
2. Once all cars are in working order, start the time trials. I used two photogates as timers, 7.5 m apart and linked by a 10 m phone cord. There must be a pair of students: one flipping the switch, the other catching the car and switching the motor off.

Now the teams can see how they rate against each other. The fastest car recorded a speed of 2.776 m/s and had a mass of 298 g.

3. Allow the students to make further modifications before the finals. We had battery holders for both AA and D batteries. Two teams chose the larger batteries, incorrectly supposing that they supplied more power. During time trials, their mistake became obvious (their cars had twice the mass and half the speed of the others), and they quickly switched to the lighter AA batteries.
4. Divide the class into groups of three cars per race. The lane position during the race will be very important, and there must be some way to determine who gets what lane. If your car runs straight, you want a middle lane. If your car goes a little left, you want the far right lane.

I allowed the fastest cars during time trials to select their lanes first and had textbooks lined up as retaining walls for the cars to stay on track. During the race, contact was allowed between the cars. In fact, it was common for cars to collide.

5. Let the winners of the individual races then race each other for one overall winner.

The two fastest cars during head-to-head racing were not at the top of the list during time trials. This turned out to be the result of a hidden variable – the orientation of the switch. Most teams copied the prototype, so the switch was flipped backwards to turn the motor on, giving the car backward momentum that needed to be overcome. Two cars had the switch reversed, giving them large head starts when pitted against other cars. This did not show in the time trials because cars were timed not from a standstill but when passing the first photogate.

This turned out to be a fantastic opportunity to teach test variables (mass of the car, aerodynamics of the body shape, detrimental fric-

Images courtesy of Nicolas Poynter

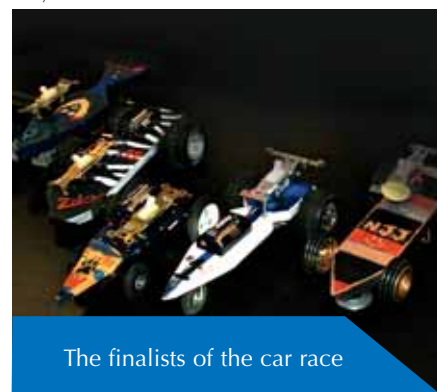


The 2010 derby champion

tion, tyres, how well the parts were assembled) and controlled variables (chassis material, gearbox, switch, 3 V battery power). The orientation of the switch came as a surprise test variable also to me: we had to analyse data to find out why the cars that won time trials did not win the races. I figured it out, but did not tell my students. To my delight, several teams came to the same conclusion independently, which was the reason for the project in the first place – to get the students thinking.

Conclusion

Through this project, my students not only achieved the academic objectives but also became better problem solvers and learned practical skills that will stay with them for the rest of their lives. Although the project needs a prototype and directions, I would suggest keeping as much variability as possible. In fact, I encouraged my students to deviate from the prototype as long as they stayed within the rules. Although some of their designs were functional disasters, the students were deeply involved in the scientific process.



The finalists of the car race

Reference

Hsu T (2005) *Foundations of Physical Science* 2nd edition. Cambridge, MA, USA: CPO Science. ISBN: 9781588921574

Web reference

w1 – You can buy a three-gear box and other supplies for building electrical and mechanical models from Tamiya. See: www.tamiya.com

Resources

If you enjoyed reading this article, you might also want to take a look at the physics articles previously published in *Science in School*. See: www.scienceinschool.org/physics

Nicolas Poynter has a BSc in chemistry from the University of Oklahoma, USA, and worked for 20 years as an analytical chemist in environmental laboratories and as a field chemist, searching for underground petroleum leaks on cross-country pipelines. In 2009, he decided to focus on training and education, because he found that he enjoyed this part of his job more than any other. Nicolas now teaches physical science (the first block of which is physics, the second being chemistry) at Choctaw High School in Choctaw, Oklahoma, USA.



Can you spot a cancer mutation?

How does cancer develop, and how can geneticists tell that a cell is cancerous? This teaching activity developed by the **Communication and Public Engagement team** from the Wellcome Trust Sanger Institute, UK, answers these and other related questions.

All cancers result from changes to the DNA sequence in some of our cells. Because the genetic material within cells is exposed to mutagens such as UV radiation, it can accumulate mistakes during replication. Occasionally, one of these mutations alters the function of a critical gene, providing a growth advantage to the cell in which it has occurred and its offspring; these cells will divide at a faster rate than their neighbours. Gradually, the DNA acquires more mutations, which can lead to the disruption of other key genes, resulting in particularly fast-growing and invasive cells. The result is tumour formation, the invasion of the surrounding tissue and eventually metastasis – the spread of the cancer to other parts of the body.

Genes that lead to the development of cancer when mutated are known as ‘cancer genes’.

Tumour suppressor genes (TSGs, Figure 1) encode the information for making proteins that normally slow down cell growth, preventing unnecessary division or promoting apoptosis (programmed cell death) if the cell’s DNA is damaged. Both copies of a TSG would have to be inactivated by mutation before this control of the cell cycle is lost. If one functional



- ✓ Biology
- ✓ Medicine
- ✓ Mutation
- ✓ Ages 15+

REVIEW

The teaching activities described in this article aim to actively involve advanced secondary-school biology students in a search for mutations that could potentially lead to cancer development, using real genomic data. The procedure is not a truly experimental one, so no real laboratory instruments are needed. Instead, the search is a theoretical one based on authentic data. All materials required to run the activity along with detailed directions can be freely downloaded from the programme website.

Apart from describing the various steps of the activity, the article and the supporting website include important information on what cancers are, what causes them, how they develop and how genomic information can be useful in developing treatments. Furthermore, several discussion points are suggested to enhance students’ understanding of cancer.

Michalis Hadjimarcou, Cyprus

copy remains, there is still a ‘brake’ on the cell’s growth.

Proto-oncogenes (Figure 2), in contrast, encode proteins that promote cell division and differentiation (specialisation). When these genes acquire mutations that either make the pro-

teins continually active or lead to the gene’s activity not being regulated anymore, they become oncogenes, promoting uncontrolled cell growth and division. For proto-oncogenes, a mutation in one copy of the gene can be enough to drive cancer develop-

Images courtesy of the Wellcome Trust Sanger Institute Communication and Public Engagement team

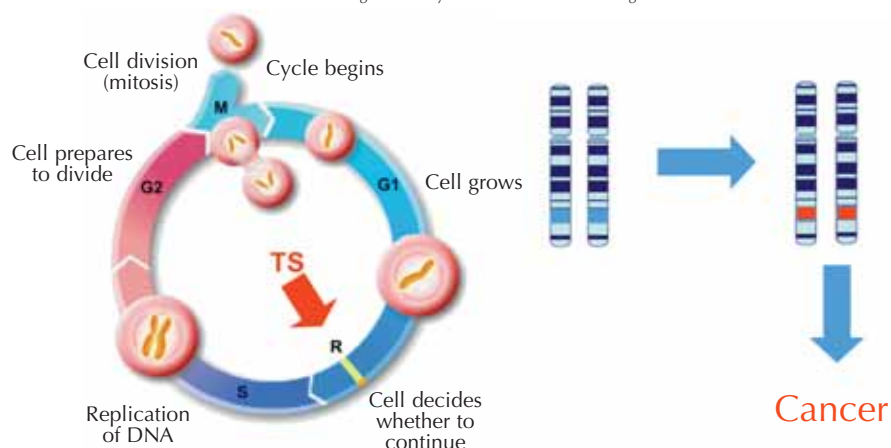


Figure 1: Tumour suppressor genes normally function to *prevent* cell growth and division. To lead to cancer, both copies of the gene would have to be mutated (marked in red)

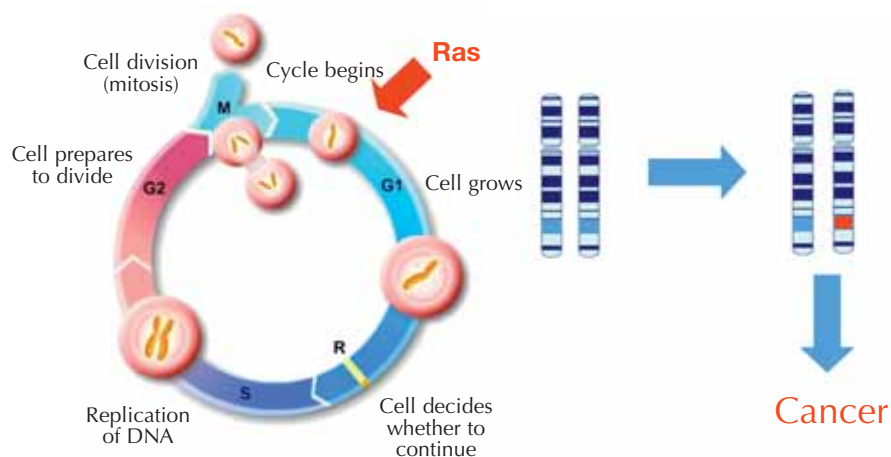


Figure 2: Proto-oncogenes normally function to *promote* cell growth and division in a controlled manner. A mutation in one copy of the gene (marked in red) can be enough to drive cancer development

Image courtesy of the Wellcome Trust Sanger Institute Communication and Public Engagement team

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Amino acid code

- A - Alanine
- C - Cysteine
- D - Aspartic acid
- E - Glutamic acid
- F - Phenylalanine
- G - Glycine
- H - Histidine
- I - Isoleucine
- K - Lysine
- L - Leucine
- M - Methionine
- N - Asparagine
- P - Proline
- Q - Glutamine
- R - Arginine
- S - Serine
- T - Threonine
- V - Valine
- W - Tryptophan
- Y - Tyrosine

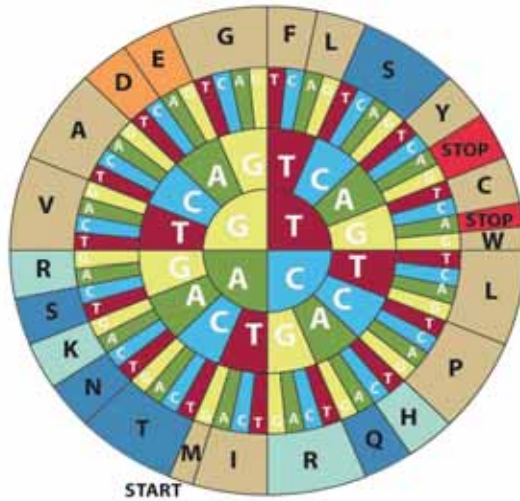


Figure 4: Use the codon wheel to translate DNA codons into amino acids. To decode a codon find the first letter of your sequence in the inner circle and work outwards to see the corresponding amino acid. For example, CAT codes for H (histidine). Note that this diagram uses the sense DNA codons (5' to 3')

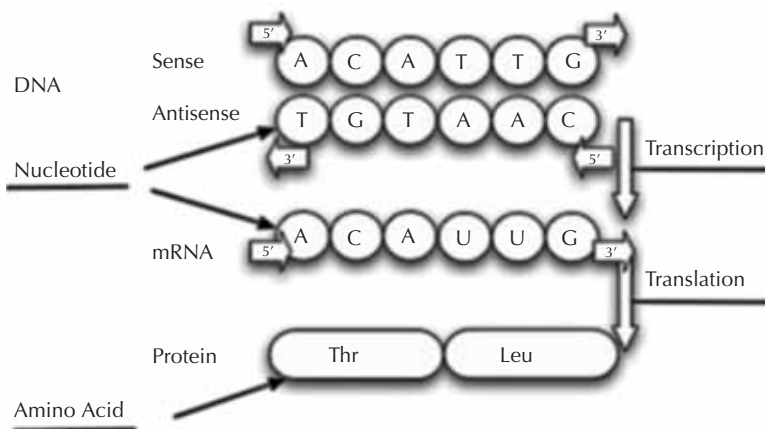


Figure 5: mRNA is synthesised from the antisense strand of DNA. The sense strand of DNA, used in this activity, has the same sequence as the corresponding mRNA strand, except that T is replaced by U

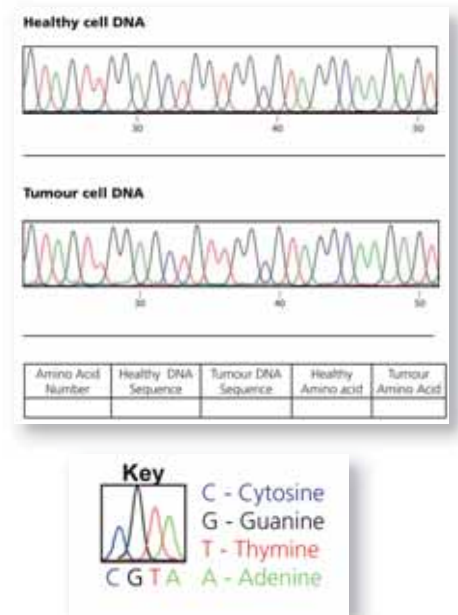


Figure 6: Example from a student worksheet

tions on the gene sequence, squares for marking regions which have been checked (KRAS_annotations.pdf), and reusable adhesive (e.g. Blu Tack®) for sticking arrows and squares to the gene sequence banner. Find out more about how to use this method in the downloadable teacher notes^{w6}.

In addition, you might find it helpful to have DNA, peptide and/or protein models to hand, and to use the Wellcome Trust Sanger Institute cancer animations (*Cancer: Rogue cells* and *Role of cancer genes*) on the KRAS activity website^{w6}.

Introduction to the activity

The *Investigating Cancer* presentation (available online^{w6}) provides students with an overview of cancer. It introduces the concept that cancer arises due to abnormalities in DNA sequence, explains the various causes of these mutations and introduces the worksheets and activity. Several sections of the presentation encourage student discussions (see the presentation notes^{w6}).

In the first part of the activity, students identify differences between KRAS gene sequences in healthy and

dents. For large groups (20 or more), use two sets of worksheets, providing double coverage of the gene.

- One KRAS gene sequence banner (KRAS_gene_banner.pdf; Figure 3) for the whole class, and one KRAS gene sheet (KRAS_genesheet_yg.pdf; Figure 3) per group of students. The gene sheet (printed on A3 or A4) requires little preparation time. The KRAS banner, printed on several sheets of paper that are then stuck

together, enables the results from the whole class to be displayed simultaneously.

- One codon wheel sheet (KRAS_codon_wheel.pdf or any other codon table for sense DNA, 5' to 3') per group, see Figures 4 and 5
- One summary sheet (KRAS_data_sheet.pdf) per group
- Pens
To use the banner, you will also need large arrows for marking muta-

tumour cells on their worksheets, and mark these on the *KRAS* banner or gene sheet.

The worksheets have raw *KRAS* DNA sequencing traces from healthy and cancerous cell samples, represented as coloured line plots – one for each region of the gene. The four bases are represented on these plots by four different colours. Each coloured peak represents an individual DNA base:

Red: T

Green: A

Blue: C

Black: G (normally these peaks are yellow but this is not easy to read on paper)

There are 11 numbered worksheets in total, each showing two different regions of the *KRAS* gene. The six mutations in the *KRAS* gene are on worksheets one to six, so be sure to mix the sheets up before distributing them to the class. All must be completed to ensure full coverage of the gene. It is important to point out to the students that mutations are (relatively) rare, so not everyone will find one; this can be used to explore the importance of negative data and comprehensive coverage in scientific studies.

Identifying the mutations

Using the worksheets, the students will compare a section of DNA sequence from a healthy cell and a tumour cell from the same patient. The easiest way to identify whether a mutation has occurred is to write the DNA sequence below the coloured peaks (there is a colour key on the sheet to help) and to compare the written sequences.

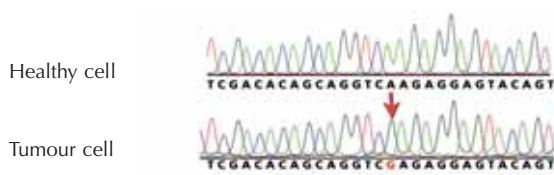


Figure 7: Identifying sequence mutations

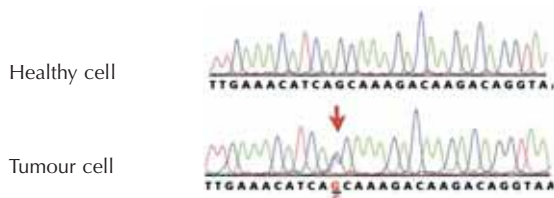
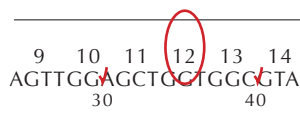


Figure 8: A heterozygous mutation

Figure 9: Ticking off the gene regions that have been checked, and marking any mutations



If one of the letters is different (a peak has changed colour), this indicates a mutation in the sequence. In Figure 7, the A in the DNA sequence from the healthy cell has been replaced by G in the tumour cell.

If the students find a double peak at one base position, this should be recorded with the two alternative bases at that position, one above the other. In the example below, the healthy DNA sequence has a G, whereas the tumour sequence has both G and C. This is not an insertion: it represents a heterozygous mutation where only one copy of the gene has substituted a C for a G. In this case the tumour sequence has replaced G with a C.

All students should indicate the gene regions they have checked by ticking off the relevant region on the gene sheet (see Figure 9).

Students who find a mutation should indicate the specific base by circling it on the gene sheet (see Figure 9) and make a note of which codon this lies in (in this example, codon 12).

They should also fill in the table at the base of the worksheet, using the codon wheel to translate the DNA sequence into the amino acid, as shown in Table 1:

Amino acid number	Healthy cell DNA sequence	Tumour cell DNA sequence	Healthy cell amino acid	Tumour cell amino acid
12	GGT	GTT	G (glycine)	V (valine)

Table 1: Mutations as listed on the individual worksheets

When all mutations have been found, record them on the summary data sheet (see Table 2).

Amino acid number	Healthy cell DNA sequence	Tumour cell DNA sequence	Healthy cell amino acid	Tumour cell amino acid
12	GGT	GTT	G (glycine)	V (valine)
13	GGC	GAC	G (glycine)	D (aspartic acid)
30	GAC	GAT	D (aspartic acid)	D (aspartic acid)
61	CAA	CGA	Q (glutamine)	R (arginine)
146	GCA	CCA	A (alanine)	P (proline)
173	GAT	GAC	D (aspartic acid)	D (aspartic acid)

Table 2: Mutations as recorded on the summary data sheet

Discussing the results

The results above are all single base substitutions. These mutations within the protein-coding region of the *KRAS* gene may be classified into one of three types, depending on the information encoded by the altered codon.

- Silent mutations code for the same amino acid.
- Missense mutations code for a different amino acid.
- Nonsense mutations code for a stop and can truncate the protein.

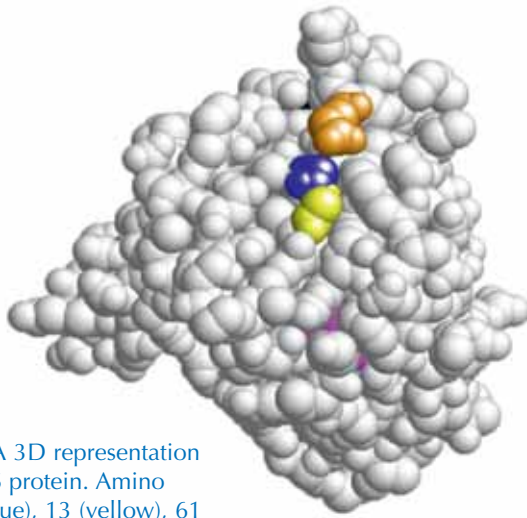


Figure 10: A 3D representation of the KRAS protein. Amino acids 12 (blue), 13 (yellow), 61 (orange) and 146 (pink) are those which carry mutations

Discuss whether the mutations are significant – will they have an impact on protein function or are they ‘silent’? In this activity, codons 30 and 173 are silent and therefore do not have a functional impact.

The presentation has a 3D space-fill image of the KRAS protein (Figure 10); slides 26–30 show where on the protein the significant mutations are, and you will notice they are all in the same region. Codons 12, 13 and 61 were the first mutations to be associated with oncogenic transformation in the KRAS protein; mutation 146 was only discovered in 2005. Use these slides to discuss the impact that the mutations could have on protein structure and KRAS’s function in growth signalling.

As an optional activity, the students can use RasMol, the molecular modelling software used to create the images on slides 26–30, to highlight the mutated amino acids in the protein structure. See the teacher notes^{w6} for details.

How does information like this influence our approach to cancer?

The teacher notes^{w6} contain a wealth of background information, using *KRAS* as an example, to stimulate dis-

cussion on how genomic information can be used to further our understanding of cancer and develop cancer treatments. Discussion points for students include:

- What experiments or approaches could be used to establish which cancers involve *KRAS* mutations?
- What could be the advantages of knowing this information?
- Cancer is a genetic disease: it is a result of changes in the DNA sequence. This is why many people believe that significant funding of research into cancer genetics is the best way of developing new cancer treatments and thus dealing with the disease. Cancer treatment and care for patients also requires large amounts of money (the UK National Health Service spent more than £2 billion on cancer care alone in 2000). Where and how do students think money should be spent?

Web references

w1 – Learn more about the Cancer Genome Project at the Wellcome Trust Sanger Institute here:
www.sanger.ac.uk/genetics/CGP

w2 – To learn more about the Wellcome Trust Sanger Institute in Hinxton, UK, a leader in the Human Genome Project, see: www.sanger.ac.uk

The institute offers visits for school classes, teachers and the general public, as well as teacher support and further opportunities to get involved. See:
www.sanger.ac.uk/about/engagement

w3 – The Yourgenome.org website was launched by the Sanger Institute to stimulate interest in and discussion on genetic research. It includes a section of varied and well developed resources for teachers, including the activity presented in this article. See:
www.yourgenome.org

w4 – The European Learning Laboratory for the Life Sciences (ELLS) at the European Molecular Biology Laboratory provides continuing professional development courses (LearningLABs) in molecular biology for European secondary-school science teachers. In March

Amino acid number	Healthy cell DNA sequence	Tumour cell DNA sequence	Healthy cell amino acid	Tumour cell amino acid	Type of mutation	Significant yes / no
12	GGT	GTT	G (glycine)	V (valine)	Point (missense)	yes
13	GCC	GAC	G (glycine)	D (aspartic acid)	Point (missense)	yes
30	GAC	GAT	D (aspartic acid)	D (aspartic acid)	Point (silent)	no
61	CAA	CGA	Q (glutamine)	R (arginine)	Point (missense)	yes
146	GCA	CCA	A (alanine)	P (proline)	Point (missense)	yes
173	GAT	GAC	D (aspartic acid)	D (aspartic acid)	Point (silent)	no

Table 3: Type of mutation, as recorded on the summary data sheet

2010, ELLS ran the first bioinformatics LearningLAB for teachers at the European Bioinformatics Institute in the UK. For information on ELLS courses, please go to: www.embl.org/ells

w5 – To find out more about the European Bioinformatics Institute, see: www.ebi.ac.uk

w6 – To download all materials for the KRAS activity and for more background information, see: www.yourgenome.org/teachers/kras.shtml

Resources

Websites for student reference and discussion

The Cancer Research UK website offers accessible information on all the major cancers and current research. See: <http://info.cancerresearchuk.org/cancerandresearch>

The *New Scientist* website has an area focusing on cancer, featuring the latest articles on cancer research developments and interactive animations demonstrating targeted cancer drug functions. See: www.newscientist.com/topic/cancer

Nature Milestones in Cancer offers a collection of selected review-type articles and an online library of recent research papers from Nature Publishing Group, available for download as PDFs. It also has a cancer timeline showing major milestones in cancer research. See: www.nature.com/milestones/milecancer

The Inside Cancer multimedia website created by the DNA Learning Center offers a multimedia guide to cancer biology, diagnosis and treatment. See: www.insidecancer.org

Recent news articles

The BBC News website has published an interesting article on how newly discovered genetic hotspots for bowel cancer might help doctors

to treat the disease better. See: <http://news.bbc.co.uk> or use the direct link: <http://tinyurl.com/28o7zgf>

Sample I (2009) First cancer genome sequences reveal how mutations lead to disease. *The Guardian*. See www.guardian.co.uk or use the direct link: <http://tinyurl.com/yeknj5x>

Roberts M (2009) Scientists crack 'entire genetic code' of cancer. *BBC News*. See <http://news.bbc.co.uk> or use the direct link: <http://tinyurl.com/yb59qcz>
This article includes a video interview with Professor Mike Stratton, leader of the Cancer Genome Project.

Further reading

Friday BB, Adjei AA (2005) K-ras as a target for cancer therapy. *Biochimica et Biophysica Acta – Reviews on Cancer* **1756**(2): 127-144. doi: 10.1016/j.bbcan.2005.08.001

Futreal A et al. (2004) A census of human cancer genes. *Nature Reviews Cancer* **4**: 177-183. doi: 10.1038/nrc1299

The author version of this paper can be freely viewed online. See: www.ncbi.nlm.nih.gov/pmc or use the direct link: <http://tinyurl.com/3x5hah6>

For a full catalogue of somatic cancer genes (COSMIC) described in the above paper and created by the Cancer Genome Project, see: www.sanger.ac.uk

Stratton MR, Campbell PJ, Futreal AP (2009) The cancer genome. *Nature* **458**: 719-724. doi: 10.1038/nature07943

Download the article free of charge from the *Science in School* website (www.scienceinschool.org/2010/issue15/cancer#resources), or subscribe to *Nature* today: www.nature.com/subscribe.

For more information on how genetic

mutations cause diseases, see:

Patterson L (2009) Getting a grip on genetic diseases. *Science in School* **13**: 53-58.

www.scienceinschool.org/2009/issue13/insight

For an interview with cancer researcher Joan Massagué, see:

Sherwood S (2008) On the trail of a cure of cancer. *Science in School* **8**: 56-59.

www.scienceinschool.org/2008/issue8/joanmassague

For a classroom activity to discuss the ethics of knowing what your genes have in store for you, including the possibility of cancer, see:

Strieth L et al. (2008) Meet the Gene Machine: stimulating bioethical discussions at school. *Science in School* **9**: 34-38.

www.scienceinschool.org/2008/issue9/genemachine

If you enjoyed this article, why not take a look at other medicine-related articles previously published in *Science in School*? See:

www.scienceinschool.org/medicine

The Wellcome Trust Sanger Institute Communication and Public Engagement programme communicates the nature, discoveries and wonder of science and its implications for individuals and society. It tries to make complex biomedical research accessible to a range of audiences, including school students and their teachers, through a visit programme, a range of collaborations, and the Yourgenome.org website^{w3}. For more information about the programme, see:

www.sanger.ac.uk/about/engagement; to contact the team, email pubengage@sanger.ac.uk.



LeSa21: primary-school science activities



- ✓ Primary
- ✓ General science
- ✓ Chemistry
- ✓ Ecology
- ✓ Ages 5+

The Lesa21 website contains a very handy and convenient alphabetical list of topics and associated activities for primary school. A good number of these are not restricted to the science classroom, which makes integration between different subjects easier. The topics can therefore also be used as inspiration for interdisciplinary secondary-school projects.

The teaching activities detailed in this article may be used as a model of how real-life situations, in this case oil spills, can be used as a starting point for learning science. The article should be of particular interest to teachers in coastal areas, which are the first to suffer the consequences of such disasters.

The experiments are interesting and may be used on their own or in conjunction with other activities such as comprehension exercises and discussions. Questions to ask could include “What are the main challenges during an oil clean-up operation?” (e.g. weather conditions), and “What can we do on an individual level to minimise the possibility of such disasters?” (e.g. reduce oil consumption). One can also look at the implications for the individual, such as how to dispose of cooking oil, or how to clean something covered in oil.

Paul Xuereb, Malta

REVIEW

Teaching science in primary school can be challenging. **Astrid Kaiser** and **Marlene Rau** describe a rich source of online materials in three languages – and highlight some activities about oil and water.

Image courtesy of Hedwig Storch; image source: Wikimedia Commons

Launched in 2002 by Astrid Kaiser from the University of Oldenburg, Germany, the LeSa21 website^{w1} offers a range of experiments, resources and background information for primary-school science and humanities lessons. Materials for both teachers and their pupils are available on a wide range of topics (currently 93), including ‘The eye’, ‘bicycles’, ‘spring’, ‘health and disease’, ‘girls and boys’, ‘planets, the Moon and the stars’, ‘electricity’, ‘water’ and many others. These materials are developed mainly by university students who are training to be primary-school teachers.

Available in English, German and Spanish, the ‘Learning’ section is suitable for both children and teachers, and includes experiments, sto-

ries, poems, pictures, book recommendations and links to relevant websites for each of the topics.

The pages for teachers (in German only) contain information, didactical hints, literature and web links to background information and further resources on each of the topics. Pupils at the six schools involved in the project contribute to further German-language sections. There, they can share their own experiments and ideas on the topics, and discuss a selection of the topics in an online forum.

Below are some activities from the LeSa21 project, which could form the basis of a teaching unit on oil and water, including surface tension and the removal of oil spills, suitable for older primary-school children. The individual experiments and further materials on the topics can be found on the LeSa21 website^{w1}.

Soap has magic powers – surface tension

This experiment introduces the notion of surface tension.

Materials

- Two bowls of water
- Ground pepper
- A pin
- A spoon (the size is not important)
- Liquid soap or washing-up liquid

Procedure

1. Half fill both bowls with water.
2. Sprinkle a spoonful of pepper onto the water in the first bowl. Take a close look while you are doing this.
3. Let the pin float in the second bowl of water.
4. Add a drop of soap to each bowl.
5. What happens? Draw what you observe.

What happens?

Initially, both the pepper and pin float. One reason is that they are both

very light; the other is that water has a kind of thin, invisible ‘skin’ on its surface. Light things do not break this skin, but are supported by it – some animals, e.g. water striders, can even walk on it (see image on page 45). This thin skin is caused by *surface tension*.

When you added the soap drop, the pepper probably moved away from it and slowly sank. The pin would have sunk immediately.

Why is that? The soap breaks this thin skin of the water – you could also say that soap reduces the surface tension. As the skin disappears, there is nothing left to hold the pepper and the pin on the surface of the water, so they sink. Although this is how it may look, pepper and soap do not repel each other – the tension of the rest of the water (where the soap has not yet reached) pulls the floating pepper away from the soap.

Soap has magic powers – mixing oil and water

Materials

- Two glasses
- Water
- Food colouring or ink
- A spoon (the size is not important)

- Oil
- Liquid soap or washing-up liquid

Procedure

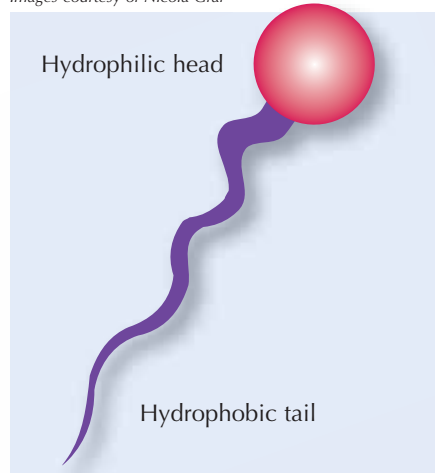
1. Half fill the glasses with water.
2. Add some food colouring or ink to one glass, and mix it with a spoon. Leave it for a while until the water is still again.
3. Add a spoonful of oil to each glass. Observe what happens.
4. Add 1-2 drops of soap to each glass and mix it with a spoon.
5. What do you think will happen? Observe carefully and draw what you can see.

What happens?

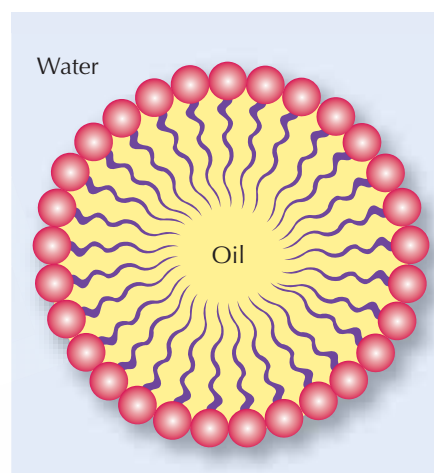
Oil and water usually do not mix well. The reason is that water molecules can form hydrogen bonds with each other and with *hydrophilic* (‘water-loving’) molecules, but not with oil-like *hydrophobic* (‘afraid of water’) molecules. In addition, oil is lighter than water; it has a lower density, so if you try to mix them, the oil layer stays on top of the water. If you add some soap and stir it for a while, the oil and water can be mixed together. If you leave it for a while, the oil and water will separate again.

Why is that? Soap contains special

Images courtesy of Nicola Graf



Surfactant



Surfactant-stabilised oil droplet



Fire boats trying to put out the blaze on the oil rig *Deepwater Horizon* on 21 April 2010

Image courtesy of US Coast Guard; image source: Wikimedia Commons

ingredients called surfactants, which reduce the surface tension of water and allow water and oil to mix. This makes soap a wonderful cleaning agent: not only water-soluble dirt but also oily dirt can be washed away into water.

Surfactant molecules have two different ends, as shown in the diagram (left). One end (the head) is hydrophilic; the other end (the tail) is hydrophobic. Soap contains many surfactant molecules, and each of them binds water at one end and oil at the other end, which is how they help water and oil to mix, and also bind to oily dirt.

After a while, the oil and water separate again, because the bonds between water molecules are more stable than those between the surfactant molecules and the oil or the water.

The oil spill

In April 2010, an explosion on the oil rig *Deepwater Horizon* in the Gulf of Mexico led to a catastrophic oil spill. As we go to press, an estimated 5000-100 000 standard barrels of oil per day have been leaking out for several months, the spill eventually

reaching the southern coasts of the USA. Attempts to remove the oil included burning it and using chemical and mechanical binding agents.

Similar accidents have happened in Europe, too: in Autumn 2002, the oil tanker *Prestige* was involved in an accident off the Spanish coast and sank. Up to 63 000 tonnes of oil were spilt into the sea, and hundreds of kilometres of the coastline of northern Spain and France were polluted with oil. Many animals died: more than 18 000 oil-contaminated birds were counted. Many volunteers helped to clean the beaches, and special ships tried to stop the growing oil slicks.

Let's find out what oil does to bird feathers and how we can remove the oil from the water.

Materials

- Several big glasses or china bowls
- Water
- Vegetable oil
- Feathers
- A spoon
- A paper coffee filter
- A straw
- Wooden sticks
- Fine sawdust
- Wood shavings



Image courtesy of LeSa21

- Cat litter
- Sand
- Oil binding / absorbing powder (used for oil spills, can be bought online or in well-stocked paint shops or chemists)

Procedure

1. Pour some oil into a bowl and add some feathers.

See how they stick together and imagine what effect an oil spill would have on birds and other animals, once the oil reaches the shores.

How might oil spills be cleaned up in open water, to prevent them from reaching the shores?

We will test various methods of removing the oil from the water. Either ask the children to get into groups, with each group testing a different method, or let the whole class

Images courtesy of LeSa21



Investigating oil spills



Materials



Step 1



Step 2



Step 3



The origins of Lesa21: boxes of experiments

BACKGROUND

The origins of Lesa21 go back to the RÖSA project^{w2}, which is still continuing at the University of Oldenburg. Since 1994, images, stories, experiments and background information for primary-school science and humanities lessons (*Sachunterricht*) have been sorted by topics and collected in boxes that local teachers can borrow.

The experimental equipment in the boxes is mostly recycled material found in standard households or industry, such as broken mirrors, pipettes from empty medicine bottles, boxes of old buttons, stones and used guitar strings. The objects not only provide an inexpensive source of experimental equipment, but also

demonstrate to the children that materials can be used over and over again in different and creative ways. Individual boxes have been created on 70 different themes, many of them the same as the current Lesa21 topics. The ideas and materials are tested in local schools by university students and trainee teachers.

Several satellite *Lernwerkstätten* offer similar collections of boxes, mainly in schools across northern Germany, but also at the *Pädagogisches Beratungszentrum*^{w3} (education centre) in Brixen, northern Italy. In addition, a book has been published for Japanese teachers, who are now also working with the box system (Kaiser et al., 1999).

watch as you try out all methods together.

2. Take a new bowl, fill it with water, add some oil and stir. What happens?
3. Skim off the oil with a spoon.
4. Skim off the oil with a coffee filter.
5. Try to push the oil together with sticks.
6. Mix the oil with wood shavings. Now try to push the oil-soaked wood shavings together.
7. Does it work better with cat litter? If so, why?
8. Bind the oil with sawdust (it will float due to the oil's hydrophobicity and lower density) and remove it from the water using a spoon or paper coffee filter.
9. Try to weigh down the oil with sand to make it sink.
10. Use oil binding / absorbing pow-

der to bind the oil and remove it using a spoon.

Compare and discuss the results of the experiments. The children should realise that the best results are achieved with a combination of (mechanical and chemical) methods. They may also consider the factors affecting the efficiency of each method, e.g. the volume of removal agent used. Finally, they should notice that there will always be some oil left in the water at the end; in real-life situations, we have to rely on the ecosystem to deal with this remainder over time.

Which other methods of cleaning the water can you imagine? Let the children come up with some ideas for real-life 'oil spill removal machines'. Ideas might include a ring of cat litter to stop the oil from floating away,

plus mechanical diggers to remove the floating oil film.

Comprehension questions

1. What happens if you pour oil into water?
Answer: oil and water don't mix - the oil floats, forming iridescent streaks and / or grease drops.
2. How can you separate the oil from water?
Answer: using a combination of the above methods, but it is difficult.
3. Is the water clean again after your experiment?
Answer: no, some oil will always remain.
4. What is left in the water?
Answer: oil, some of which is clumped together with cleaning agents.



Step 4



Step 8



Step 9



Step 10



Discussion

Acknowledgements

The two experiments 'Soap has magic powers' are part of the book *Chemie in der Grundschule (Chemistry in Primary School)*; Kaiser & Mannel, (2004). Published in German, it contains many other experiments on different topics.

Parts of 'The oil spill' experiment are from Kaiser (2009).

References

Kaiser A et al. (1999) *Topic – bezu Sogo gakushu. Doitzu no Kyoiku tonu Sissen taiwa – Nisiu itteheikino Gakkou wo hiraku*. Kyoto, Japan: Kitaoji-Shobo. ISBN: 4762821578

Kaiser A, Mannel S (2004) *Chemie in der Grundschule*. Baltmannsweiler, Germany: Schneider Verlag Hohengehren. ISBN: 9783896767660

Kaiser A (2009) *Praxisbuch handelnder Sachunterricht Band 1* 3rd edition. Baltmannsweiler, Germany: Schneider Verlag Hohengehren. ISBN: 3834000167

Web references

w1 – For more information about LeSa21, see: www.lesa21.de
To reach the English and Spanish versions of the 'Learning' section, click on 'Lernen / Learning / aprendizaje' in the top menu, then choose your language flag on the left-hand side.

w2 – To learn more about the RÖSA project, see: www.roesa.uni-oldenburg.de

w3 – Find out more about the Pädagogisches Beratungszentrum in Brixen, Italy, here: www.schule.suedtirol.it/pbz/brixen/

Resources

The Australian Maritime Safety Authority has developed a series of very good educational resources for primary- and secondary-school children about oil spills, including several games, animations and the mathematics of oil spills. See the website (www.amsa.gov.au) or use the direct link: <http://tinyurl.com/375ny3e>

You might also want to browse the 'Bridge' collection of free marine education resources from the Virginia Institute of Marine Science, USA, searching for 'oil spill': www2.vims.edu/bridge

The US National Wildlife Federation offers a special section on the 2010 oil spill in the Gulf of Mexico, including background information and teaching activities. See the website (www.nwf.org; search for 'oil spill school') or use the direct link: <http://tinyurl.com/36sqg45>

The US National Oceanic and Atmospheric Administration has developed a comprehensive teaching module on how an ecosystem recovers from a major oil spill, based on the 1989 Exxon Valdez disaster in Alaska's Prince William Sound ('Prince William's oily mess'). See the website (<http://oceanservice.noaa.gov>) or use the direct link: <http://tinyurl.com/ofvaxk>

The US education organisation The League offers a four-lesson plan on oil, water and wildlife: <http://learningtogive.org/lessons/unit377>

For a broader consideration of hydrocarbon fuels, see:

van Dijk M (2009) Hydrocarbons: a fossil but not (yet) extinct. *Science in School* 12: 62-69.
www.scienceinschool.org/2009/issue12/energy

If you enjoyed reading this article, you might want to browse the other *Science in School* articles for primary-school teachers: www.scienceinschool.org/primary

Both RÖSA and LeSa21 were initiated by Professor Astrid Kaiser at the Carl von Ossietzky University of Oldenburg, Germany, where she is the director of the Institute of Education Science and teaches didactics for primary-school science and humanities lessons (*Sachunterricht*). Her main focus is on gender issues, science, ecology and energy education in primary school and kindergarten. She has published numerous research papers and more than 40 books.

Dr Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology Laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been one of the editors of *Science in School*.



Solar cars: the future of road transport?

Ever dreamed of a car that needed no fuel and produced no pollution? **Mico Tatalovic** investigates the solar car.

“I would like to tell you something about the first tour ever of a vehicle that drove around the world without petroleum-based fuel: it was a solar car,” says Louis Palmer, a Swiss mathematics teacher who travelled around the world in a solar car. He did it to make a point: at least in theory, all the energy necessary for powering cars could be derived directly from the Sun – with no need for polluting petroleum.

The chic, blue Solartaxi got most of its energy from the solar panels on its trailer. On a cloudy day, Palmer recharged the car from the electricity grid, but he made sure that it was clean solar electricity by installing solar panels on his house and feeding the electricity produced into the grid. He claims that electric car technology is viable, and solar panels can fuel all of our road travel. “Sunshine is free,” he says.

Palmer says that he had wanted to do a road trip around the planet to “see the beauty of this world” since he was eleven, back in 1982. But his teacher warned him that such a trip would damage the planet – polluting gases from the exhaust pipe would contribute to the growing pollution and global warming of the very plan-

et he was so eager to get to know better. By the time he was 14, Palmer made plans for an eco-friendly solar car; he figured that in 20 years time, everyone would be travelling in solar-powered electric cars anyway. With all the problems that petroleum-fuelled cars caused, such as global warming, polluted air and oil-based conflicts, he thought that electric solar cars would soon replace them.

Some 20 years later, in 2004, Palmer decided: “OK, if I cannot buy a solar car, I will build it myself. But then I realised I had no idea how to build a car and no money to do it.” These two problems might have discouraged a less optimistic person, but not Palmer: “I thought that if it was a good idea, I would get support.” And indeed he did: more than 200 friendly individuals and several corporations helped him make a car that would take him across 38 countries in 18 months, without emitting any carbon dioxide and using only clean solar energy.

Of course, building the car and its solar panels requires energy and causes carbon dioxide emissions, but once built, Palmer’s Solartaxi did not emit any carbon dioxide. He believes, therefore, that solar cars have an



- ✓ Physics
- ✓ Chemistry
- ✓ Social studies
- ✓ Energy
- ✓ Ages 12+

Renewable energy is an important topic, discussed in all European countries; students hear about it not only at school but also in the media. The topic is an exciting one for young people, and this article could be used for all topics involving energy – not only physics but also in interdisciplinary discussions (e.g. physics, chemistry and social studies). Since the author highlights how it is possible to build and use solar cars, the students could discuss the problem of storing energy for night or cloudy days.

Alessandro Iscra, Italy

REVIEW



Images courtesy of Louis Palmer and solartaxi.com

Louis Palmer and his Solartaxi in Monument Valley, Arizona, USA



Cambridge University
Eco Racing car



Cambridge University Eco Racing car

Images courtesy of Cambridge University Eco Racing

springs to mind: Why aren't we seeing more of these cars available for purchase at our local car dealerships?

David Sims-Williams, an engineer from the University of Durham, UK, and a technical advisor to Durham University's solar car team, another undergraduate team of solar racecar engineers, says that solar racecars "are not intended to be prototypes of future road vehicles". For the small solar panels on their roofs to be enough to power them, solar cars have to be extremely light and aerodynamic. As a result, most solar racecars are single-seaters, looking more like space rockets than normal cars – they are built to win races, not to accommodate families on their shopping trips. Although they do not translate directly into commercial cars because their purpose is so different, they are still important in raising public awareness of this technology.

At the moment, it would be very difficult to power large, heavy cars purely with solar panels on their roofs. The solar panels that racecars use are expensive and easily damaged, so most commercial solar cars have thus far used less efficient (but cheaper and less sensitive) solar panels that can only partially power them, for example by supplying just the energy to run the car's air conditioning, such as in Toyota's Solar Prius or Pininfarina's BlueCar.

Nonetheless, says Sims-Williams, the technology developed for solar racecars will find its way into mainstream motoring eventually, as big car manufacturers pick up on technological advances made by the specialised race teams, and start implementing them in commercial cars, usually with a lag of about 10 years.

Everyone Palmer talked to in every corner of the globe would love to buy a completely solar car, but "to bring this technology to the mainstream market, the cost of straightforward, non-solar electric cars has to come down," he says. This would require

Similar student efforts have helped build many different solar racecars for the World Solar Challenge^{w1} since 1987. More than 40 universities have solar car teams that compete at this biennial event in Australia. The 2007 winners averaged speeds of more than 90 km/hr, were powered solely by the Sun, and covered 3021 km from Darwin to Adelaide.

Similar races take place elsewhere, such as the American Solar Challenge^{w2} (Plano in Texas, USA, to Calgary, Canada, biennially since 2001) or the South African Solar Challenge^{w3} (from Johannesburg to Pretoria via Cape Town and Durban, since 2008). But with some of the brightest young engineers working on designing solar cars for more than 20 years now, an obvious question

important role to play in slowing global warming. Furthermore, three years after his world tour in 2007, Palmer is still using the Solartaxi as his personal vehicle, driving on the same batteries, paying nothing for fuel and spending nothing on repairs (there have been none).

To design and construct the Solartaxi, Palmer had the help of students from four Swiss universities.



Solartaxi in the mountains of southern China



Solartaxi and Louis Palmer on Taupo Racetrack in New Zealand

Images courtesy of Louis Palmer and solartaxi.com

- w5 – Find out more about the Australian car manufacturer HybridAuto Ultracommuter here: www.hybridauto.com.au
- w6 – Learn more about the Zero Emissions Race here: www.zero-race.com
- w7 – Bluesci is a student-run science magazine at Cambridge University. See: www.bluesci.org
- w8 – To learn more about SciDev.Net, see: www.scidev.net

Resources

The Suntutrek website enables you to ‘take a journey into space and find out more about the Sun and its effect on the Earth’, including a range of school activities and projects. See: www.suntutrek.org

‘Formula Sun’ is a project for UK secondary-school students to build solar boats and race them in a national challenge, delivered by the ‘Engineering your future’ initiatives. See: www.engineeringyourfuture.com

Solar-Active offers educational resources, workshops and courses in sustainable development, energy efficiency and renewable energy technologies, including solar power. See: www.new.solar-active.com

Born in Rijeka, Croatia, Mico Tatalovic did a bachelor’s degree in biology at Oxford University, UK, and then a master’s in zoology at Cambridge University. While working on Cambridge University’s *BlueSci*^{w7} magazine, he developed a love for science writing and went on to do a master’s in science communication at Imperial College, London. He is currently the deputy news editor at SciDev.Net, the Science and Development Network^{w8}.



more investment in the mass production of electric cars to overcome some of the associated problems. Like all electric cars, solar cars need an electric battery, which has a limited range, especially when the Sun isn’t shining. So far, these batteries have been rather heavy and expensive to fit into cars – a limitation that has turned buyers away from electric (and thus solar) cars in the past.

So far, although a few solar cars such as Palmer’s Solartaxi, the French company Venturi’s Astrolab^{w4} or the Australian UltraCommuter^{w5} exist, the vast majority of cars in use today are not solar or even electric. Commercialising the solar car technology is still in its infancy. So will the solar electric car technology ever revolutionise the way we drive? Palmer says

this is up to us. For him, it already has.

As we speak, Palmer’s next quest is to organise an electric car race – the Zero Emissions Race^{w6} – in which international teams of engineers will design cars dependent on renewable energy and capable of racing at fast speeds, again to raise awareness of electric cars’ capability. As we go to press, the race is planned to start on 15 August 2010 and will go around the world in 80 days, returning to its starting point in Geneva, Switzerland.

Web references

- w1 – To find out more about the World Solar Challenge in Australia, now the Global Green Challenge, see: www.globalgreenchallenge.com.au
- w2 – Learn more about the American Solar Challenge here: <http://americansolarchallenge.org>
- w3 – For more information about the South African Solar Challenge, see: www.solarchallenge.org.za
- w4 – The French automobile manufacturer Venturi built the electro-solar hybrid concept car Astrolab. See: www.venturi.fr/electric-vehicules-astrolab-concept.html

Evaluating a medical treatment

Sarah Garner and Rachel Thomas consider why well-designed and properly analysed experiments are so important when testing how effective a medical treatment is.

In a medical trial, one group of people is given the new treatment and the other group, a placebo or an existing treatment

Image courtesy of iStockphoto / gemphotography

Suppose a new medical treatment has been developed that may reduce high blood pressure. The treatment has been extensively tested in the laboratory and on a few volunteers, and the researchers believe that it will work on the general population. Now it is time to find out if they are right.

Historically, doctors found out whether a treatment worked in practice by using it on their patients. They could then compare the patients' responses to the new treatment and to previous treatments for the same illness, and also compare how responses to the new treatment varied between patients. However, if patients did indeed recover from their condition, there was no

Image courtesy of iStockphoto / thelinke



How do we test whether a new drug for reducing blood pressure really works?

way of telling whether it was due to the treatment or to something else.

There are many other factors that could have caused the patients to recover: for example, they may have felt better simply because they were being treated by a doctor (a reaction known as the placebo effect); they may have recovered anyway, regardless of the treatment; or perhaps their recovery was due to changes in their personal circumstances or lifestyle. Without taking these and other factors into account, it could be easy to conclude incorrectly that the treatment worked. Doctors would then incorporate it into their everyday practice, mistakenly believing it to be effective.

The development of the randomised-controlled trial

In the 19th century, scientists proposed a method of controlling exactly what was happening and recording any changes in the patients' condition. In these controlled experiments, there were two groups of patients – the study group, which received the new treatment, and the control group, which received a placebo (an inert medication) or an established treatment. The patients were then observed, and the outcomes of the

two groups (such as whether each patient lived or died) were recorded and compared.

Some time later, in 1917, the process of 'blinding' improved the scientific method even further. If neither the patient nor the researcher knows which treatment the patient is receiving, then the results cannot be interfered with either intentionally or unintentionally. This is known as a double-blind trial (in a single-blind trial, either the patient or researcher knows which treatment is being received).

However, the results could still be deliberately biased to prove that a treatment worked, by including sicker patients in the study group than in the control group. The solution to this, first used by the UK's Medical Research Council in the 1940s for its study of whooping cough vaccines, is to randomly choose which patients will get the new treatment, and which will get the control treatment.

Controlled trials with random allocation to the two groups became known as randomised-controlled tri-



- ✓ Biology
- ✓ Mathematics
- ✓ Health education
- ✓ Statistics
- ✓ Ethics
- ✓ Sociology
- ✓ Ages 14+

The article gives an insight into modern, evidence-based medicine, covering the often overlooked and seldom understood route from drug development to successful medical treatment. Statistical methods and their problems are discussed, providing interdisciplinary opportunities for teaching students aged 14 and over.

It is full of hot topics to be discussed with older students and teachers of different subjects. For example:

- 'Knowledge' is not static: as new side effects are reported or other new evidence is accumulated, the accepted knowledge can change.
- Often the clinical trials that are necessary before a drug can be marketed require more time than some very ill people have to live; who should be allowed to take part in a clinical trial – and which of those patients should get the control treatment and which the new drug?
- Why might the reporting of new treatments be biased?
- Do statistics give a false sense of security?

Picking up on the example of blood pressure and how variable this is, the class could measure their blood

pressure and see how it varies from student to student. They could then run up and down the stairs a few times and see how one person's blood pressure can vary. Against this background level of variation, how do researchers determine the effect of drugs to lower blood pressure?

The article could also be used to spark off larger activities. For example, the students could be given newspaper articles about a piece of clinical research or a 'wonder drug', perhaps related to conditions they are familiar with, such as migraine, glucose intolerance or allergies. In groups, the students could use textbooks, the Internet and other sources of information to research:

- The disease being treated;
- Which treatments are available so far for that disease;
- Whether the new treatment has been tested on animals;
- Whether previous clinical trials on that treatment have been published;
- How the current clinical trial was designed and what statistical analysis was done;
- How they think the trial could have been improved.

On the basis of this research, each group of students could then write their own newspaper article about the clinical research. Do they think the original newspaper article was accurate? If not, why not?

For most teachers, the article will also be a valuable source of information on the history of medical research and randomised-controlled trials.

Friedlinde Krotscheck, Austria

als or RCTs. By randomising, you not only end up with a random distribution of sicker and healthier patients between the two groups, but also achieve a random distribution of things you do not know about (but which may also affect the patient's health and therefore the outcome of the treatment). Then – because, in theory, the only difference between the two groups is whether they received the treatment being tested – you can assume that any differences in outcome are most likely due to the treatment and nothing else.

RCTs are now universally used in clinical research to evaluate new treatments.

Designing and analysing RCTs

More people, more power

If you are planning to test your blood-pressure treatment with an RCT, you need to design it carefully. One important question is: How many patients should you include in the trial? This depends on how big an effect the new treatment has: the bigger the effect, the smaller the number of patients you need to distinguish it

from the random fluctuations that happen by chance.

Of course, the effect of the treatment is exactly what you want to find out with your RCT. Before you start an RCT, however, you will already have some evidence that the treatment works, perhaps from laboratory or small-scale testing. This allows you to estimate the effect size.

Image courtesy of iStockphoto / wwing



Normal blood pressure is between 90 and 120 mmHg

In a healthy patient, blood pressure should be between 90 and 120 mmHg. But patients with high blood pressure will consistently have measurements of more than 140 mmHg, putting them at increased risk of heart attack and stroke. You might estimate that

the new treatment will reduce a patient's maximum blood pressure by 5 mmHg: after treatment, you would expect that the average blood pressure of the study group would be at least 5 mmHg lower than the average blood pressure of the control group.

There are statistical formulae to determine the sample size you need to have a good chance of detecting that estimated effect^{w2}. For your blood-pressure treatment, these formulae tell you that you would need around 64 patients in each group to detect a treatment difference of 5 mmHg^{w3}.

How different is different?

The trial has run its course, the participants have been monitored, and you have recorded a difference in blood pressure between the patients in the study and control groups. Thanks to randomising, you know that the two groups were comparable before the trial. So either your new treatment has had an effect, or a very surprising event has occurred: the treatment really has no effect at all and the difference you recorded in your RCT was due to chance alone.

Imagine that the average blood pressure of the study group was 5.2 mmHg lower than the average blood pressure of the control group. How do you decide if that difference is due to chance or to a real effect of the treatment? After all, blood pressure can vary for many reasons, not all of which can be controlled in your RCT.

What statisticians do is to allow for some variation; rather than rely on one average for each group, they calculate a range of values for each group that they are pretty confident will include the true value. This range of values is called a *confidence interval*. If the confidence intervals in your blood-pressure study are 141.2-148.9 mmHg in the control group and 133.7-139.3 mmHg in the study group, you can see that the two



Before running an RCT, the treatment is tested in the laboratory and on small groups of volunteers

Image courtesy of iStockphoto / hipokrat



Image courtesy of iStockphoto / sculpin

For a medical trial to work, the people taking part must be representative of the real-world population of people to be treated



BACKGROUND

Evidence changes medical practice

Before 1994, doctors recommended that patients with lower back pain rest in bed. However, after reviewing all the available evidence, the Clinical Standards Advisory Group realised that bed rest was not beneficial and was perhaps even harmful. This led to a radical change in treatment, with patients being advised to remain active^{w1}.

confidence intervals do not overlap. Statisticians, therefore, say that the observed difference between the two groups is statistically significant – and you can assume that it really was caused by the treatment.

But how confident is confident? Statisticians usually say that 95% confident is good enough; this means that they are prepared to live with the

fact that 5% of the time (or 1 in 20 times) they will be wrong due to chance alone. To be even surer that you have the right value, you have to measure more patients and even then, the only way to be 100% sure is to measure the whole population!

If the result turns out not to be statistically significant, one of the key questions to ask is whether you

included enough patients in the trial. Perhaps the effect of the treatment is smaller than you estimated – with a larger sample size, you might have detected a difference between the two groups of patients.

Applying RCTs to the real world

A well-designed and properly analysed RCT is a very powerful tool for medical researchers – providing doctors with the information they need to make the right decisions when treating their patients. Nonetheless, RCTs do have limitations.

Firstly, it is not enough to know that the new treatment makes a statistically significant difference. Is the difference also clinically significant – for example, does a decrease in maximum blood pressure of 5 mmHg make a real difference to a patient's health and well-being? After all, in our example, the treatment still did not reduce the blood pressure to the



Evidence can change views

A systematic review of the evidence for minocycline, an antibiotic that was heavily promoted as the best cure for acne, was recently conducted to investigate its efficacy and its safety.

One side effect of minocycline is potentially fatal autoimmune liver problems. These problems are rare and can have a number of causes. Most doctors do not come across them, and even if they do, the connection

might not necessarily be made with the drug.

It was only when all the information was reviewed together that the link was made. A systematic review showed that there was no evidence that minocycline was any better at curing acne than any other known treatment. Given the risks, the authors of the review concluded it should not be used in preference to other treatments (Garner et al., 2003).

normal range of 90-120 mmHg. To judge if this is clinically relevant, doctors may have to turn to other types of research.

A further limitation of RCTs is that patients in the trial may not represent the real-world population of people to be treated. Because trials aim to control as many factors as possible, they usually have strict inclusion and exclusion criteria. For example, pregnant women are not included due to potential risks to the unborn child; this meant that no one realised that thalidomide caused birth defects until it was introduced into general practice in the late 1950s^{w4}.

Then there is the question of how RCTs are reported. No one wants to publish bad news, particularly people who have spent time and effort to develop a new treatment. Historically, therefore, researchers did not publish trials that showed no difference or even that an older treatment was better. Some unscrupulous researchers have also reported selective or incomplete results, which made a new treatment look better than it really was. The research community has taken steps to stop both these biases by making companies and researchers register the start of a trial, so that it is more difficult to hide unfavourable outcomes, although there is still no

requirement to report all outcomes.

Journals are also standardising the information they require researchers to submit with their manuscripts, which makes it more difficult for bad results to be hidden.

Above all, RCTs are expensive and time consuming. As a result, many trials are not conducted at all, or their sample size or duration is limited. This may mean that the trial is not powerful enough to detect whether a treatment is effective, when in fact it is. Smaller trials may also miss important adverse effects (which may be rare), and shorter trials are unable to capture long-term outcomes.

Clinical researchers, therefore, often review the outcomes of a number of trials together in a meticulous analysis known as a systematic review – this effectively increases the sample size. Organisations such as the Cochrane Collaboration^{w5} and the UK's National Institute for Health and Clinical Excellence^{w6} base their recommendations to the medical community on systematic reviews.

Since the 1940s, the use of RCTs has significantly changed medical practice. Doctors are no longer reliant on their own observations but can rely on rigorous evaluation to ensure that the benefit of a new treatment outweighs the risks.

Acknowledgement

If you enjoyed this article but would like to learn more about the mathematics involved, read the original, longer version of this article^{w3}, which appeared in *Plus* magazine^{w7}, a free online magazine which opens a door to the world of mathematics with all its beauty and applications.

Reference

Garner SE (2003) Minocycline for acne vulgaris: efficacy and safety. *Cochrane Database of Systematic Reviews* 1: CD002086. doi: 10.1002/14651858.CD002086

Web references

- w1 – For more information about recommendations for bed rest, see the 'management' section of the article 'low back pain and sciatica' on the Patient UK website (www.patient.co.uk) or use the direct link: <http://tinyurl.com/y9gghww>
- w2 – You can read a good explanation of how treatment effects and sample size can affect statistical power in Jerry Dallal's *Little Handbook of Statistical Practice*: www.jerrydallal.com/LHSP/sizenotes.htm
- w3 – For the original version of this article, including more details of the

Image courtesy of stevecoleccs / iStockphoto



statistics, see:

Garner S, Thomas R (2010)

Evaluating a medical treatment – how do you know it works? *Plus Magazine*.

<http://plus.maths.org/latestnews/jan-apr10/rct>

w4 – To learn more about the thalidomide disaster and also about recent research into thalidomide and limb formation, see:

Zimmer C (2010) Answers begin to emerge on how thalidomide caused defects. *New York Times* 16 Mar: D3. www.nytimes.com

w5 – The Cochrane Collaboration is an international network of people helping healthcare providers, policy makers, patients, their advocates and carers make well-informed decisions about human healthcare. See: www.cochrane.org

w6 – The National Institute for Health and Clinical Excellence (NICE) is an independent organisation responsi-

ble for providing UK national guidance on promoting good health and preventing and treating ill health.

See: www.nice.org.uk

w7 – To learn more about *Plus*, the free online mathematics magazine, visit: <http://plus.maths.org>

Resources

For a brief description of the four phases of a clinical trial, see the information box in:

Wynne K, Bloom S (2007) Oxyntomodulin: a new therapy for obesity? *Science in School* 6: 25-29. www.scienceinschool.org/2007/issue6/oxyntomodulin

Ledford H (2010) Companies pledge to make more trial data public. *Nature News* 15 Jun. doi: 10.1038/news.2010.299.

To listen to the podcast that accompanied the original version of this article (*Plus* podcast 22,

February 2010: Evaluating a medical treatment), visit: <http://plus.maths.org/podcast>

The charity Sense About Science has produced a useful guide about interpreting medical claims in the press (I've got nothing to lose by trying it). It can be downloaded free from the Sense About Science website (www.senseaboutscience.org.uk) or via the direct link: <http://tinyurl.com/63zv4l>

Freiberger M (2010) Medical research plagued by bad reporting. *Plus Magazine*. <http://plus.maths.org/latestnews/jan-apr10/reporting>

Plus Magazine offers a range of articles, podcasts and classroom activities addressing the mathematics behind health and medicine: 'Do you know what's good for you?' See: <http://plus.maths.org/wellcome>

If you enjoyed this article, you might like to browse the other medicine-related articles in *Science in School*. See: www.scienceinschool.org/medicine

Dr Sarah Garner is the associate director for research and development at the National Institute for Health and Clinical Excellence (NICE)^{w6}, which bases its recommendations to the medical community on systematic reviews.

Rachel Thomas is co-editor of *Plus*^{w7} magazine.



Cold seeps: marine ecosystems based on hydrocarbons

Thousands of white crabs grazing on an extensive mussel bed at a cold seep off the coast of Pakistan

David Fischer takes us on a trip to the bottom of the sea to learn about cold seeps – their ecosystems, potential fuels, and possible involvement in global warming.

What are cold seeps?

Cold seeps are often oases for microbial and macrofaunal life on the sea floor – similar to hydrothermal vents, where hot water emerges under high pressure, several kilometres below the sea (see Little, 2010). In contrast to hydrothermal vents, however, cold seeps can occur at water depths of between a few metres and several kilometres, often along continental margins.

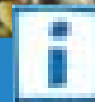
They are places where hydrocarbons – mostly methane but also ethane, propane, or even oil – seep from the sediment. Unlike at hydrothermal vents, the emanating fluids (gases and liquids) are no hotter than the surrounding seawater, and they are not necessarily under high pressure.

These hydrocarbons form up to several kilometres below the surface of the sediment when organic matter is degraded by either high temperatures or micro-organisms. When the hydrocarbons are produced in very large quantities, or where tectonic stress



Microbes covering cold seeps in an anoxic region, which does not support macrofauna

Image courtesy of MARUM, Bremen University



Glossary

Chemosymbiosis: a symbiotic association between a multi-cellular organism (the host), which provides a protected environment, and a bacterium that oxidises specific chemicals to obtain energy and synthesise organic carbon that is required by the host

Methanotrophic: a methanotrophic organism metabolises methane as its only source of energy and carbon

Pore water: the water that fills the space between individual grains of sediment

Thiotrophic: a thiotrophic organism oxidises sulphur compounds

Trophosome: a specialised internal organ in tube worms, hosting symbiotic bacteria

BACKGROUND

squeezes the sediments, the fluids rise to the sediment surface through cracks and fissures. The fluids may seep out at a continuous, low rate or the rate may vary.

Life at cold seeps: anybody home?

Some fascinating creatures can be found at deep-water cold seeps, including giant tube worms, mussels, clams and crabs. How are these ecosystems supported?

Almost the entire seabed is home to micro-organisms. However, to support significant levels of microfauna in deep water, where the sunlight does not reach, requires oxygen-rich water and an alternative energy source – such as hydrocarbons.

One such energy source is methane, released at cold seeps. The anaerobic oxidation of methane (AOM) is a metabolic process with sulphate as the final electron acceptor, mediated by a symbiosis of methane-oxidising (**methanotrophic**) archaeans and sulphate-reducing bacteria.



AOM takes place in anoxic marine sediments, wherever methane from deep down and sulphate from the seawater meet. The end products of AOM, bicarbonate and sulphide ions, are released into the surrounding sediment and **pore water** (see glossary for all terms in bold).

At locations where high methane concentrations are found close to the

surface of the sediment (as in cold seeps), the sulphide produced by the micro-organisms can fuel an entire ecosystem. Microbial or faunal colonies at cold seeps can be between 100 cm² and several hundred square metres in diameter. Where the sulphide-rich pore water escapes from the sea floor, the seep site will be colonised concentrically around these spots: closest to them will be those organisms which tolerate the highest concentrations of otherwise toxic sulphide (see upper image on page 62).

At the basis of these ecosystems are methanotrophic and **thiotrophic** bacteria. Some of them live in **chemosymbiosis** with mussels (methanotropic bacteria), clams and



- ✔ Biology
- ✔ Chemistry
- ✔ Earth science
- ✔ Marine environments
- ✔ Ecosystems
- ✔ Energy
- ✔ Biodiversity
- ✔ Climate change
- ✔ Ages 15+

If you are curious about the extremes of life on Earth, this is the article for you. David Fischer reports on exotic biological communities living at the bottom of the sea and on the exploration of these environments.

The language is easy enough to understand, with a glossary for technical terms. The article can be used in different subjects (biology, earth science, chemistry) to address a whole range of topics, such as: ecosystems, energy metabolism, food chains, natural resources, sedimentary rocks, non-renewable energy sources, marine environments and biodiversity, air pollution and the greenhouse effect, oceanographic research, hydrocarbons, clathrates, or redox reactions. Some of these topics (e.g. ecosystems, energy sources) are particularly suitable for an interdisciplinary approach.

The text also provides valuable background reading to introduce the origin of life at the bottom of the sea, for example with a comparison to hydrothermal vents.

In addition, the article provides references to content-rich websites (MARUM, NOAA) where the reader can find further information and resources (including teaching materials) on the topic. Therefore, I suggest completing the teaching unit with an activity from one of the cited web resources.

The article can also be used as a comprehension exercise. Possible questions include:

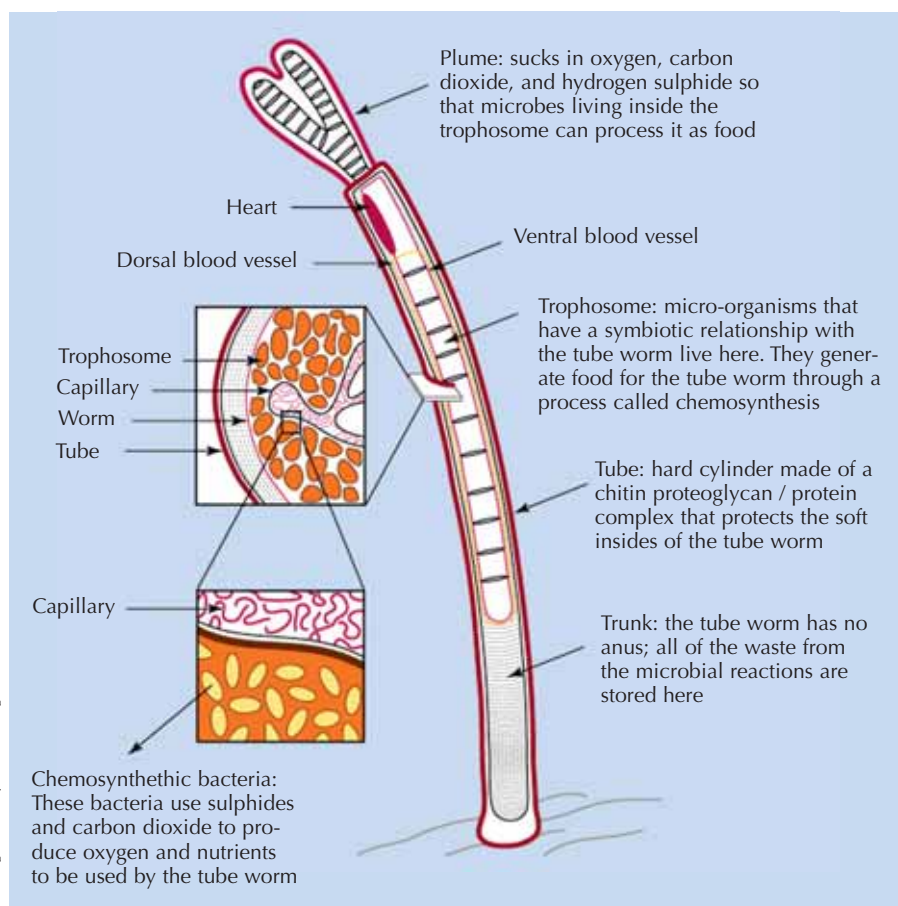
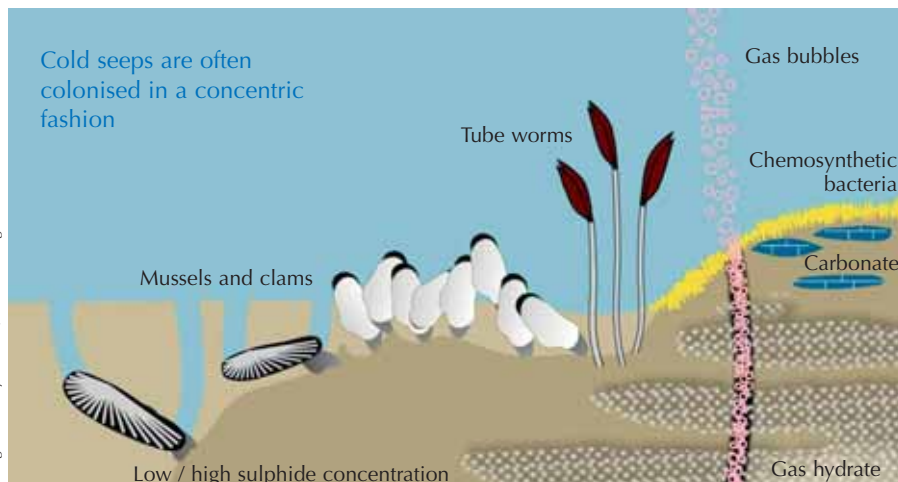
In AOM

- a) sulphate is oxidised to sulphide
- b) sulphide is reduced to sulphate
- c) methane is reduced to bicarbonate
- d) methane is oxidised to bicarbonate.

Gas hydrates

- a) consist of water molecules surrounded by gas molecules
- b) consist of gas molecules surrounded by water molecules
- c) are formed under high-temperature and low-pressure conditions
- d) are formed under high-temperature and high-pressure conditions.

Giulia Realdon, Italy



Tube worms host chemosymbiotic bacteria in their trophosome. This is a cross-section of *Riftia pachyptila*, which is found at hydrothermal vents

tube worms (thiotrophic bacteria). The mussels and clams harbour the bacteria in their gills, whereas the tube worms shelter the bacteria in their **trophosome**; the bacteria, in return, supply their host with organic carbon (see image above).

The formation and fate of gas hydrates

Cold seeps are not only interesting because of the ecosystems they host: they could be important contributors to climate change and valuable new sources of hydrocarbons, to satisfy

our increasing energy demands. Cold seeps generally indicate large amounts of hydrocarbons below the seabed, and they are comparably easy to identify because of their typical colonisation by specialised organisms.

Most interesting in this respect are gas hydrates. In these ice-like crystalline compounds, water molecules form a cage structure called a clathrate around individual gas molecules (see image on page 63) – in natural gas hydrates, this is mostly methane. Gas hydrates form where pore water is saturated with methane gas, within a narrow window of low-temperature and high-pressure conditions found only in deep permafrost soils – and in marine sediments at depths below about 400 m (see lower image on page 63). At atmospheric pressure, gas hydrates are unstable and rapidly decompose into water and free gas.

Gas hydrates store large amounts of chemically bound energy: because of the specific molecular structure, one litre of gas hydrate holds 0.8 l of water and 164 l of methane gas. The total energy resources in gas hydrates on Earth are estimated to be greater than those of all other known fossil fuels combined – ever.

Several countries, including the USA, Japan, South Korea, India and China, are exploring ways to harvest gas hydrates – safely, which is not a trivial matter. More importantly, however, it is essential to stop the gas hydrates from melting. Global warming is increasing the oceans' temperatures, and this could cause a large-scale melting of gas hydrates in the sediment.

If they were to melt, the methane released into the atmosphere would react with atmospheric oxygen to form CO₂, very efficiently enhancing the greenhouse effect. Left undamaged, gas hydrates act as stabilising agents for the continental slopes. If they were to melt, the slopes could destabilise, resulting in huge submarine landslides and tsunamis.

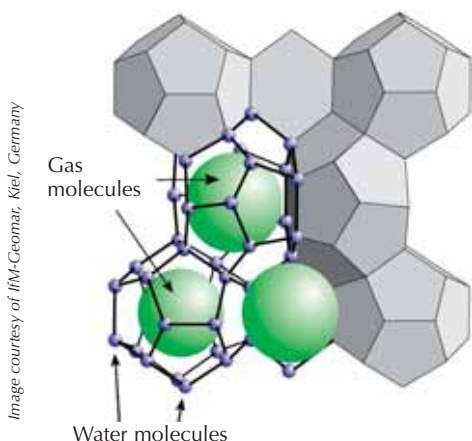


Image courtesy of IfM-Geomar, Kiel, Germany

Clathrate structure of gas hydrates



Burning gas hydrates



White gas hydrates consolidate sea floor sediments

Images courtesy of MARUM, Bremen University

How do we study cold seeps?

Studying cold seeps is obviously a big challenge for scientists: how can gases, water, sediment and organisms be sampled up to several kilometres below the sea surface? First, you have to reach your sampling location – this may take several days by ship, even for cold seeps on the continental shelf, and maintaining such a research vessel costs several tens of thousands of Euros a day. And when you get there, how do you reach the sea floor? Until the 1990s, the only way was to lower special tools on the end of a long steel cable, and recover them as soon as

they had filled with sample material. This of course made it very difficult to have any visual control of where the tools hit the ground.

Matters have improved dramatically with the development of sophisticated underwater technology, such as remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs), equipped with an array of cameras, lamps and sampling devices. MARUM^{w1} has its own workshop to develop such tools and robots for ocean research. Researchers use them to investigate cold seeps by either having them dive to individual spots

to collect samples or taking photos of a larger area to provide an overall picture of a cold seep location.

There is still a lot of research to be done into the development and stability of cold seeps over time, and little is known about the organisms colonising them. Yet the most important question about cold seeps is how much methane is transferred into the ocean and subsequently into our atmosphere, where it will contribute to global warming. For me, it is very exciting to take part in this research.

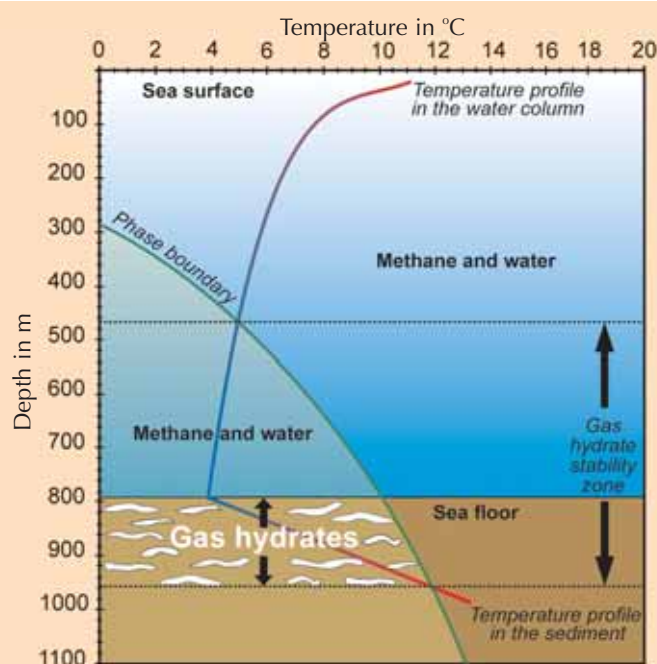


Image courtesy of David Fischer, MARUM

Under specific combinations of high pressure (water depth) and low temperature, methane can crystallise with water to form gas hydrates, as indicated by the phase boundary line. At higher temperatures or shallower depths, methane will instead dissolve in water.

In the ocean, there are additional complications: in the water column, temperature decreases with increasing water depth, whereas in the sediment, temperature increases with increasing depth. The points at which these temperature profiles cross the theoretical phase boundary determine the depths at which gas hydrates may be found (the gas hydrate stability zone).

Furthermore, it is mostly in the sediment that methane concentrations are high enough to form gas hydrates (marked in white) – they have seldom been observed in the water column.

Note that the scale in this diagram is an example and can vary depending on conditions



MARUM-QUEST 4000m, an ROV suitable for depths of up to 4000 m, equipped with a large number of cameras, spotlights, corers and other tools to collect samples from the sea floor as small as single organisms only a few millimetres long



Close-up photograph of the symbiotic vestimentiferan tube worm *Lamellibrachia luymesii* from a cold seep at 550 m depth in the Gulf of Mexico. The tubes of the worms are stained with a blue chitin stain to determine their growth rates. Approximately 14 months of growth is shown by the staining here

clams found at cold seeps. See <http://www.marum.de/marumTV.html>

The US National Oceanic and Atmospheric Administration (NOAA) offers a number of lesson plans and downloadable teaching activities on cold seeps for all ages, plus background information. See the NOAA website (<http://oceanexplorer.noaa.gov>) or use the direct links:
<http://tinyurl.com/36zuhfb> ('Windows to the Deep')
<http://tinyurl.com/32f6me6> ('Expedition to the Deep Slope 2006')
<http://tinyurl.com/35g3qrk> ('Expedition to the Deep Slope 2007')

For some general information about gas hydrates, see the MARUM website (www.marum.de) or use the direct link:

<http://tinyurl.com/3xzzpj>

For more information on hydrocarbons, including gas hydrates, see: van Dijk M (2009) Hydrocarbons: a fossil but not (yet) extinct. *Science in School* 12: 62-69.

www.scienceinschool.org/2009/issue12/energy

If you enjoyed reading this article, you might like to browse our other articles on science topics in *Science in School*: www.scienceinschool.org/sciencetopics

Born in Jülich, Germany, David Fischer has always been fascinated by science and the sea. After graduating in physical geography, marine geology and biology from the University of Bremen, he is now working towards a PhD in marine geology at MARUM, investigating the biogeochemistry of cold seeps. He has participated in a number of research expeditions to the North Sea, the Baltic Sea, the Arabian Sea, the central east Atlantic, and the Southern Ocean near the Antarctic Peninsula.



Acknowledgements

The author would like to thank Dr Pape (MARUM^{W1}) for valuable comments, particularly about gas hydrates. Moreover, *Science in School* and the author thank the publisher Inter-Research for permission to reuse the image from Sahling et al. (2002).

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The article can be downloaded free of charge from the Inter-Research website: www.int-res.com

Web reference

- w1 – To learn more about MARUM – the Center for Marine Environmental Sciences, an independent DFG-funded research facility at the University of Bremen, Germany, see: www.marum.de

Resources

MARUM offers a large selection of German-language resources and activities for teachers and school students, including videos and articles on research topics, a large selection of workshops for both primary- and secondary-school students in the MARUM teaching lab, workshops for primary-school teachers, experimental science theatre workshops for primary-school children, and much more. See: www.marum.de/en/entdecken.html

MARUM has produced a wonderful (English-language) video on cold seeps and methane hydrates. See www.marum.de/marumTV.html

In addition, MARUM has produced, in co-operation with the Deutsche Forschungsgemeinschaft, a 12-episode series of films about its research (DFG Science TV). Episode six (German only) tells the story of

Publisher: EIROforum,
www.eiroforum.org

Editor-in-chief: Dr Eleanor Hayes,
European Molecular Biology
Laboratory, Germany

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Printers: ColorDruckLeimen,
Germany
www.colordruck.com

Webmaster: Alexander Kubias
Email: mail@alexander-kubias.net

ISSN:

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

Cover images:

Octopus

Image courtesy of Tammy616 /
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Anne Weaver, flying doctor
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- Eye protection is worn whenever there is any recognised risk to the eyes
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Science in School is a non-profit activity. Initially supported by the European Commission, it is now funded by EIROforum.

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Sven-Olof Holmgren: science education is more complex than particle physics

Images courtesy of the ATLAS Experiment at CERN



Image courtesy of Kajsa Kax Wågghals



Sven-Olof Holmgren

Do you think particle physics is a complex subject? Having moved from basic research to science education, Sven-Olof Holmgren would disagree. He tells **Lucy Patterson** and **Marlene Rau** about the challenges of this shift, and about a major reform in the Swedish education system.



The tile calorimeter goes down into the ATLAS cavern

Sven-Olof Holmgren began his career as a particle physicist. He obtained his PhD in 1970 and a professorship from Stockholm University, Sweden, in 1992, where he also served as Head of the Physics Department for several years. During this period, Sven-Olof and his group worked on a number of big experiments, including several at CERN^{w1} in Geneva, Switzerland. Involved in both the development of detectors and data analysis, they most recently worked on the ATLAS detector of the Large Hadron Collider (LHC). Sven-Olof's group built the readout electronics for the tile calorimeter, which will collect the energy deposited by secondary particles in the proton-proton collisions. Of course, Sven-Olof is eager to

see the results that the LHC will deliver: "After decades of preparation, this is the time to reap the reward."

Since 1997, however, Sven-Olof's interests have shifted to encompass science education as he became involved in the development of a science education programme by the Royal Swedish Academy of Sciences^{w2} (KVA). He describes his transition into science education and the last 13 years with the KVA schools programme as among the most exciting times of his career. However, it has been "a bumpy road with ups and downs", as Sven-Olof puts it. One of the big changes for him was coping with the shift in his research work from the pure science of physics to



- ✓ General science
- ✓ Science education
- ✓ Ages 12+

Physics is an exact science, using clearly articulated and universal laws and quantitative methods in research. By testing hypotheses, it seeks to make accurate predictions. Unlike physics, science education is a complex field, dominated by a series of psychological and social theories, some running in parallel. In this article, Sven-Olof Holmgren describes his career shift from research in particle physics to science education.

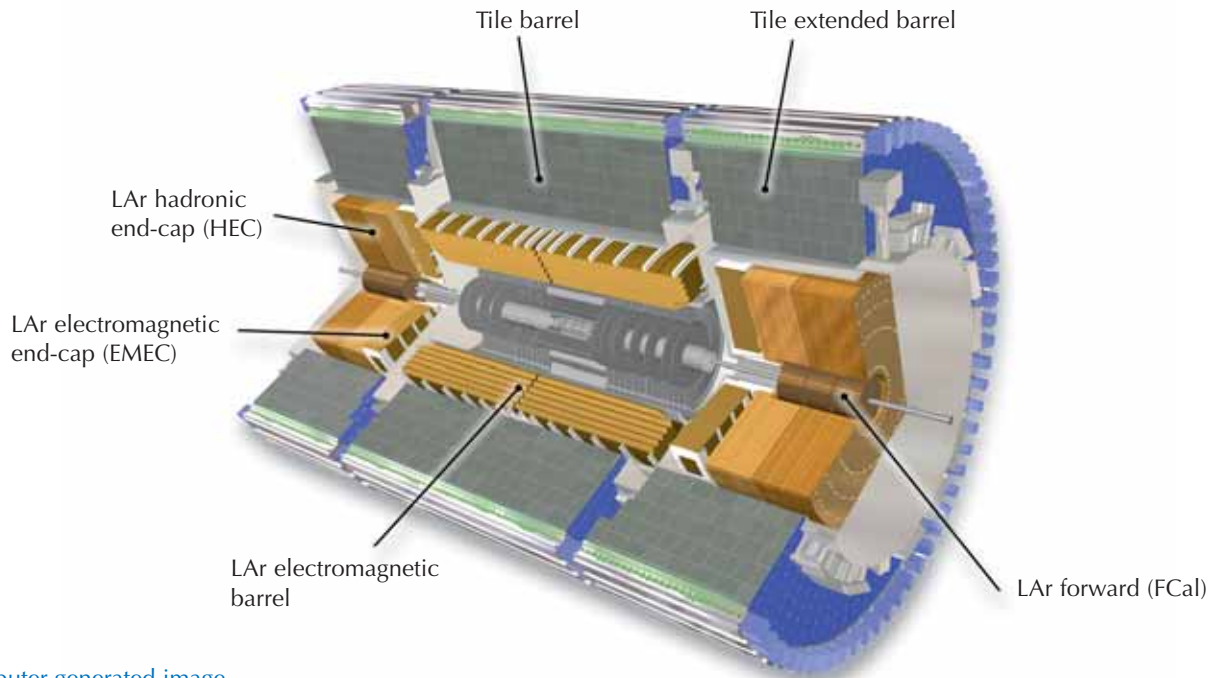
For science teachers, it will also be stimulating to read about an educational reform which made science compulsory from grade one. The Swedish NTA programme shows foresight by being based on inquiry-based learning. The reform is thus aligned with the Rocard report, *Science Education Now – a Renewed Pedagogy for the Future of Europe*^{w6}.

The article can be used in the classroom to stimulate a discussion of the relations between science and science education.

Niels Bonderup Dohn,
Denmark

REVIEW

Images courtesy of the ATLAS Experiment at CERN



A computer-generated image of the ATLAS calorimeter

the social science of education. Now, he is even co-supervising a PhD student in science education.

“The change has opened up a whole new world for me and a new kind of research. I have spent most of my professional life working on hard-core, basic physics. But the way I see it now, physics is really the simplest of the sciences because we can really control our experiments. Take a pendulum, for instance: suspend a weight from a string, give it a push and measure the time it takes to swing from one end to the other – you will soon find out that its period is constant. You can then formulate a theory on what this may depend on – the mass or size of the weight, the length of the string, etc.; do controlled experiments, changing just one variable at a time, while keeping the others constant; and eventually you will find that the period depends on the length of the string only. There’s a consensus that scientific experiments should be done like that, under controlled conditions – and in physics, it’s relatively

easy to do that – even complicated experiments such as the LHC are performed according to these principles.

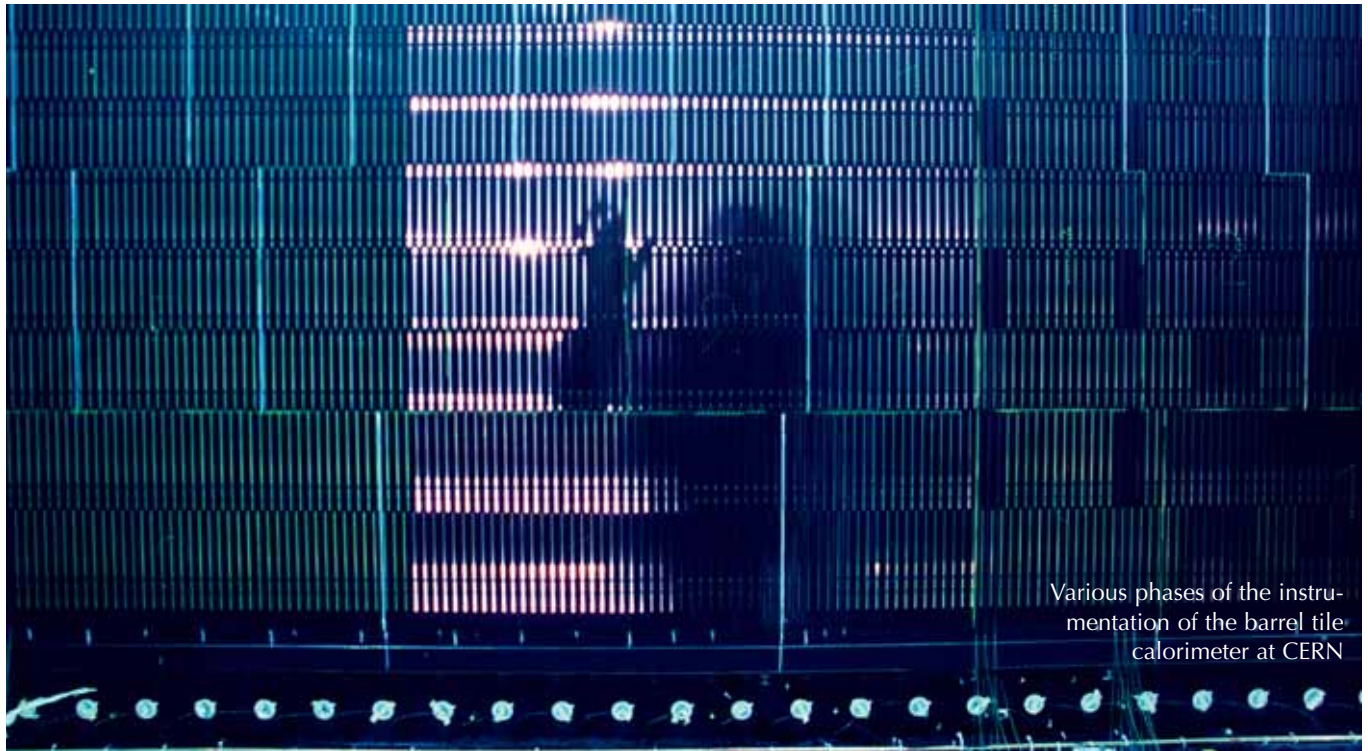
“There is a kind of increase in complexity through chemistry and biology, until you get to the social sciences, which are about as complex as you can get. There, research is completely different. A theory in social science is not at all the same as a theory in science. It’s psychology – you have to take into account peoples’ way of thinking. Of course it’s called *social science* because one tries to apply scientific reasoning. But for me, many of the theories in social science, and indeed in science education, seem more like perspectives. You interpret your data from one perspective and even design your study from that perspective. However, someone else could come along and see the same thing from a very different angle. So you can have several different theories running in parallel and it’s very hard to see the development. It’s very difficult to prove that one theory is better than another because it’s all so

complex. This is something we natural scientists have to get used to – and I think we have been criticising each other far too often.

“In education science you don’t have just one individual – you have a class of thirty or so students and a teacher, all interacting with one another – it’s a very complex system. There have been attempts to directly compare two ways of teaching the same science subject – in an inquiry-based versus a traditional setting: the researchers didn’t find much of a difference. Yet they mostly evaluate the results in terms of how much of the subject matter was conveyed. In terms of the students’ or teachers’ motivation or enthusiasm for science, which are important in the inquiry-based approach, there might well have been a difference.

“Personally, I believe that we have been concentrating solely on the knowledge of the subject matter for too long. We should not only be teaching the results, but also how they are achieved – how science is

Image courtesy of the ATLAS Experiment at CERN



Various phases of the instrumentation of the barrel tile calorimeter at CERN

done. This is often lacking not only in school but even at the undergraduate university level, and I think it's high time for a paradigm shift. Then again, this is of course also another perspective, and possibly difficult to prove."

Since moving into education, Sven-Olof has witnessed a shift in attitudes towards science education and teaching in general in Sweden – an interesting time for him to hone his new skills. "In the past, science teaching in

Sweden at primary level was rather more haphazard. This all changed gradually, culminating in 1994 with the introduction of major reforms in the Swedish education system, including new National Standards.



The Swedish NTA programme

BACKGROUND

In 1997, the Royal Swedish Academy of Sciences^{w2} (KVA) and the Royal Swedish Academy of Engineering Sciences^{w5} (IVA) began to develop a new inquiry-based science education programme for primary and secondary schools, which became known as NTA: 'Natural science and Technology for All'^{w4}. As a member of the KVA, Sven-Olof became involved in the project early on and currently chairs the development group.

The NTA scheme comprises a series of themed units for primary and lower secondary school, covering different topics from the areas of biology, chemistry, physics and

technology (e.g. 'floating or sinking' or 'plant growth and development'), along with all materials and specific training for teachers. Following its initial success, the NTA program is steadily growing and being taken up by an increasing number of schools and municipalities across Sweden. The latest counts (Spring 2010) include 96 000 students and more than 7 000 teachers. In addition, KVA organises 'teacher inspiration days', where members of the Academy talk about their research to science teachers; and they award annual prizes for teachers' biology, physics, chemistry and mathematics projects.

These defined certain 'goals to achieve' and 'goals to strive for' that would have to be met by grades five and nine. Crucially, however, it didn't prescribe exactly how to reach them. This handed back control to local municipalities, schools and teachers who are now expected to design exactly what gets taught when, using their best professional judgment. At the same time, de-centralising control over the schools' economy and education policy – which was also handed over to the local municipalities – has helped to create a real bottom-up education system."

In Sweden, students attend nine years of compulsory school (*Grundskola*), after which there are three years of optional secondary school. With educational targets in science subjects that have to be met by grade five (age 11), the reforms mean that the planning to reach these goals has to start from grade one (age 7). Inspiration for the new National Standards was taken from ongoing work in other countries, particularly at the National Academy of Sciences^{w3} in the USA. This work called for a new science education strategy. Sven-Olof himself has been involved in the development of a new science education programme called NTA^{w4} (Natural science and Technology for All; see box).

Sven-Olof agrees that the best time to introduce science to children is at primary school, while students are still trying to understand the world for themselves. "By the time children are about five or six, they have already pieced together a basic model of how the world works, based on intuition. However, this model is very limited because our senses are very limited. Science challenges this model: when you start to measure the world in a scientific way, you find it doesn't fit the basic intuitive model anymore. So again you have to revise and refine your model. You then make more detailed experiments that

challenge even the improved model, and so on.... And we never get more out of it than when we see a flaw, because then we have to revise the model.

"For me, science literacy is about getting beyond that first model we develop based on our senses – it's about challenging our intuition and accepting ideas that might seem counter-intuitive concepts."

And as far as Sven-Olof is concerned, the need for science literacy is even greater for the coming generations. "We're facing a big problem today. If you ask 15-year-olds, they're very keen to discuss societal problems like climate change, sustainable development and changing values, but they often lack the scientific basis to understand and tackle these issues. We are not talking about science for specialists and researchers – this is science for everyone. And that, to my mind, is what we really need. Science literacy will be really essential to understand the alternatives and make the right decisions. For me, in the end it's a question of democracy and even of the future of this planet."

Web references

- w1 – For more information about CERN, the European Organization for Nuclear Research, see: www.cern.ch
- w2 – To find out more about the Royal Swedish Academy of Sciences, see: www.kva.se
- w3 – Learn more about the US National Academy of Sciences here: www.nasonline.org
- w4 – For more information about the 'Natural science and Technology for All' programme, see: www.nta.kva.se
- w5 – Find out more about the Royal Swedish Academy of Engineering Sciences here: www.iva.se
- w6 – The Rocard report, with proposals for widening European educational approaches to science, can be

downloaded from the European Commission website (<http://ec.europa.eu>) or via the direct link: <http://tinyurl.com/2mjrd7>

Resources

- To learn more about the Large Hadron Collider at CERN and the particle physics involved, see: Landua R (2008) The LHC: a look inside. *Science in School* **10**: 34-45. www.scienceinschool.org/2008/issue10/lhchow
- Landua R, Rau M (2008) The LHC: a step closer to the Big Bang. *Science in School* **10**: 26-33. www.scienceinschool.org/2008/issue10/lhcwhy

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Originally a developmental biologist, Dr Lucy Patterson is now as a science communicator. She currently works for the Max Delbrück Center for Molecular Medicine in Berlin, Germany – a research institute specialising in molecular biology that also tries to apply what researchers learn to help diagnose, treat and prevent diseases. Here she helps the scientists to communicate better with the rest of the world, and with each other.

Dr Marlene Rau was born in Germany and grew up in Spain. After obtaining a PhD in developmental biology at the European Molecular Biology Laboratory in Heidelberg, Germany, she studied journalism and went into science communication. Since 2008, she has been one of the editors of *Science in School*.



The physics of inspiration: teaching in Austria

Rudolf Ziegelbecker



Image courtesy of Ortweinschule Fotografie

Gyro-cars, gymnastic cats and a slow-motion slap in the face. **Lucy Patterson** spoke to Rudolf Ziegelbecker, an Austrian physics teacher, about how to catch the imagination of even the most anti-physics students.

Using a high-speed camera to record how a water-filled balloon bursts



Image courtesy of Rudolf Ziegelbecker



Image courtesy of Jakob Jöbstl

What happens when you let a drop hit the water surface? Jakob Jöbstl investigated at home, inspired by the school project

Image courtesy of Jakob Jöbstl

Unenthusiastic students can be a challenge for even the best teachers. Rudolf Ziegelbecker teaches physics at an Austrian school specialising in civil engineering and in art and design^{w1}. With such a strong focus on vocational education in the curriculum, teaching more traditional academic subjects, such as physics, can be a challenge. “Many of the arts students who choose to come to our school are not very good at mathematics and science. Nonetheless, the curriculum requires them to study

physics for the first three of their five years here. Unsurprisingly, some students are quite unwilling to learn.”

Rudolf enjoys sharing his own enthusiasm for physics and encouraging the students to develop their own ideas. This has led to some impressive successes over the years, often in collaboration with his colleagues from other disciplines: building a paper bridge which can carry up to 1.6 tonnes, boats light enough to float on gaseous CO₂, and innovative paper boats which can carry several kilo-

Image courtesy of Rudolf Ziegelbecker



A strong paper bridge which can carry up to 1.6 tonnes

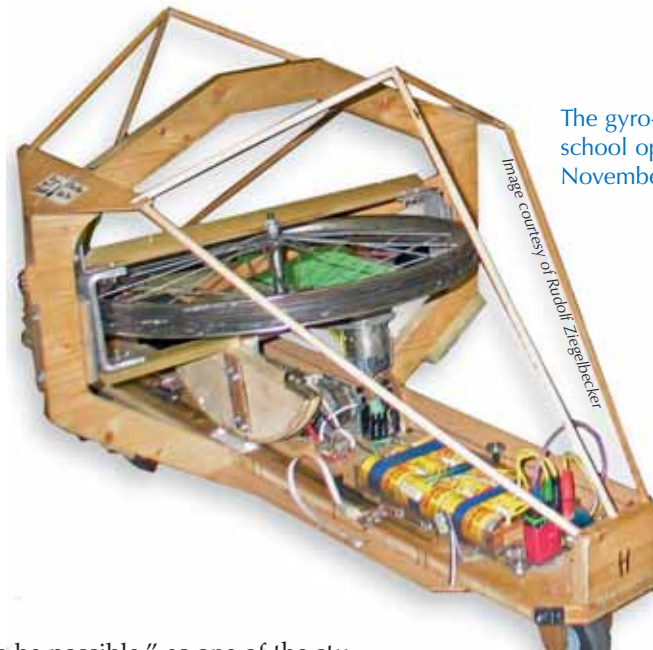
Image courtesy of Rudolf Ziegelbecker



Light boats floating on CO₂

grams despite weighing only 10 grams; designing a sustainable solar and hydro-electric power plant for the local river, and a (fish-shaped) aerodynamic vehicle which they tested in a home-made wind tunnel...

One award-winning project was the gyro-car: together with eight volunteer students in an afternoon physics club, Rudolf designed and built a remote-controlled 1 m long gyromobile capable of balancing automatically on its two wheels. It was exhibited at science shows, presented at Physics on Stage 2000^{w2}, and appeared on TV during the Austrian Science Week 2003, crossing the local river Mur while balancing along the handrail of the main bridge in Graz. The project was a big hit for the school and the students involved: "It helped me realise that, sometimes, the impossi-



The gyro-car at a school open day in November 2009

ble can be possible," as one of the students put it.

In 2002-2003, Rudolf and his students took on another project: 'The turning cat' was to be a robot that could simulate a falling cat's righting reflex – how the cat twists to face downwards for landing, without changing its net angular momentum (zero). After a series of prototypes, the team designed and built what Rudolf believes to be the "only radio-controlled cat model in the world". Operated by remote control, it can be turned during freefall for a perfectly upright (albeit cushioned) landing. Their project won several awards and prizes, and is still proudly shown at every school open day.

Rudolf also tells the story of a shy girl who had not dared to confess to her previous teacher that she was actually interested in physics. When a student dropped out of the school's team for the Austrian Young Physicists' Tournament^{w3}, Rudolf suggested she join. He successfully coached her, and she even ended up in the team representing Austria in the international tournament in Australia^{w4}.

Inspired by a 'string telephone' experiment on resonance that she had performed for the contest, she then came up with a very practically minded diploma project for her *Matura*:



Image courtesy of the HTBLVA Graz Ortweinschule

'The turning cat' in freefall



Image courtesy of Rudolf Ziegelbecker



A special type of school

After middle school, at the age of 14, students in Austria have at least one more year of compulsory school education. If they wish to go to university, they can attend a secondary school for four more years to obtain the *Matura* (final secondary-school examination, required to enter university). Alternatively, they can spend three to four years at a vocational school, or five years at a combined technical college, which not only offers the *Matura*, but also the completion of a professional education. The HTBLVA Ortweinschule^{w1} in Graz is such a college, catering for 14- to 19-year-olds, and specialising in civil engineering and in arts and design.

BACKGROUND

Spring-coupled masses were added to the pedestrian bridge in Graz after two of Rudolf's students discovered that its resonance was dangerous

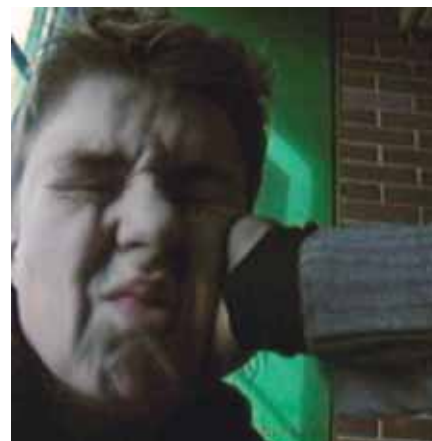
"Crossing a pedestrian bridge in Graz with a classmate, the two friends noticed how it seemed to resonate rather a lot, so they decided to do their project on the resonance of bridges. They took friends and family to the original bridge to measure its resonance, and 'tested' it so thoroughly that at one point the supervising teacher decided to call off the experiment for fear of the bridge collapsing! They filed their results with the city authorities of Graz. As a consequence, the bridge was closed, investigated by stress analysts, and re-opened only after the resonance had been damped by spring-coupled masses which you can see under the bridge today," Rudolf says.

Most recently, Rudolf and his students participated in the 2010 'Jugend innovativ' competition^{w5}, a national innovation award for secondary-

school students aged 15 and above. "I started the project in two classes, but after a few weeks, the other classes became interested as well, and eventually joined and contributed to the final report. Although we didn't win any prizes, it was an invaluable experience for the students. We used a cheap high-speed camera to film a range of effects – from the vibrations of a stretched rubber band or the firing of a blowpipe shot, to what happens to the water in a water-bomb when it bursts, or even the (scientific) repercussions of the slap of a girl's hand on a boy's face (without my permission! But at least it got them interested in the science) – and then analysed the slow-motion replay in order to understand the physical principles involved.

"This project managed to engage even some of my most anti-physics

Images courtesy of Robert Purkarthofer



What are the (scientific) repercussions of a slap in the face?

students in a second-year graphics design class, who, intending to pursue a career in arts, were convinced they'd never need physics again in their lives. I appealed to their honour, showing them what the first-year arts students had achieved. This got them interested. They performed their own experiments on one of the ideas – observing what happens to a drop of water falling onto a water surface. Soon, the entire class was involved in a scientific discussion about the fact that, when the drop hits the surface, a chain of drops leaps back up, raising questions like 'How much of the initial energy and volume is conserved in these secondary drops? Are they composed of literally the same liquid as the first drop? Is the effect caused by surface tension, wave reflection or hydrostatic pressure?'

"For the project's success, it was essential that almost all of the ideas emerged from the students. The feedback was really positive: those students who had initially been most sceptical and disinterested were those who by the end of the project were not only much more respectful – of me and of the lessons – but also seemed to have developed a new-found interest in physics! And it seems to be lasting."

Web references

- w1 – Find out more about the HTBL-VA Graz Ortweinschule here: www.ortweinschule.at
- w2 – Physics on Stage – now Science on Stage – is a European initiative designed to encourage teachers from across Europe to share best practice in science teaching. See: www.scienceonstage.eu
- w3 – To learn more about the Austrian Young Physicists' Tournament, see: www.aypt.at
- w4 – Find out more about the International Young Physicists' Tournament here: www.iypt.org
- w5 – The 'Jugend innovativ' website offers more information about this Austrian competition for secondary-school students. See: www.jugendinnovativ.at

Resources

If you enjoyed reading this article, you might want to browse the full collection of teacher profiles published in *Science in School*. See: www.scienceinschool.org/teachers

Originally a developmental biologist, Dr Lucy Patterson is now as a science communicator. She currently works for the Max Delbrück Center for Molecular Medicine in Berlin, Germany – a research institute specialising in molecular biology that also tries to apply what researchers learn to help diagnose, treat and prevent diseases. Here she helps the scientists to communicate better with the rest of the world, and with each other.



Jean-Luc Solandt: diving into marine conservation

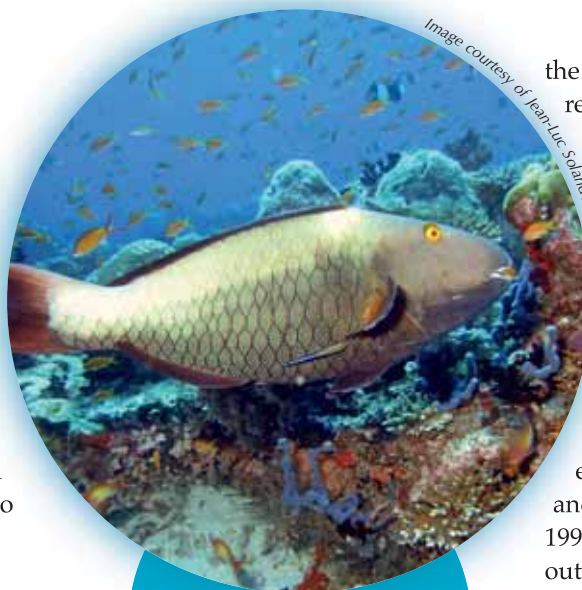
Soft coral with
reef fish
(Anthias)

Marine biologist Jean-Luc Solandt tells **Karin Ranero Celius** about his commitment to study and preserve one of the world's biggest treasures: the ocean.

Jacques Cousteau's beautiful images of colourful and bizarre underwater sea life have inspired millions of people around the globe – including Jean-Luc Solandt. "I became interested in science after learning about Cousteau's explorations; they made the marine world seem smaller – yet wondrous." These days, as the biodiversity policy officer at the Marine Conservation Society^{w1}, Jean-Luc Solandt helps to safeguard this wondrous world.

At school in London, Jean-Luc found science breathtaking, especially anatomy and functional design. As his passion and interest for science grew, he did a marine biology degree at Liverpool University, UK, and then spent a year volunteering on the Great Barrier Reef in Australia, where he surveyed reef fish and monitored the fecundity of corals, witnessing the mass spawning of hard corals.

"The reefs of the tropic are similar to the great plains of the Serengeti,



A parrotfish, vital for keeping algal growth in check (photographed during surveys of Maldives reefs in 2007)

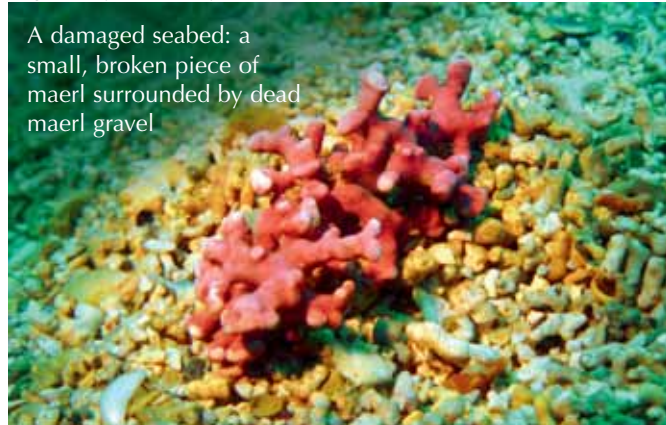
but instead of the large numbers of ungulate [hoofed] grazers, these are replaced by colourful parrotfish and surgeonfish, which are vital for keeping the algae in check and allowing

the hard corals to grow. In a healthy reef system, the balance between these herbivores and the algae are vital to keep the coral healthy."

Back in the UK, Jean-Luc pursued a PhD at the University of London, doing his fieldwork in Jamaica, where the fish herbivores were (and still are) being eradicated by over-fishing. In the absence of fish, the spiny urchin, *Diadema antillarum*, was essential to keep the algae in check and give the coral space to grow. In 1990, however, a disease nearly wiped out this spiny urchin, leaving the reef ungrazed. Between 1995 and 1998, as the population recovered, Jean-Luc studied the interaction between the spiny urchins, algae and other reef species.

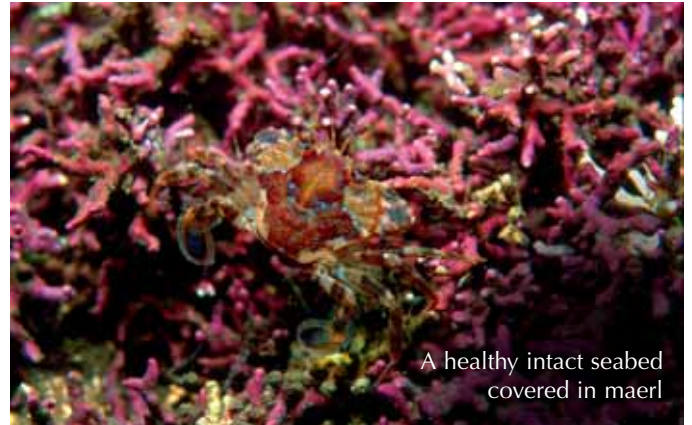
His growing interest in marine conservation then led him to Tanzania to work as an expedition scientist for Frontier^{w2} (a UK-based conservation expedition organisation), and then to the Philippines and Fiji with Coral Cay Conservation^{w3}. His responsibili-

Image courtesy of Phil Lockley



A damaged seabed: a small, broken piece of maerl surrounded by dead maerl gravel

Image courtesy of Sue Scott



A healthy intact seabed covered in maerl

Maerl is a rare calcareous, reef-forming alga, which in English coastal waters is only found near Falmouth in Cornwall. The area was also popular for scallop dredging, in which fishing gear with 15 cm long teeth was dragged along the seabed, capturing the scallops and damaging the seabed in the process. In 2007, scientific surveys revealed that maerl was growing within the scallop-dredging area and as a consequence, scallop dredging was restricted in the surrounding area

Image courtesy of Colin Speedie



A basking shark, on the 'red list' of threatened species of the International Union for Conservation of Nature. The basking shark migrates thousands of kilometres

ties included training the volunteers – many of whom knew little about marine biology. They soon learned, however, to identify more than 75 fish species and 40 coral species, as well as many other invertebrates that they then recorded during scuba surveys.

“On a typical day, you wake up at six in the morning, organise the dive, meet the volunteers, lecture them, tend to sores and headaches, go on the dive, record and enter the data, lunch on rice and beans, fill the air tanks, teach the volunteers, go on a second dive, go into town to resupply fuel, food and the repair kit, and then carry on entering data,” Jean-Luc says.

These were months of very long days and hard work, but with a very important purpose: to recommend areas that needed protection, something that Jean-Luc became increasingly involved in. It was the success of these recommendations – including the establishment of the Danjungan Islands Marine Reserve^{w4} – that encouraged him to dive further into applied conservation work – cam-

paigning for UK marine protected areas at the Marine Conservation Society^{w1}.

The oceans harbour many diverse and co-existing ecosystems, and have always been a dependable source of food for humans – but the vulnerability of these ecosystems is becoming increasingly evident. As shown by recent data, “commercial fish stocks have been reduced by about 95% in UK waters alone in the past 100 years [Thurstan et al., 2010],” notes Jean-Luc. Moreover, 88% of Europe’s fish stocks are overfished or depleted. For this reason, the Marine Conservation Society campaigns worldwide to establish areas where marine wildlife can recover and flourish. These could either be marine protected areas, in which one or more features are protected, or marine reserves, which offer the highest level of protection: no fishing or catch of any kind, and no dumping, dredging or other modification of the environment.

“We know from studies abroad that reducing the level of fishing can allow the marine environment to recover somewhat,” Jean-Luc says. “However, this alone is not enough: it is also essential to have marine reserves – and big enough ones.” A good exam-

Image courtesy of meavans / iStockphoto

ple is the five large Georges Bank marine reserves, which cover a total of 17 000 km² off the north-eastern coast of the USA, and which have allowed scallop numbers to increase by 2000% and yellowtail flounder (a flat-fish) by 500%. Analysis of the effects of 124 international marine reserves have revealed an increase in the biomass of previously exploited species by 446% and in their diversity by 21% (Lester et al., 2009).

Marine reserves not only benefit the ecosystem within the reserve but also affect what happens outside their boundaries. "In a phenomenon called 'fishing the line', catches are higher around the edge of the reserve than further away: 73% of the haddock fished in the north-eastern Atlantic is caught within 5 km of the Georges Bank reserve boundaries. This helps fishermen to be more certain of catching fish, whilst reducing their overheads, because they do not have to waste time and fuel searching for fish," Jean-Luc says. So even the fishermen benefit from the reserve. This effect has also been recorded for lobster and fish catches around small Mediterranean marine reserves (Goñi et al., 2008).

"Small-scale marine reserves have been shown to be beneficial to relatively sedentary species and fish that do not move large distances during their life history. However, to benefit larger, more migratory species such as haddock, we need marine reserves on

the scale of the Georges Bank marine reserves."

For species that migrate between oceans, however, marine protected areas and reserves are of limited use. For the past six years, therefore, Jean-Luc has participated in a project to protect the basking shark, which migrates over huge distances and between oceans. "Basking sharks are the second largest fish in the world. They are planktonic filter feeders, up to 12 m long, and are highly endangered because of their low fecundity (about six pups every two years) and late age of maturity (about 18 years)."

In 2007, the project succeeded in making it illegal to fish or trade basking sharks or their body parts in EU waters. On behalf of the Marine

Conservation Society, Jean-Luc records and maps sightings by the general public of basking shark: since 1987, the Marine Conservation Society has compiled more than 12 000 reports of over 25 000 sharks^{w5}. "It is partly due to this data set that there has been such interest in the species, allowing the UK government to support the protection of the basking shark in international waters. So public participation can lead to greater protection for vulnerable species."

Jean-Luc is also involved in a wide variety of projects involving the public, such as the Seasearch project^{w6}, in which volunteer scuba divers record what is living on the sea bed around Britain and Ireland, finding out which are the richest sites for marine life, and which sites need protection. He also helps to run the 'Your seas your voice' project^{w7}, in which members of the public can vote for marine areas (including those outside UK waters) that they think should be protected.

The people who report sightings of basking sharks, vote for a marine protected area or take part in dive surveys are concerned and knowledgeable about the condition of our seas. Unfortunately, most people simply care less about the health of the seas than the health of the land. This is one reason why Jean-Luc believes that

Aerial view of the Great Barrier Reef in Australia

Image courtesy of ifish / iStockphoto

Fire urchin, *Astropyga radiata*

science education is vital – to demonstrate that with the help of conservation science, we can have both a more productive fishing industry and healthier seas. Furthermore, he stresses, individuals can make a difference. “To help safeguard our oceans, you can eat sustainably sourced fish^{w8}, vote for a marine reserve^{w7} or support organisations like the Marine Conservation Society^{w1}.”

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This article is freely available from the *Marine Ecology Progress Series* website: www.int-res.com/abstracts/meps

Lester SE et al. (2009) Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series* **384**: 33-46. doi: 10.3354/meps08029

This article can be downloaded free of charge from website of the Partnership of Interdisciplinary Studies of Coastal Oceans (www.piscoweb.org) or via the direct link: <http://tinyurl.com/336rvm6>

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Web references

w1 – The Marine Conservation Society is a UK charity dedicated to the protection of the marine environment and its wildlife. See: www.mcsuk.org

w2 – Learn more about Frontier, the UK’s leading conservation expedition organisation, here: www.frontier.ac.uk

w3 – Coral Cay Conservation is an award-winning specialist in coral reef and tropical forest conservation. See: www.coralcay.org

w4 – To learn more about the Danjungan Islands Marine Reserve, see: www.prrcf.org

w5 – *Basking Shark Watch*, the Marine Conservation Society’s report, can be downloaded from the society’s website (www.mcsuk.org) or via the direct link: <http://tinyurl.com/3yaxbaf>

w6 – If you would like more information about Seasearch, see: www.seasearch.org.uk

w7 – For more information about the Marine Conservation Society’s ‘Your seas your voice’ project, see: www.yourseasyourvoice.com
Some scientists recommend that 20-30% of ocean habitats should be set aside as marine reserves. Currently less than 0.0005% of UK waters are in marine reserves. As a result of a campaign by the Marine Conservation Society and other organisations, however, the Marine and Coastal Access Act was passed

in November 2009, ensuring that a network of marine protected areas will be established around the English coast by 2012. To learn more, see the website of the UK Department for Environment, Food and Rural Affairs (www.defra.gov.uk) or use the direct link:

<http://tinyurl.com/3yugxxx>

w8 – To find out which fish are sustainably fished, see: www.fishonline.org

Resources

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Karin Ranero Celius obtained a bachelor’s degree in physics and psychology, and then an MSc in museum studies. Her passion for educating others about the wonders of science has led her to become a science communicator. She has been dedicated mainly to outreach and education, first at the IAC (Instituto de Astrofísica de Canarias) in the Canary Islands, Spain, and then at ESO (the European Southern Observatory) in Munich, Germany.



Image courtesy of Frank / iStockphoto

School of masked butterfly fish

Image courtesy of Jodijcobson / iStockphoto

Clownfish in a pink sea anemone

Life Ascending: The Ten Great Inventions of Evolution

By Nick Lane

Reviewed by Michalis Hadjimarcou, Cyprus

Life Ascending: The Ten Great Inventions of Evolution gives a detailed account of the ten events that author Nick Lane considers to be the most important in establishing the direction that evolution has taken ever since the beginning of life on Earth. The list of events does not follow a strict chronological order; instead, it is a sum of events, developments and phenomena that have shaped life on the planet. The first of the 'great inventions' is, as expected, the origin of life. Of course, strictly speaking, this is not an evolutionary event, but an 'invention' necessary for evolution to take place. Nevertheless, the list would be incomplete without it.

The other nine events are not immediately obvious: DNA, photosynthesis, sex, consciousness and death, for example.

Each event is thoroughly examined. The author takes the time not only to present the well-known hypotheses to explain a certain event in evolution, but also to elaborate on less well-known ideas, some of which might come as a surprise even to those who have studied evolution in detail.

Readers interested in the study of evolution will enjoy this book, but the casual reader will be overwhelmed by the wealth of information and detail presented and will have a hard time

reading all the way to the end. Also, the richness of the language requires a good mastery of English.

One of the book's best attributes is the collection of small pieces of information and examples that are presented either to support the candidacy of any given invention for membership in the list or just to explain the invention itself more thoroughly. This collection is not a plain presentation of scientific facts and hypothesis. Instead, it is a lively and often humorous discussion that not only makes the book more interesting but also provides important information on evolution and many other aspects of science and life in general.

In the biology classroom, the teacher could make a selection of items from the collection and use it to enrich the teaching of many topics. Also, upper secondary-school biology students could use some of the information in the book for small projects to further investigate evolutionary topics. For example, they could compare contrasting theories concerning the evolution of specific phenomena. Alternatively, they could debate these theories in the classroom. The material in the book provides a plethora of opportunities for such activities; the only drawback is that the students must have a very good knowledge of the English language.

Details

Publisher: Profile Books

Publication year: 2010 (paperback)

ISBN: 9781861978189



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