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Christmas books From Stephen Hawking to the Simpsons
Artistic revelations Probing masterpieces with microscopy
How much do you know? Take our new quiz of the year

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The conference is a Greek EU Presidency 2014 event under the auspices of the General Secretariat of Research & Technology (GSRT). It has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under the grant agreements n° 608672 and 609321.

physicsworld

Gulliver's Travels, Leipzig Edition, 1910

Politics – fiction and the US shutdown 14

Ryan Matthew Smith/Modernist Cuisine LLC

Christmas books – exquisite photography 37

On the cover

How climate change is affecting the Arctic 24–27
(*Bernd Römmelt/Mauritius/SuperStock*)
Christmas books: Stephen Hawking to the Simpsons 29–39
Probing masterpieces with microscopy 19–23
Take our new quiz of the year 48

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Features

Quanta

For the record

We are not able to promise you, neither in quantity nor in timing, a job that corresponds to your merits

Fernando Ferroni, *president of the Italy's National Institute of Nuclear Physics, writing to staff*

Congratulating physicists in Italy for their contribution to discovering the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012, Ferroni warns that the funding situation in Italy will result in researchers leaving for other countries that support science better.

I'm feeling a little tingly

Geoffrey Marcy *from the University of California, Berkeley, quoted in the* New York Times

Marcy was commenting on a paper he co-authored that suggests, using Kepler data, that one in five Sun-like stars could have an Earth-sized planet in the habitable zone – with conditions where life could develop.

People love dysprosium, but they can live without it too

Chen Kerong, *production director at miner Molycorp, quoted in the* New York Times

Companies have had to reduce the use of rare-earth elements after their price soared two years ago following a territorial dispute between Japan and China.

They were not left enough intellectual space to criticize the Gaussian world

Statistical physicist **Jean-Philippe Bouchaud** *of École Polytechnique near Paris quoted in the* Financial Times

Bouchaud says that many physicists absorbed financial orthodoxy rather than change it when they were hired by banks "for the wrong reasons".

At stake is our whole vision of physics

CERN theorist **Gian Giudice** *quoted in the* Financial Times

After the discovery of the Higgs boson at the LHC, Giudice says that the subject is at a crossroads as researchers look for physics beyond the Standard Model.

Indicators should come with a health warning

University of Cambridge cosmologist **Martin Rees** *writing in* Nature

Rees calls for an international data watchdog due to "serious weaknesses" in data quality in many areas of public policy.

Seen and heard

Julie McGavigan

Black-belt physics

Not many school pupils can boast having had a world-champion physics teacher, so say hello to Julie McGavigan, who teaches physics at Eastwood High School near Glasgow and bagged a gold medal at the World Karate Championships in Denmark in October. The 27 year old, who says the win in Denmark came as "quite a shock", is a 3rd Dan in Shotokan karate and has taught physics for five years after studying the subject at the University of Glasgow. McGavigan also teaches karate at evening classes at Eastwood High, where she puts physics principles to good use. "Physics helps me understand why certain stances, moves and combinations work when practising karate," McGavigan told *Physics World*. In fact, she often refers to physics in her karate lessons. "I find the students enjoy this link to physics, gaining a greater understanding of what they are studying," she says. As she's a karate world champion, we're not going to disagree.

Mining quantum stuff

Everyone knows that quantum physics is weird – at least for our classically trained minds. So how do we learn to "think quantum"? The answer could lie with playing Minecraft – a computer game enjoyed by millions worldwide in which people build structures by using and mining different kinds of "blocks" in a virtual world. Google's quantum artificial intelligence lab has now teamed up with researchers at Caltech to create a new add-on to Minecraft called "qCraft". This addition features blocks that exhibit quantum-mechanical properties such as entanglement and superposition, allowing players to experiment with quantum mechanics. For example, once a quantum block is placed in the Minecraft world, it will appear as stone if its north or south face is the first observed but as dirt or gravel if its east or west face is seen first. "Millions of kids are in Minecraft, not just digging caves and fighting monsters, but building space shuttles and programmable computers, all in the name of experimentation and discovery," says Google's quantum team in a post on Google+. Yet qCraft isn't a perfect representation of quantum mechanics, so don't expect to carry out your quantum simulations there. "It's a fun way for players to experience a few parts of quantum mechanics outside of thought experiments or dense textbook examples," adds Google's statement.

Show's not over

The Sky at Night – one of the BBC's longest-running TV shows – has been saved after the BBC suggested earlier this year that the show could be axed. Following a petition signed by some 40 000 people, the BBC decided to keep the programme although it will be shunted from BBC1 – the main channel of the broadcaster – to BBC4. First broadcast in 1957, the show had been presented by Sir Patrick Moore until his death last December aged 89. While viewing figures will likely be hit as the show changes channel, astronomy fans will nevertheless be happy that it will now run for an extra 10 minutes. The main presenter of the show remains unclear but surely former-Queen-guitarist-turned-astronomer Brian May, who has previously appeared on *The Sky at Night*, would be the perfect host.

Shutterstock/italianestro

Leaky matters

In what seems like an early contender for an IgNobel prize, researchers from Georgia Institute of Technology have been studying high-speed video of animals at a local zoo to come up with a universal "law of urination" among difference species (arXiv:1310.3737). The researchers noticed that animals of various sizes – ranging from rats and dogs to elephants – all took around 21 seconds (± 13 s) to urinate despite a huge variation in bladder sizes. Not to be outdone, a group of physicists at Brigham Young University have also been using high-speed cameras – but this time to film jets of liquid from a "synthetic urethra" striking toilet walls. They found that the stream of liquid breaks up into droplets when it is about 15 cm from the urethra exit. So all you men out there – get nice and close when doing your business to avoid the dreaded "splashback".

Frontiers

In brief

LUX dark-matter search comes up empty

The Large Underground Xenon (LUX) detector at the Sanford Underground Research Facility in the US has failed to find any evidence for dark matter in the first three months of its operation. In particular, the preliminary results suggest that previous hints of low-mass dark-matter particles reported by some other experiments might not be credible. Located 1500 m under the Black Hills in South Dakota to shield its sensitive detectors from cosmic rays and other background radiation, LUX is one of the world's most sensitive dark-matter detectors. It has now managed to put more stringent limits on what this elusive substance could be. LUX is designed to detect hypothetical dark-matter particles – weakly interacting massive particles – which are expected to collide occasionally with xenon atoms in the tank (arXiv:1310.8214).

Blue is the colour for quantum computers

A common blue dye used in £5 Bank of England notes could hold the key to spintronic devices after physicists in the UK and Canada discovered that its electron spins have surprisingly long quantum decoherence times. The researchers have found that copper phthalocyanine (CuPc), which has been used as a dye since the 1930s, can have a decoherence time of as long as 3 μs. While this is still shorter than the times available using the spins associated with nitrogen vacancy (NV) impurities in diamond, the latter structures can be difficult to work with. Unlike NVs, CuPc interacts strongly with visible light – a property that could be used to create quantum devices that use both spins and light to process quantum information (*Nature* 10.1038/nature12597).

New 'leviton' quasiparticle spotted

A new type of quasiparticle – dubbed the "leviton" – has been seen by physicists in Europe. First predicted in 1996 by a team led by Leonid Levitov, the phenomenon involves the excitation of as few as one electron to create a wave that propagates coherently through a metal. Levitons are created at one end of a thin metal-film device using an electrode that applies an electrical pulse with a specific temporal shape. They then travel through a narrow gap between two electrodes halfway along the device. The gap becomes a 1D channel for electrons when an appropriate gate voltage is applied and, once they have passed through, their charge is detected using a fourth electrode. The ability to make levitons on demand could lead to the creation of quantum-electronics circuits (*Nature* 10.1038/nature12713).

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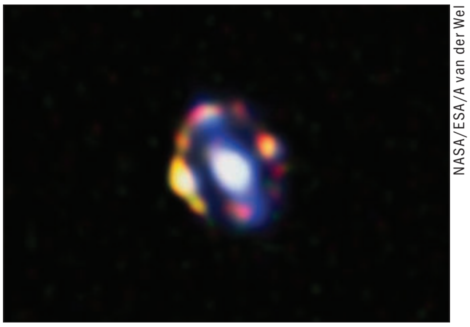
Furthest gravitational lens spotted



NASA/ESA/A van der Wel

Ring of fire Hubble image of the most distant gravitational lens.

The most distant gravitational lens yet has been found at the colossal distance of 9.4 billion light-years from Earth. A gravitational lens is a large galaxy or group of galaxies that bends light from a distant source as it travels towards an observer, as predicted by Einstein's general theory of relativity. In rare cases the lens, the distant light source and the observer line up precisely and the result is an "Einstein ring" – a perfect circle of light around the lensing mass.

The new discovery was made by a team led by Arjen van der Wel from the Max Planck Institute for Astronomy in Heidelberg, Germany, along with colleagues in Italy and the US. Van der Wel was reviewing observations made with the Large Binocular Telescope in Arizona that were part of another study when he noticed a galaxy that was "decidedly odd".

It looked like "an extremely young galaxy, and at an even larger distance than I was aiming for", he says. Intrigued by the anomalous object, Van der Wel looked at other images of the object taken with the Hubble Space Telescope and saw similar results. He then combined all the available images of the object and corrected for the haze of the lensing galaxy's stars to see a "quadruple lens" that formed an almost perfect Einstein ring.

As the light deflected from the lens travelled nearly 9.4 billion years before reaching us, the lens is much further away (at a redshift of $z = 1.53$) than other lenses discovered to date – light from the previous record-holder took about 8 billion years to reach Earth. Seeing an Einstein ring also means that both the lens and the background light source are aligned to better than 0.01 arcseconds, which is equivalent to a 1 mm separation at a distance of 20 km.

Light from the background galaxy travelled for over 11 billion years to reach us. The galaxy itself was found to be a "starbursting dwarf galaxy" – a comparatively low-mass galaxy that is extremely young (only about 10–40 million years old) and produces new stars at an enormous rate. Such galaxies are thought to be rare and the chance of them being lensed is small. Yet, as the second starbursting dwarf galaxy found to be lensed, the result might force astronomers to re-think their models of galaxy evolution, as starbursting dwarf galaxies might be much more common than previously thought (*Ap J.* **777** L17) .

Forming a Fermi sea

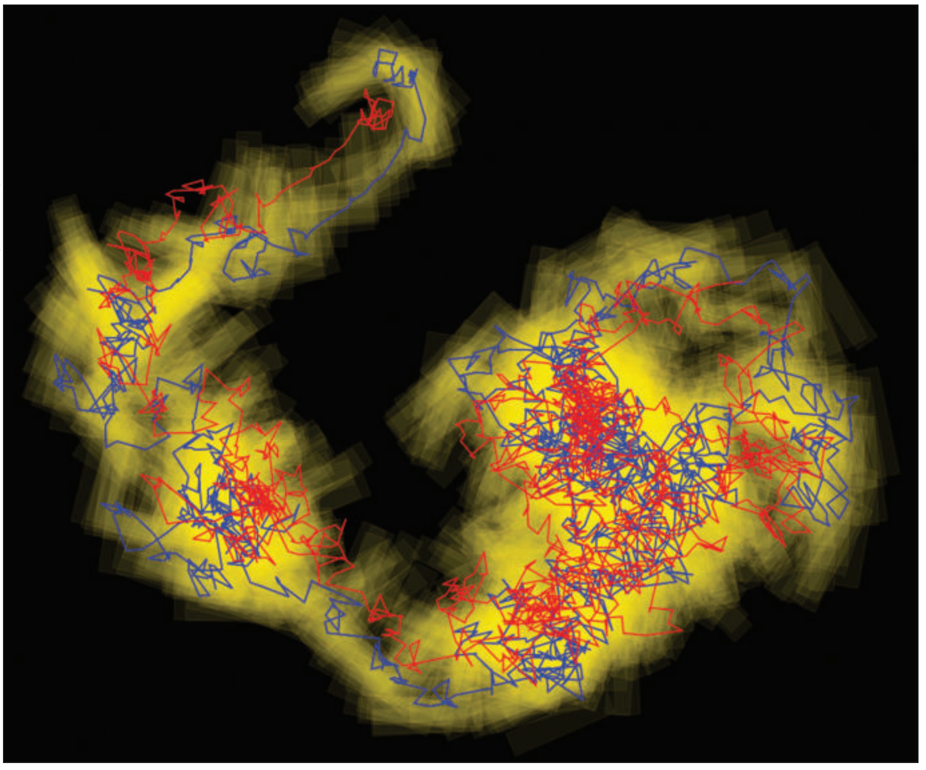
How big must an ensemble of particles be before the exact number of individual particles becomes inconsequential and the entire system can be described using many-body theories? This important question in condensed-matter physics has proved difficult to answer, but now researchers in Germany have observed the transition from "few" to "many" in an experiment using ultracold fermionic atoms.

Studying systems with many particles can be challenging. One solution is to assume that the system is made up of an infinite number of particles. By doing so, the variables of the system go from being discrete to continuous and this makes the system much easier to study. But knowing exactly when this transition occurs can be tricky.

What Selim Jochim, Andre Wenz and colleagues at the University of Heidelberg in Germany, have done is to observe this crossover by studying a quasi-1D system of ultracold atoms using identical fermionic lithium atoms. The experiments look at how an increasing number of lithium atoms interact with a single "impurity" atom – a fermion that is in a different spin state from the rest. The impurity is used to probe the behaviour of the majority atoms. By measuring the energy of the system the team found that the atoms exhibited characteristics of a many-body system – which is known as a Fermi sea – when as few as four majority atoms were present.

Wenz told *Physics World* that the result was surprising and was not theoretically clear when the researchers began their studies. In terms of 2D and 3D few-particle systems, Wenz speculates that the minimum number of particles necessary for collective behaviour would probably be higher, but possibly 10 particles might suffice (*Science* **342** 457).

A Chakrabarty *et al.* *Phys. Rev. Lett.* **111** 160603



Brownian boomerangs head in the right direction

The bright and abstract colours you see above may seem like modern art, but the image actually shows tiny boomerang-shaped colloidal particle whizzing about in water. Brownian motion describes the random, erratic motion of tiny particles dispersed in a fluid, collectively called a colloid. Now, however, Qi-Huo Wei and Jonathan Selinger of Kent State University in Ohio and colleagues have found that particles that are clearly non-spherical – such as a boomerang-shaped particle – do show a preferred direction of motion, at least initially. Their observations showed that, for the first minute, each of the boomerangs moved in the direction of the line bisecting its arms. The image above depicts the trajectory of one such particle in water. Starting from the top of the image, the blue line tracks the point at the base of the boomerang where the arms meet and the red line tracks the "centre of hydrodynamic stress," – a point along the axis bisecting the angle of the arms. The boomerang itself is shown in yellow. The team's findings may increase our understanding of the diffusion of complex biomolecules and improve drug-delivery techniques (*Phys. Rev. Lett.* **111** 160603).

Slaying 'dragon kings'

Physicists in Brazil, Switzerland and the US have predicted the onset of extreme events in a chaotic electronic circuit and then worked out a way of preventing the events from happening in their system. They believe the work could provide important insights into how to prevent "dragon kings" – extreme events such as earthquakes and financial crashes that can occur with devastating effect in complex systems.

Researchers who study these extreme events use the term dragon king to distinguish an extreme event that is predictable – at least in principle – and not a random "act of God". The term was coined by Didier Sornette of ETH Zürich, who cites the emergence of "megacities" such as Paris as a further example of dragon kings. This is because, if all the information regarding the development of Paris was available, the reason for the city's vast size could be deduced.

Now Sornette has joined forces with Hugo Cavalcante and Marcos Oriá at the Universidade Federal da Paraíba, Edward Ott of the University of Maryland and Daniel Gauthier of Duke University to create an electronic system that exhibits dragon kings. It comprises two electronic circuits that are coupled together and both undergo chaotic oscillations. The team used this system to create and control dragon kings, before looking carefully at the conditions from which they emerged. According to Cavalcante, the dragon kings occur when the parameters of one of the oscillators approach a region where it is very unstable. When this happens, the parameters of the two oscillators diverge rapidly and am extreme event occurs (*Phys. Rev. Lett.* **111** 198701).

Innovation

Metamaterial looks cooler when heated

A special coating that can hide its own temperature from thermal cameras has been developed by researchers in the US. The technology relies on the properties of vanadium oxide, a material that undergoes extreme electronic changes over a narrow range of temperatures. When placed on a sapphire substrate and heated from room temperature, the material's thermal radiation rises normally up until 74 °C, but by 80 °C , it suddenly appears to drop to around 20 °C colder than in it is in reality.

This unusual finding arises from the fact that vanadium oxide not only undergoes a transition from an insulating to a conductive, metallic state when heated, but also changes from being almost transparent to infrared light to being reflective. This transition does not, however, occur instantaneously – and between these two states, vanadium oxide behaves as a highly absorbing dielectric. So, when a thin film of vanadium oxide is placed on a highly reflecting sapphire substrate, the film creates a combined structure that is either very absorbing or reflecting, depending on temperature.

"We [have] demonstrated a structure that emits less light as it is heated over a certain temperature range – a very counter-intuitive effect," explains lead researcher Mikhail Kats, who works with Federico Capasso at Harvard University. The team also rather fortuitously discovered that the nanoscale structures appear naturally in the transition region of vanadium oxide, making it a spontaneously structured material that acts as a "natural, disordered metamaterial", according to Capasso. Artificially creating such nanostructures in the lab can be extremely difficult.

The team believes that with minor modifications, potential applications for the new technology will be manifold. Doping the coating with tungsten, for example, would bring down the effect's thermal range to room temperature. Such an altered coating could be used to passively camouflage a vehicle against thermal-imaging cameras. Alternatively, different coatings could be used to create thermal beacons in communication arrays, to carry out more sensitive remote measurements with infrared thermometers, or even used to create surfaces on which "secret" messages could be left, such as an infrared blackboard.

Furthermore, as thermal emissions carry heat away from objects, the coating's radiative properties could be used to deliberately speed up or slow down cooling (*Phys. Rev. X* **3** 041004).

News & Analysis

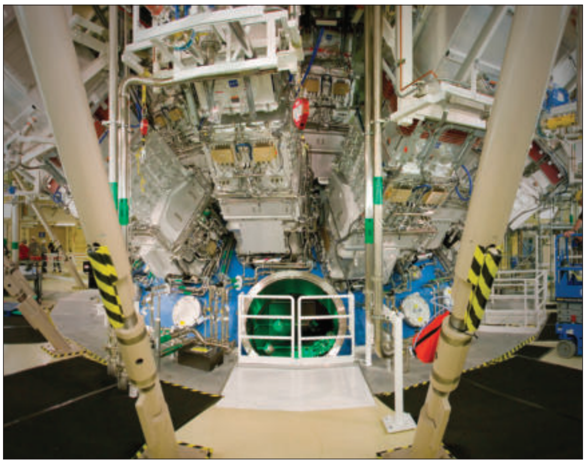
US nuclear lab faces troubling times

The Lawrence Livermore National Laboratory has been knocked by budget cuts, delays in its flagship project, a loss of morale among staff and is now searching for a new director, as **Peter Gwynne** reports

The director of the Lawrence Livermore National Laboratory (LLNL), Penrose Albright, has announced his resignation after just two years in charge. His unexpected departure is the latest in a number of setbacks for the lab, which earlier this year was forced to lay off almost 8% of its 6500 staff through voluntary redundancies. The lab is also having to deal with a number of workers laid off in previous cutbacks who are suing the lab for wrongful dismissal. Coupled with continuing questions about the nature of the lab's missions, Albright's loss is likely to hit morale further.

While the lab looks for a new boss, Bret Knapp – principal associate director for weapons programmes at the Los Alamos National Laboratory – has been appointed as interim director. Knapp possesses inside knowledge of Livermore, having spent 26 years there in a variety of roles before moving in 2009 to Los Alamos – the nuclear national laboratory that is a competitor and collaborator of the LLNL. Knapp, who assumed the post on 1 November, is unusual among leaders of US weapons laboratories in that he did not train as a physicist and does not have a doctorate. He earned his bachelor's and Master's degrees in mechanical engineering from the California Polytechnic State University and the University of California, Davis, respectively.

The press release reporting Albright's departure noted that he was leaving "to pursue his broader interests and contributions to the US national security enterprise". That form of words suggests that Albright's departure was not entirely voluntary. However, Norman Pattiz, chairman of the Lawrence Livermore National Security (LLNS) board of governors, was quick to praise Albright's achievement. "The LLNS board respects and accepts [Albright's] decision and appreciates his many contributions to LLNL and the nation," he noted in a statement. "[Albright] has been a strong advocate and spokesman for expanding the contributions of LLNL to the entire spectrum of lab programs and has brought about significant advancements in how the laboratory executes work for interagency sponsors."



LLNL

A change at the helm
The director of the Lawrence Livermore National Laboratory, Penrose Albright, has stepped down "to pursue his broader interests" just two years into the job.

But Steven Aftergood, director of the government secrecy programme at the Federation of American Scientists, says that any transition period between directors can involve instability and anxiety. "You don't know if the incoming director will be a saviour or will make things worse," says Aftergood. "To the extent that there are deeper structural problems regarding the future of the weapons complex, it may be beyond the power of any director to resolve." Indeed, Aftergood has unearthed an internal LLNL report that warned of the "increased stress and reduced morale" among LLNL employees in the weapons programme "stemming from a combination of reduced resources and increased work requirements".

The failure of NIF

With a current annual budget of \$1.5bn, the LLNL was established in 1952 as one of the US's biggest nuclear-research organizations. Since 2007 the LLNS – along with a conglomerate of technology companies and the University of California, Berkeley – has managed the lab for the National Nuclear Security Administration (NNSA), a branch of the Department of Energy (DOE). The LLNS took over the operation of the LLNL from the University of California, which had solely managed the lab since its inception, after a series of management problems and security lapses.

In addition to tightening LLNL's management, the NNSA charged the new owners with broadening Livermore's mission beyond its traditional role of ensuring the continuing reliability of US nuclear weapons, otherwise known as stockpile stewardship. Part of this is through the lab's flagship experiment: the \$3.5bn National Ignition Facility (NIF), which is aiming to achieve "ignition" – the point at which a nuclear fusion reaction becomes self-sustaining – by firing 192 laser beams at pellets containing the hydrogen isotopes deuterium and tritium. NIF's value to the LLNL stems from the insights it can provide into high-density physics, an understanding of which is crucial to stockpile stewardship. The NNSA has also encouraged the lab's leaders to pursue commercial ventures with corporations based on the R&D carried out by its staff.

Unfortunately, NIF, which was initially headed by Ed Moses, failed to reach its goal of achieving ignition by September 2012. That setback triggered a three-year plan by the NNSA that basically replaces the achievement of ignition with a goal of determining whether its "indirect drive" technology can even produce ignition. "To date there is no compelling scientific information suggesting that the indirect drive approach cannot achieve ignition," an NNSA report on laser fusion asserted last December. "Because the indirect drive approach has the closest relevance to nuclear weapons physics, this will remain the mainline approach for ignition either until it achieves ignition or until there is sufficient scientific understanding supporting a conclusion that priorities should be reset to favour an alternative approach."

NIF has, though, had some recent

successes. An experiment in August, for example, released nearly 3×10^{15} neutrons – about three times the facility's previous best yield. "The yield was significantly greater than the energy deposited in the hot spot by the implosion," says Moses. "This represents an important advance in establishing a self-sustaining burning target, the next critical step on the path to fusion ignition on NIF." Earlier this year, Albright moved Moses away from direct management of NIF, a decision that had caused some discontent in his group. Then in October, shortly before he announced his departure, Albright appointed Moses to a new role, leading a two-year effort to explore the science and applications of ignition, including fusion energy.

Despite NIF's recent progress, the facility has fallen down the NNSA's priority list, with the Obama administration's budget request of $329m for NIF in 2014 – yet to be voted on by Congress – cutting $48m (or 12.7%) from the final 2013 figure. Several anonymous bloggers inside the laboratory have speculated that the LLNS forced Albright out because he failed to defend NIF strongly enough in consultations with the NNSA and Congress.

Bumpy ride for the Lawrence Livermore National Laboratory

1952
The Lawrence Radiation Laboratory at Livermore is established as an offshoot of the existing University of California Radiation Laboratory at Berkeley.

1971
The lab is renamed the Lawrence Livermore Laboratory (LLNL), adding the "national" tag in 1980.

2007
A consortium – Lawrence Livermore National Security – assumes management of the LLNL from the University of California.

2009
Over budget and five years behind schedule, the $3.5bn National Ignition Facility (NIF) opens.

2012
NIF fails to achieve its target of ignition – the point at which fusion reactions become self-sustaining and produces more energy than it consumes.

2013
Chemical engineer Jeffrey Atherton takes over as director of NIF from Ed Moses in May. Six months later LLNL director Penrose Albright steps down.

Burgeoning difficulties

The LLNS's handling of recent issues such as the reduction of staff has also come under harsh criticism. Partly as a result of budget cuts, the lab's staff numbers have plummeted by about a third since 2006, when it employed about 9400 scientists, technicians and administrators. While the lab has offered a series of programmes for voluntary retirement over the years, it has also laid off several employees without that option, with some saying that the many redundancies have drained the lab of experience and know-how.

However, some of the dismissed workers fought back through the law. This year, a local court found the LLNS liable for false dismissal of five Lawrence Livermore workers, to whom it awarded $2.7m. Another 125 former staffers are pursuing their own cases of wrongful dismissal, which the LLNS is defending. On top of that, another issue is the perceived lack of scientific productivity by LLNL researchers. In 2011 Livermore employee Jeff Colvin told a working group of the National Academy of Sciences that the annual number of peer-reviewed articles published by lab scientists had fallen from about 1400 in 2005 to roughly 800 in 2010.

Neither Albright or LLNS representatives responded to a request for an interview with *Physics World*. Instead, the LLNS issued the following statement: "The lab continues, and will continue, to do important work in service to [the US]. Lab employees are committed to this task." It added that the budget "remains a concern" and that Knapp, the lab and the LLNS are "working together to address this issue and ensure the lab meets its national security needs for years to come".

Space

India launches first mission to Mars

India launched its first mission to Mars last month in what was seen as a "textbook launch". Built by the Indian Space Research Organisation (ISRO), the mission took off from the Satish Dhawan Space Centre on the country's east coast in Sriharikota, Andhra Pradesh. The Mangalyaan craft is expected to "focus on life, climate, geology, origin, evolution and sustainability of life on the planet", according to the ISRO. In doing so, it will attempt to shed light on whether Mars has a biosphere or even an environment in which life could have evolved.

The probe, which was launched on a polar-satellite launch vehicle, is expected to arrive at the red planet in September 2014 after a 300-day trip.

ISRO

Mars bound
India's Mangalyaan craft is expected to arrive at the red planet in 2014.

Costing $100m, the 1350 kg craft will be placed in a highly elliptical orbit in the Martian atmosphere when it arrives, being 500 km from the red planet at its closest approach and 80 000 km away at its most distant. The mission has five scientific payloads, including a multi-spectral camera and spectrometers, as well as a highly sensitive methane sensor to assess if the gas is of "biological or geological origin".

Mangalyaan, which was approved for launch only a year ago, follows hot on the heels of India's successful maiden mission to the Moon – Chandrayaan-1 – that found evidence of water on the lunar surface in 2009. "This is our modest beginning for our interplanetary mission," says ISRO spokesperson Deviprasad Karnik.

If the satellite reaches its destination, India will become the fourth power – after the US, Russia and Europe – to send a probe to Mars. It would also become the first country from Asia to reach Mars after China's maiden mission to the red planet – Yinghuo-1 – crashed shortly after take-off when it was launched together with the Russian satellite Phobos-Grunt in November 2011.

But reaching Mars is not easy, with about 50% of missions to the planet having failed. So far, though, everything has gone well. "They had a perfect launch – just getting this far is a significant achievement," says Jeffrey Plescia, a Mars researcher at Johns Hopkins University in the US. "I think the trajectory they have chosen to use is very clever and it allowed them to do the mission on a small launch vehicle."
Michael Banks

People

CERN physicist picked for new UN panel

Four physicists have been appointed to a newly created panel that will advise the UN on scientific matters. The UN's scientific advisory board – set up by the UN secretary-general Ban Ki-moon – features 26 eminent scientists, including CERN particle physicist Fabiola Gianotti, who is the former spokesperson for the ATLAS experiment. The other physicists on the panel are Susan Avery, president and director of the Woods Hole Oceanographic Institution in the US, Vladimir Fortov, who is president of the Russian Academy of Sciences, and nuclear physicist Dong-Pil Min from Seoul National University.

The new board, which will offer expertise in a range of areas from medicine and plant breeding to engineering, is expected to provide advice on science, technology and innovation to the UN secretary-general and to the leaders of UN organizations. The UN Educational, Scientific and Cultural Organization (UNESCO) will host the secretariat for the board, the idea for which originated from a recommendation in a January 2012 UN report – *Resilient People, Resilient Planet: a Future Worth Choosing*. It called for a "major global scientific initiative to strengthen the interface between policy and science".


CERN

Taking a seat CERN particle physicist Fabiola Gianotti will act as a science adviser to the UN.

UNESCO says that the new body will aim to "ensure that up-to-date and rigorous science is appropriately reflected in high-level policy discussions in the UN system". It will also provide recommendations and advice on up-to-date scientific issues including informing on issues related to the "public visibility and understanding of science". UNESCO director-general Irina Bokova says the panel will "bring together scientists of international stature and will serve as a global reference point to improve links between science and public policies".

The 26-member panel also features two chemistry Nobel laureates: Ahmed Zewail from the California Institute of Technology, who won the 1999 prize for his work in femtosecond spectroscopy, and Ada Yonath from the Weizmann Institute of Sciences, who shared the 2009 prize for her work on the structure and function of the ribosome.

Members of the UN science advisory board will be expected to act in their "personal capacity and will provide advice on a strictly independent basis". The board members will serve for two years, with the possibility of renewal for one further two-year term. Gianotti told *Physics World* that the role will be unpaid. "I don't think these tasks should be remunerated," she says. The first meeting of the newly established board will take place at the start of 2014.

Michael Banks

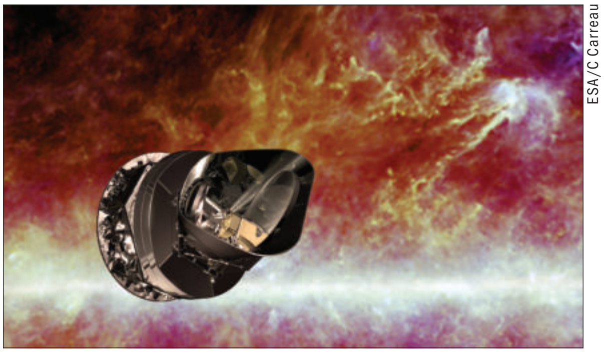
Astronomy

Final command sent to Planck mission

The Planck space telescope has finally been turned off after studying the cosmic microwave background (CMB) radiation – a remnant of the Big Bang – for four and a half years. Project scientist Jan Tauber sent the final command to the European Space Agency (ESA) satellite on 23 October.

Launched by ESA in 2009, Planck used two instruments to measure the CMB at frequencies between 27 GHz and 1 THz. It took these measurements at a point in space that is some 1.5 million kilometres further out from the Sun than the Earth. Known as Lagrange point L2, Planck hovers there, barely disturbed by stray signals from Earth and without needing to use much fuel to stay in position.

The CMB was born about 380 000 years after the Big Bang, when primordial protons, neutrons and electrons formed neutral atoms that allowed photons to "decouple" and finally move freely. Photons could then suddenly travel unhindered through space, their wavelengths being stretched by the expansion of the universe to leave a haze of microwave radiation in every direction.


ESA/C Carreau

Over and out The Planck mission has finally ended after studying the cosmic microwave background for four and a half years.

In March researchers working on Planck released the most precise measurement of the CMB to date resulting in around 30 scientific papers. The research revised downwards the proportion of the universe composed of dark energy from 74% to 68.3%, while dark matter was found to make up 26.8% of the total (up from 22%) and ordinary matter 4.9% (up from 4%). Planck also revealed that the universe is some 80 million years older than thought, dating the universe to 13.8 billion years.

The mission began drawing to a close in August, when the satellite was nudged away from the L2 point towards a more distant long-term stable "parking orbit" around the Sun. In early October the spacecraft prepared for permanent hibernation, using up all its remaining helium coolant and finally switching off the transmitter. "Planck has provided us with more insight into the evolution of the universe than any mission has before," says Álvaro Giménez, ESA's director of science and robotic exploration. "The wealth of data still being scrutinised by our cosmologists will provide us with even more details."

Michael Banks

● A feature on Planck's results will appear in an upcoming issue

Nuclear power

Korean nuclear industry hit by corruption

After a four-month investigation, a court in South Korea has indicted 100 officials and suppliers on corruption charges over bogus safety certifications for parts that were supplied to some of the country's 23 nuclear reactors. The people prosecuted include a former chief executive at Korea Hydro and Nuclear Power as well as a vice-president of Korea Electric Power Corporation. The investigation also revealed that 277 documents, or 1.2% of all safety-related certificates, had been faked at 20 of the nuclear reactors in the country.

In what is South Korea's biggest ever scandal in the nuclear industry, the episode involved allegations of collusion between parts suppliers and executives from state-run energy companies. Speaking after the indictment, South Korean president Park Geun-Hye urged officials to root out corruption in the industry. "Corruption at nuclear power plants has fuelled public anger. It makes no sense that nothing has been done about it for so long," she said. "We should take this opportunity to make it unimaginable to supply fake or substandard parts."

The public prosecutions are not the only problem to hit the Korean nuclear industry. In October a 60-strong government working group appointed by the government recommended that by 2035 South Korea's nuclear power capacity be limited to 22–29% of the total power generated by the country. Korea had planned to grow the nuclear sector to 41% in the next 20 years – a policy that was pursued by the previous government in 2008. "[This aim] was considerably dangerous and unrealistic," says Sun-Jin Yun, an environmental and energy expert at Seoul National University. "It would be more meaningful to just say whether or not to increase the number of the nuclear reactors."

Safety woes
Nuclear reactors – including those at the Hanbit nuclear site – have been hit by the discovery of faked safety documents.

Korea Hydro and Nuclear Power

Energy researcher Chang-seob Kim, from Gachon University, who heads the working group, says its plan provides only a "directional guide" on the nation's nuclear power policy and that more detailed recommendations, such as whether to shut down ageing nuclear plants or to scrap construction plans for new plants, will be made by the government. "Our suggestion is to set the direction in the policy for social consent, as there are huge social conflicts," says Kim.

The working group also said the government should hike electricity fees, while cutting rates for other energy sources such as liquefied natural gas. The government has since held public hearings to decide whether to back the recommendation and was set to release its final version of the energy plan as *Physics World* went to press. "The implementation of the energy policy doesn't just involve the government now, it's become an increasingly important and extremely sensitive issue for each and every citizen," says Kim.

Soo Bin Park
Seoul

Publishing

Conventional and novel research results in high-impact papers

Scientists aiming to produce high-impact, widely read research have a much better chance of doing so if they publish papers that have a mix of conventional and "atypical" knowledge. That is the conclusion reached by researchers in the US who also found that papers by three or more scientists are 37% more likely than those from single authors to produce novel ideas (*Science* **342** 468).

Led by economist Benjamin Jones from the Kellogg School of Management at Northwestern University in Illinois, the authors examined 17.9 million research papers on Thomson Reuters' Web of Science database to determine the extent to which papers reference novel versus conventional combinations of prior work. The analysis indicates that the highest-impact science draws primarily on conventional combinations of prior work but with "an intrusion" of combinations not likely to have been joined together before.

Jones says he was surprised by his study's findings. "Creativity is often conceived of in the sciences as new combinations of existing material," says Jones. "But high scientific impact is most likely when authors reach simultaneously toward two opposing extremes – being extremely conventional in the main yet also injecting something truly unusual."

> High scientific impact is most likely when authors reach toward two opposing extremes – being conventional in the main yet also injecting something unusual

Jones adds that there is a "sweet spot" that balances mostly conventional combinations of prior material with something new. Jones cites a 1995 paper written by four authors – "Spontaneous symmetry breaking in a one dimensional driven diffusive system" – that has been cited more than 130 times and hits this sweet spot, featuring the right mix of "conventionality and novelty" (*Phys. Rev. Lett.* **74** 208).

James Evans, a sociologist at the University of Chicago who has written about research trends, says that the work has "honed in on a very interesting phenomena and measured it elegantly". However, while adding that the authors' methods were "the right design for this study", Evans says that future studies on this topic will require the use of more defined "units of contribution that scientists themselves think about when they strategically select from prior work".

Ned Stafford

Spain

Crisis-hit council survives budget shortfall

Spain's ailing National Research Council (CSIC) has been saved from imminent bankruptcy after the government injected €70m into it in October. The CSIC, which is the country's main research institution, has been suffering from a severe budget shortfall for the last five years. However, scientists warn that the additional funding will still not be enough to solve the council's problems.

With more than 100 institutes and about 6000 scientists, the CSIC has a budget of €600m in 2013. Since 2008, however, the government has cut the CSIC's budget by 30%, forcing the council to slash spending from €935m in 2009 to €700m in 2013, meaning the CSIC still overspent by €100m this year. The CSIC has also had to cut the number of new permanent positions from 267 in 2008 to just 13 in 2013, with 350 of its 3600 full-time scientists set to retire by the end of this month.

In June the Spanish government gave the CSIC €25m to plug some of the funding gap, but a month later CSIC director Emilio Lora-Tamayo announced that the institution would be forced to close some of its centres, unless the remaining €75m was allocated before the end of the year. In previous years, the institution had tried to compensate for the deficit by using unspent money from research projects. But these savings were used up by the beginning of 2013, putting the CSIC on the edge of a liquidity crisis.

With the fresh injection of €70m, Gerardo Delgado, director of the CSIC Institute of Fundamental Physics in Madrid, says that "the most urgent part of the problem is solved in that CSIC operation is granted until the end of the year". However, he still warns that the CSIC's situation is still "very bad" and that the loss of PhD students and postdocs will have a "decade-long effect". Miguel Ángel Sanchís Lozano, vice-president of the Royal Spanish Society of Physics, adds that "The CSIC's crisis is part of the larger crisis of Spanish science, which remains mainly unsolved."

The government also announced in October that it would pump an extra €50m into the council in 2014 to save it from the same issues reoccurring next year. "This increase will likely avoid a deficit next year, but it will not solve the CSIC's problems," says chemist Alicia Durán of CSIC Madrid, who is also a representative of the union workers' commission at the institute. "Funding from contracts with private companies and from public schemes are set to be shrunk next year, so the overall activity of the council, and its staff, will be reduced too."

Shutterstock/B Stefanov

Cash injection The Spanish government has pumped a total of €95m into the National Research Council this year to save it from bankruptcy.

Michele Catanzaro

Publishing

Academics treat blogs as a 'virtual staff room'

Academics who blog are not necessarily using their blogs as a new form of outreach but rather to give away free specialist advice and academic knowledge to their colleagues. That is the conclusion of a new study showing that researchers are increasingly using their blogs to communicate with their own peer groups and students about their research, creating a new "virtual staff room".

The research, carried out by education specialists Inger Mewburn from the Australian National University and Pat Thomson from the University of Nottingham, looked at 100 blogs written by academics. They found that while about 40% of individual blog posts do indeed describe scientific research in simple terms for members of the public to understand, 41% of blog entries are written more for science colleagues covering topics such as funding, teaching, personal stories, advice for students and even office politics (*Studies in Higher Education* **38** 1105). This finding appears to contradict the often-stated rationale for academic blogging, which is that it brings research findings to wider audiences and helps researchers to communicate in a more reader-friendly style.

"Many of the things on my blog could be used for academics, but that isn't my primary motivation," says Rhett Allain from Southeastern Louisiana University, who writes the *Dot Physics* blog and agrees with many points made in the paper. "I write about things that I find interesting. You could say I write for an audience of one – me."

Although academics may not be reaching the public audience they were assumed to be writing for, the study's authors do not see this is as a problem. "In our view there is nothing wrong with academics writing for each other as part of what they do," Thomson told *Physics World*. In fact the lack of public-friendly posts is not because academics find it difficult to write in a more popular style. "The blogs that we looked at were all pretty well written and didn't show any [characteristics of poor academic writing]," says Thomson.

However, the authors do admit that their sample size was quite small, which could result in not finding as many blogs that are solely written for the general public. "We also didn't look at blogs that academics write for newspapers, online magazines and so on – this is where at least some of the public engagement work happens," adds Thomson.

Shutterstock/Syda Productions

Coffee room 2.0 A study has found that academics increasingly use their blogs to communicate with their own peer groups and students about research.

Gemma Lavender

Funding

Nobel Foundation eyes up donations

To ensure the longevity of its world-famous prizes, the Nobel Foundation is considering asking for donations from rich benefactors. The Stockholm-based foundation had already reduced the value of each of the prizes – awarded in physics, chemistry, medicine, literature and peace – by 20% last year. But it now says that neither cost-cutting nor elaborate financial investments are likely to be enough to safeguard its capital.

The Nobel Foundation was set up in 1900 to manage the money left by Swedish industrialist Alfred Nobel, who died in 1896. Nobel stipulated in his will that the money was to be "invested in safe securities" to generate interest that "shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit to mankind". For much of the 20th century, the foundation was allowed to invest only in fixed-interest bonds and loans, which led to its funds either losing value or remaining static.

Following a change in its statutes after the Second World War, the organization invested heavily in the stock market, and its capital ballooned to a high of SwKr 3.9bn (£360m) in 1999 – nearly three times the original amount in real terms. But with stock markets generally performing poorly since then, the foundation's capital stood at just 1.8 times its original value at the end of 2012. Indeed, over the past decade the foundation's costs have on average exceeded its income.

In June 2012 the foundation's board of directors decided to lower the prize amount from SwKr 10m to SwKr 8m – the first such reduction since 1949 – as well as cut the money it pays the prize committees. It also decided to prune back its lavish annual award ceremony and banquet, while in December last year the foundation said it was looking to increase its reliance on hedge funds, having already raised the fraction of its capital invested in them and private equity funds from 6% in 2007 to 24% in 2012.

However, the foundation's executive director Lars Heikensten now says that this move may not be enough and the foundation may instead "beef up" its capital via donations,

Tightening the purse strings The Nobel Foundation is examining the option of seeking charitable donations to boost its prize fund. (Nobel Foundation)

either by a broad campaign or by targeting individual investors. A former governor of the Swedish central bank, Heikensten told *Bloomberg* that the foundation has "absolutely no plans" to seek charitable donations at this point – but that this is an option it will explore "in the coming years". The foundation's minimum ambition, he says, is to maintain the monetary value of the prize in real terms, that value currently standing at 98% of the original amount.

This aim, however, is questioned by Edward Tenner, an independent historian of technology. The continuing prestige of the Nobel prizes, he maintains, depends not on giving out more cash than rivals but on ensuring that the best science is rewarded, pointing out that the Fields medal, awarded for discoveries in mathematics, is accompanied by just $15 000. He adds that asking for donations carries a risk: that donors expect their generosity to be rewarded with naming rights.

Astrophysicist and former president of the Royal Society Martin Rees agrees that money is not the key to a prize's success, arguing that "there is a poor correlation between prestige and financial value" among existing international awards. The "special prestige" of the Nobel prizes, he believes, is less at risk from dwindling endowments than it is from "an unwillingness to share an award among more than three people" and the "exclusion of an increasing proportion of the exciting frontiers of science" from the prizes.

Edwin Cartlidge

Sidebands

String quintet bag £300 000 each

Five leading string theorists will each receive £300 000 after bagging the 2014 Physics Frontiers Prize from the Fundamental Physics Prize Foundation, which is bankrolled by the billionaire Russian physicist-turned-investor Yuri Milner. The five theorists – Michael Green from the University of Cambridge, John Schwarz of the California Institute of Technology, Harvard University's Andrew Strominger and Cumrun Vafa, along with Joseph Polchinski from the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara – will also become nominees for this year's £3m Fundamental Physics Prize, the winners of which will be announced on 12 December. Meanwhile, Freddy Cachazo from the Perimeter Institute for Theoretical Physics, Shiraz Minwalla at the Tata Institute of Fundamental Research and Vyacheslav Rychkov from CERN have bagged the foundation's 2014 New Horizons in Physics Prize, worth £100 000 each.

Korea unveils lunar ambitions

Nearly a year after sending the country's first rocket – Naro-1 – into space, South Korea says that it will bring forward the launch date for its ambitious lunar programme from 2025 to 2020. The country will use its Korea Space Launch Vehicle-2 to launch a lunar rover, weighing around 20 kg, which will land on the Moon to look for signs of rare minerals. Taking off together with the rover will be a lunar orbiter that will study the Moon's surface from an altitude of 100 km. After becoming president earlier this year, Park Geun-hye has pledged to revamp Korea's space programme, making the lunar mission a national objective. The Moon project is expected to cost around $70m and will be built with help from NASA.

Staff cuts hit Argonne lab

Argonne National Laboratory is to offer voluntary redundancy to 120 of its staff as the lab aims to cuts its budget in anticipation of reduced federal support next year. Funded by the Department of Energy, Argonne had a budget of $794m in 2012 and currently employs about 3400 workers. The lab has already had to cut staff travel expenditures but now says that it needs to do more to balance the budget. Argonne says, however, that it retains the right to refuse the redundancy package to employees whom it considers essential to the current or future programme.

So much more than invisibility

The applications of metamaterials – structures that can generate negative refractive indices – have long been overshadowed by the prospect of an invisibility cloak. **John Pendry** from Imperial College London talks to Louise Mayor about how they could be used in practice

What are metamaterials?
An ordinary material responds to an electric field, say, according to how the atoms and molecules polarize. But in a metamaterial, the atoms and molecules are replaced by slightly larger elements, such as tiny metallic rings. By designing their structure, you can design into these materials electric and magnetic properties that have never been seen in natural materials.

What are people working on now in basic metamaterials research?
What people are still doing is they're having fun, and just seeing what you can do with this technology. There's also a related technique called transformation optics, which teaches you what sort of metamaterial you need to put the electric and magnetic fields where you want them.

So nothing about Harry-Potter-style invisibility cloaks then?
The cloak, of course, was wonderful for the public because it rang so many bells, but that was just the extreme of how far can you go with these technologies.

So what could be the first application of metamaterials?
The most advanced one is by a US company called Kymeta, which is a spin-out from the patent firm Intellectual Ventures, in Seattle. Kymeta uses metamaterials to build satellite-communications receivers.

How is this different from a normal receiver?
A usual receiver is a 30 cm steerable dish. It's heavy and takes quite a bit of power to run the electric motor. There is a more sophisticated version of a receiver called a phased array and that's in the form of a flat plate that is full of little dipole antennas that you can steer the direction of electronically – nothing moves mechanically.

What's wrong with using a phased array receiver?
It's expensive – many tens of thousands of dollars! You've got hundreds of thousands of transistors, making the phased array an order of magnitude more expensive than a dish.


Institute of Physics

Metamaterials pioneer John Pendry, who won this year's Newton Medal from the Institute of Physics, giving the Newton Lecture.

So how can metamaterials help?
Metamaterials are cheap and can do this job of making a phased array, as you can make them tuneable by putting a little nonlinear device there.

How close is this device to market?
Kymeta has a product ready to go, which it will license to satellite-communications companies. The firm has capital of around $50m – half of which came from Microsoft founder Bill Gates.

How much will this receiver cost?
Kymeta hopes to market it for under a thousand dollars. So that's one success story. It is one of the things where metamaterials are helping make things cheaper, better. The receiver can also plug into a USB port in your laptop, which is nice.

Satellite receivers are one of the things where metamaterials are making things cheaper, better

Are there any other applications for metamaterials?
My colleague Richard Syms in electrical engineering at Imperial is using hundreds of little metamaterial elements called split-ring resonators and stacking them together to make a wire. Instead of conducting electrical current, this wire conducts magnetic flux down the centre of these little resonators. It only works at one frequency but that's fine if you're dealing with magnetic resonance imaging (MRI).

How are such scans currently done?
With heart scans, for example, doctors usually cut a nearby vein and then they push this little coil of wire up near the heart so it can pick up the weak magnetic signals that are produced when hydrogen nuclei in the body are excited using an external RF field.

Why does the technique need improving?
When you turn the magnetic signal into an electrical one it travels down the wire, but the wire is about the right length to resonate with the exciting signal, which is usually quite powerful. If that wire gets hot it then sticks to the side of the vein – not a good experience.

What properties do metamaterials have to solve this problem?
While the body responds dramatically to an electrical current, it hardly responds to a magnetic one. Syms' wire takes the magnetic signal and *keeps* it as a magnetic signal that travels safely out of the body.

Why are defence agencies so interested in metamaterials research?
There's a whole lot of stuff happening that I never hear about because a lot of it has gone confidential because it's useful. The US defence agency DARPA, for example, allows you to publish everything while you're in the "what if?" stage, but once you get devices, you then find that the wraps go over it and it goes into patents and what-not.

Any defence research you can tell us about?
There is something called compressive sensing, which is a way of taking a very limited amount of data from a scene and using that data to construct a very accurate image with less information than you'd use for a whole scene capture.

How does that work?
The way they do that is a version of this satellite-communications receiver, only instead of *receiving* a signal, using terahertz or low-frequency radiation you actually throw out a signal around the room and "sense" the room.

Comment

physicsworld

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Best of the best

***Physics World*'s breakthrough and book of the year awards are now in their fifth year**

It's time this month for *Physics World*'s two annual awards – the "breakthrough of the year" and the "book of the year". We have been running the prizes since 2009, with the breakthrough award recognizing the best of the many new research findings we've reported on our website over the last 12 months, and the books prize going to the top popular-science book reviewed in the pages of this magazine during the same period. The breakthrough of the year will be announced on *physicsworld.com* on 13 December, while the book of the year will be revealed there on 17 December. In both cases, nine runners-up will be named too.

physicsworld BREAKTHROUGH OF THE YEAR 2013

The winners of both awards are selected by the *Physics World* editorial team, with the breakthrough of the year chosen from the more than 300 news stories we've published this year online. Those articles have covered everything from atomic physics to astronomy, and from particle physics to polymers – so picking a winner is not easy. But we do try to be a bit scientific about our decision-making, choosing our top 10 breakthroughs based on four clear criteria. These are that the work should be fundamentally important, show a significant advance in knowledge, have a strong connection between theory and experiment, and be of general interest to all physicists.

As for the book of the year, we also try to be systematic when making that choice. The first hurdle for any book is getting selected for review in *Physics World*, which rules out, for example, textbooks or monographs as we stopped reviewing them years ago when most became too specialized to have broad appeal. Books that have garnered poor or lukewarm reviews in our pages get struck off next, leaving a long list of titles that either *Physics World* staff members or our expert reviewers have praised. From that, we pick our top 10 based on three somewhat subjective criteria – that the books should be well written, scientifically interesting and novel.

You might be wondering what right *Physics World* has in picking winners in this way and sometimes we've asked ourselves the same question. But in fairness, there aren't many other publications that follow what's going on in all areas of physics all over the world as assiduously as we do. Last year's breakthrough of the year was an unusually easy one to make, going to the discovery of the Higgs boson by the ATLAS and CMS teams at CERN's Large Hadron Collider, while the book of the year prize was awarded to David Kaiser for his superb *How the Hippies Saved Physics*. This year's picks look, however, to be a much closer-run affair.

So while you might not agree with our choices, we like to think that – having notched up our 25th anniversary earlier this year – we have a reasonable inkling of what we're talking about. Be sure to visit our website later this month to find out who's come up trumps in the 2013 awards.

physicsworld 25 years

Don't miss the first *Physics World* focus issue on medical imaging, brought to you in partnership with our sister publication *medicalphysicsweb.org*. Covering clinical applications and research advances, it includes a look at how magnetic resonance imaging is being used to map connections in babies' brains. The focus issue has been mailed to all full members of the Institute of Physics and is also free to read online at http://ow.ly/qM7pj.

Critical Point Longing for Laputa

Recent loony events in Washington have led **Robert P Crease** to wonder whether scientists shouldn't rule after all

Nice idea? Laputa: a nation governed by scientists.

Gulliver's Travels, Leipzig Edition, 1910

Can you miss a fictional place? I do, thanks to the recent US government shutdown. The episode made me yearn for Laputa – the strange flying kingdom described in *Gulliver's Travels*. Written in 1726, Jonathan Swift's novel is a masterpiece of political satire. Among his targets was the notion that scientists would make good rulers, which Swift skewered in his depiction of Laputa. But October's events in Washington got me thinking fondly of the place.

For readers not *au fait* with the shutdown, it began when a group of Congressional Republicans blocked a federal spending bill required to keep the government operating. They did so as part of an elaborate scheme to kill a specific law they did not like. That law, which expands healthcare to the nearly 50 million Americans who lack it, had been legally enacted and declared constitutional. The Republicans, however, refused to pass the spending bill unless this law was retracted. They were able to do this because, despite the fact that their party received a minority of votes in the last election, it holds a majority in Congress thanks to quirks of the US electoral system.

According to the US financial services company Standard & Poor's, the resulting 17-day shutdown caused more than $24bn of damages. It closed federal agencies and halted much of the infrastructure behind America's eminence, including medical-research programmes, early-childhood education, climate-change research, much pollution testing and food inspection, some passport and visa approval, and trials of the $8bn James Webb Space Telescope.

Laputa was borderline functional, but the episode left me thinking that things would have played out better there.

Bacon versus Swift

In Swift's tale, Laputa is a circular flying island 7837 yards in diameter. If positioned over the Capitol Building in Washington, DC, it would just cover the National Mall along with the White House, Supreme Court and most key administrative buildings. Laputa flies using a magnet, resembling a large weaver's shuttle, six yards long and three yards wide at its maximum cross-section. Thanks to magnetic features of Balnibarbi – the land below that Laputa governs – Laputa's scientists can move the flying island by changing the magnet's orientation.

Swift was spoofing Francis Bacon's work *New Atlantis* (1624), which depicted a scientific society called Solomon's House that governs a utopia called Bensalem. Swift was also spoofing the Royal Society, whose founding in 1660 was partly inspired by Bacon's work. Science apart, Laputa is fairly dysfunctional. Its inhabitants are hyperfocused on abstract and speculative ideas and have next to no patience for practical matters. To cope with their short attention spans, Laputans hire servants to flail them with sticks to remind them to focus during conversations, and to prevent them from slamming into things while walking.

The Laputans are "slow and perplexed" when thinking about anything but science and music, and rarely deign to converse with Gulliver, finding him hopelessly obtuse about these matters. They disdain practical geometry so much that their houses are misshapen, built without right angles. Their clothes fit badly, for the tailors take measurements with quadrants and compasses. Laputans care about the Sun's health more than their own, and their medical practice is crude.

On the mainland, Gulliver complains of a slight bout of colic, and is taken to a doctor whose cure involves inserting a bellows into the patient's intestines and sucking or blowing out the disease. After witnessing an experimental test of that procedure carried out on a dog, which dies on the spot, Gulliver declines treatment. Gulliver talks to scientists pursuing schemes to soften marble to make pillows, extract sunlight from cucumbers, turn ice into gunpowder, and resolve political disputes by sawing the brains of opponents in half and putting them together. Left to themselves inside one skull, he is assured, the brains will quickly achieve moderation and "good understanding".

Scientists, in Swift's send-up, would make poor rulers. Even Bacon, whose *New Atlantis* was the first scientific utopia, implicitly recognized this; while Bensalem's key institution is Solomon's House, it is not the sole governing body. One reason why Bacon thought scientists should not rule alone is that, while scientists pursue knowledge as an end in itself, politicians seek to use such knowledge as a means for other ends. The realities sought and delivered in the laboratory, in other words, are a different kind from those sought and delivered in the political arena.

Another limitation of scientists is timescale, a point pithily expressed by the sociologists Harry Collins and Robert Evans. "The speed of politics," they write in *Rethinking Expertise* (2009), "exceeds the speed of scientific consensus formation." These two features make it likely that the outcome of scientific rule would look more like Laputa than the utopian Bensalem.

The critical point

After the shutdown started, US politicians made special arrangements to reopen certain of the country's most famous symbols, including the Statue of Liberty – a symbol of American openness – and Mount Rushmore in South Dakota, which features sculptures of the heads of four famous US presidents. The politicians also retained their perks; the Congressional gyms, for example, remained open. Otherwise, they pursued their cause with a messianic zeal. In a beautiful example of circular reasoning, Republican Representative Steve King from Iowa said he and his bedfellows were taking action "because we're right, simply because we're right", continuing to demand that the hated healthcare law be retracted as the price of reopening the government.

Laputa's buildings may have been crooked, its land poorly cultivated, its healthcare scary, and its leaders confounded by practical tasks. But even its scientific rulers did not treat their opinions as gospel truth, and practised inquiry as a precondition for resolving disputed matters. And at least Laputa flew.

Robert P Crease is a professor in the Department of Philosophy, Stony Brook University, and historian at the Brookhaven National Laboratory, US, e-mail robert.crease@stonybrook.edu

Boosting women in Latin America

Latin America is slowly overcoming difficulties in getting more women in physics, but **Lilia Meza-Montes** believes increased co-operation is needed in the region to reduce the gender gap further

Latin America – including the Caribbean – is a region composed of around 40 nations containing some 600 million people. Most of these countries were under colonial rule by European states for centuries and, after independence in the 20th century, many suffered from dictatorships, political instability and civil wars. Economically, much of Latin America is based on natural resources or manufacturing, although that is now slowly changing with around 80% of the population in Latin America living in high-density cities.

It is well known that science, technology and innovation are critical to a country's development. Yet research and development expenditure in Latin America is still very small, accounting for between 0.07 and 0.52% of GDP across the continent (compared with 2–3% in Europe and North America). The number of researchers is also critically low: according to figures from the United Nations Educational, Scientific and Cultural Organization (UNESCO), the worst offenders are Guatemala, El Salvador, Honduras, Nicaragua and Paraguay, which have the lowest rate of full-time researchers in Latin America with less than 100 per million. Only Argentina – with around 1000–2000 researchers per million – approaches the rate of developed nations.

Part of the problem is that it was not until the 1950s that physics became a professional career in nations such as Argentina, Brazil, Chile and Mexico, while for other countries in the region that switch happened even more recently. Yet for all the difficulties, according to a UNESCO headcount in 2009, almost half – 45.2% – of researchers in Latin America are women, apparently giving the region the highest average proportion of female scientists in the world.

However, the UNESCO figure contrasts hugely with other estimates. For example, a study by Argentina's Science and Technology Council in 2005 showed that only 30% of the country's researchers in physics were female. A similar headcount by the Mexican Physical Society (SMF) in 2010 revealed that of staff at universities and research centres, just 16% were women, while in Brazil, around 20% of physics faculty are female. The SMF has also published data on university departments in other countries, which show that in Chile, Colombia and Peru, for example, women account for around 16%, 12% and 6%, respectively, of all staff.

iStockphoto/yuri10b

In balance Latin America has an opportunity to strive for gender equality in physics.

With funds scarce for science in general in Latin America, talking about women in science may sound trifling. Indeed, some researchers – both women and men – consider gender-focused programs unnecessary, discriminatory or segregationist. After all, there are many other urgent issues to address in these countries – including poverty and illiteracy.

Unfortunately, other than for some of the countries mentioned above, it is very difficult to get proper statistics for the number of women in science across Latin America. Few national science councils provide such information and university research groups on gender and science are scarce. But despite the limited data, there does seem to be a large gender gap within Latin America and, as with every other gap, it should be addressed. Increasing the number of female scientists would boost the overall scientific population and help the region overcome its inequity. Quite simply, there needs to be a robust scientific structure in Latin America where both women and men have the facilities that support their research, help solve national problems and spur economic development.

Concrete steps

Apart from knowing exactly how many women work in physics in Latin America, there is also a need to continue to support them. We need additional funds to help women and mechanisms to recognize their work and promote them to high-rank faculty positions. Giving women more visibility will provide girls with role models and may convince them to pursue a career in science. But as physics has become a profession only in recent years, I believe our community is open-minded and supportive of such changes. Increasing awareness of discriminatory attitudes, sexual harassment or machismo in general will give women a motivating and friendly environment that will benefit all of us.

In some countries, steps have already been taken and policies introduced. For example, in Brazil an analysis of the number of papers and the paucity of women in the highest levels of academia has led to the introduction of new programmes that support girls at risk of dropping out of school. Argentina, Brazil and Chile now give parental leave to graduate students who have children. And in Mexico there is a programme of scholarships at bachelor level for single mothers, while extended periods for research evaluation and awards are allowed for women who taken time off to have a family. This year's national conference of the Mexican Physical Society also saw a panel discussion on gender issues.

Yet these programmes, although welcome, are not enough and more action has to be taken. As a result of recent International Union of Pure and Applied Physicists (IUPAP) conferences on women in physics, various national working groups were set up. Teams from Argentina, Brazil, Colombia, Ecuador, Mexico, Peru and Puerto Rico aim to jointly develop a common framework to study the situation of women in physics that allows us to propose public policies to tackle the issue. I am convinced that such joint action is needed. By working together, with the support of IUPAP, women will be able to expand their capacities and increase their contribution to physics.

Lilia Meza-Montes is at the Instituto de Física, Benemérita Universidad Autónoma de Puebla in Mexico and sits on the IUPAP Working Group on Women in Physics, e-mail lilia@ifuap.buap.mx

Feedback

Letters to the editor can be sent to *Physics World*, Temple Circus, Temple Way, Bristol BS1 6HG, UK, or to **pwld@iop.org**. Please include your address and a telephone number. Letters should be no more than 500 words and may be edited. Comments on articles from *physicsworld.com* can be posted on the website; an edited selection appears here

Open-access queries

I share the concerns of your correspondent Telford Moore (Feedback, November p24) regarding the potentially adverse consequences of current proposals for open-access publishing. Moore was concerned about how the article publication charges associated with "gold" open access would affect independent scientists, but in fact the effects may not be limited to this group. Many applied research laboratories also occasionally discover and publish results of fundamental interest. There may be less enthusiasm for this among the managers of such institutions if publication is going to incur a substantial cost with no benefit to their main objectives.

If people feel that publicly funded research should be freely available to the public, then authors or their sponsors can pay for their publications to be made open access. But it is not clear why this requirement should be imposed on *non*-publicly funded research, thereby suppressing a lot of it. This will defeat the presumed purpose of open access, which is to make the results of scientific research, wherever it happens to be done and however it happens to be financed, more easily available.

Wilfred Smith
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wilfredsmith@mypostoffice.co.uk

A question of firsts

In your article "Under a limitless sky" (October p59), you describe Meg Urry as the Yale University physics department's "first ever tenured female faculty member when she was hired in 2001". This is incorrect, since I (a woman) was on the faculty at Yale with a primary appointment in the applied physics department and a joint appointment in the physics department from 1989 to 2000, became a tenured associate professor of applied physics and physics in 1995, and was subsequently promoted to professor in both departments in 1999.

The complicated history of tenured women in the physics department at Yale arises from the university's system of joint appointments, and creates considerable opportunity for confusion. For example, since, at Yale, tenure is formally granted by the primary department (in my case applied physics), it would be technically correct to say that Urry was the first woman to be *granted* tenure by the Yale physics department, even though she was definitely not the first tenured woman *in* the Yale physics department. As this distinction is much too subtle and legalistic to be suitable for news and feature articles, I would suggest that such claims be avoided altogether.

Karin Rabe
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Comments from *physicsworld.com*

As part of *Physics World*'s 25th anniversary celebrations in October, we published a series of five physics-related puzzles that were created exclusively for us by employees of the British intelligence agency GCHQ. The first puzzle was printed in the October issue, while the full set appeared on the *physicsworld.com* blog on successive Tuesdays throughout the month (physicsworld.com/puzzle).

Although we received one or two comments criticizing our association with GCHQ, the overall response was hugely positive, with thousands of people solving at least one puzzle and hundreds sharing their joy at being the first – or even the 561st – person to complete each challenge. We will publish the answers in January, so if you haven't tried the puzzles yet, it's not too late. In the meantime, here's a sample of the feedback.

#12. Now to get back to work...
Robin S

#16 overall! Phew. That was both fun and infuriating at the same time. See everyone again in 25 years for the next one?
Leigh

#17 overall. I'll really miss these weekly puzzles – thank you very much *Physics World* for the brain-mangling I have enjoyed throughout this October!
Ruth R

#21. I'll cast a vote for a regular puzzle slot!
Mat W

#23. My brain hurts.
Phil

#24 – I can go to sleep now!
S

#28. I've done more thinking this month than I've done in years!
Natasha

#34 – finally! All great fun. What will we all do next Tuesday??
lisa

#40. You must do this again – but not too soon. I have real work to do.
Ian

#46, from a non-physicist. Thanks for helping pass some long hours! For the third puzzle, not having heard the story/joke before, I would never have logically reached that conclusion with the information provided (had to rely on hints). Back to work for me...now what will I do on Tuesdays?
Laura

#57 – not bad for a retired clinical biochemist who last did physics at A-level in 1968. Great fun.
Dennis

#69. Lots of wrong guesses on puzzle five, and puzzle four was a real face-palm "D'oh!" moment when the penny finally dropped. Thanks to the puzzle-setters for a lot of fun.
Ian P

#73. Many thanks to everyone involved for organizing these.
Julia

#77. Nice mix of puzzles, with numbers two and four my favourites. Learned a lot about cryptography and physics over the last few weeks. A big thank you to all involved – it was fun.
Andrew W

#78. Puzzle three was nice – I have read one of Gamow's books and knew the joke. Puzzle four was more code-breaking than physics. Last one was a hard slog. I was going nuts...
Dead or alive

#84 – took some wrong turns with question five but got there in the end. Thanks for the mental workout, *Physics World* and GCHQ. Now...back to the more difficult problems of real life.
James E

#86! The fifth one was tough, but I finally got the "Eureka!" moment. Nice feeling. Thanks, thanks, thanks! I want more of this stuff!
Malisha

- Since you all asked so nicely, we've included another puzzle on the page opposite.

physicsworld.com

Read these comments in full and add your own at physicsworld.com

Odd ON out

A number of particles have collided, but which is the odd ON out?

GLUTTON
BARON
POSERON
ELEMION
BOVITRON
LEPASON
PHOCTRON
MUTTON
FERRYON
HADON
ON

This little bonus puzzle follows on from a set of five that were designed specially for our 25th anniversary by staff at GCHQ. We will give the answers to all the puzzles in the January issue. If you haven't already, you can try the previous puzzles at physicsworld.com/puzzle.

Next month in Physics World

Perspectives on Planck
The Planck mission has produced a map of the cosmic microwave background at higher resolution than ever before, but what does it mean for cosmological theories?

Fast fallacy?
Many physicists believe that the power of quantum computers lies in their ability to perform many calculations in parallel, but others increasingly think this is a crude argument and possibly even a total misrepresentation

Fictional models
You don't have to model physical reality to derive a successful physical model, as James Clerk Maxwell showed with his electromagnetic field equations based on the idea of an ether of rotating vortices

***Plus* News & Analysis, Forum, Critical Point, Feedback, Reviews, Careers and much more**

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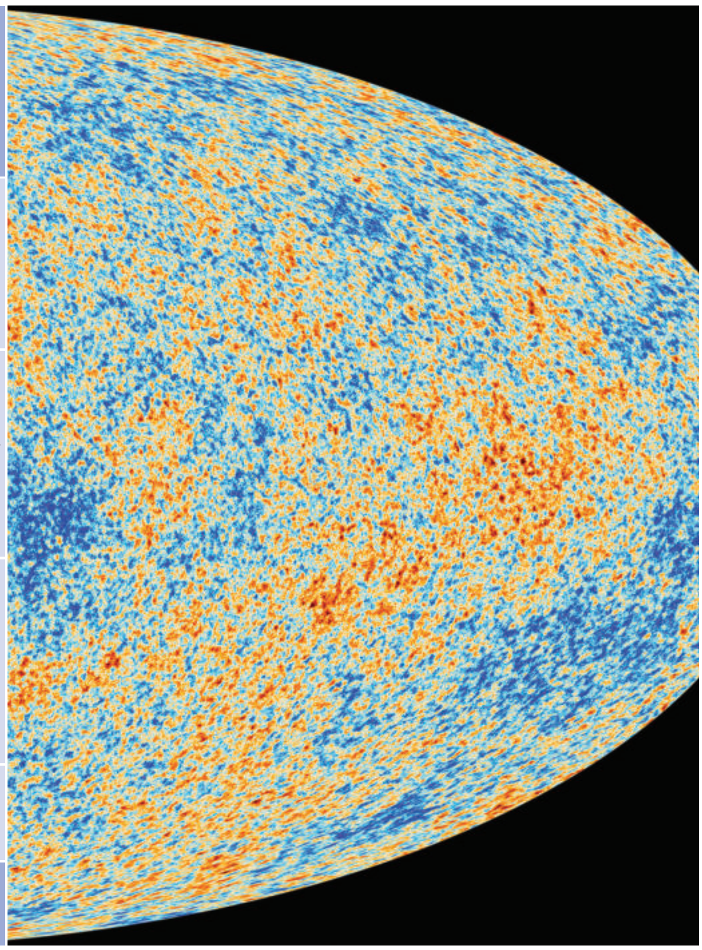


ESA/Planck Collaboration

The Crucifixion by Puccio Capanna/North Carolina Museum of Art/Gift of the Samuel H Kress Foundation

Shedding new light on old art

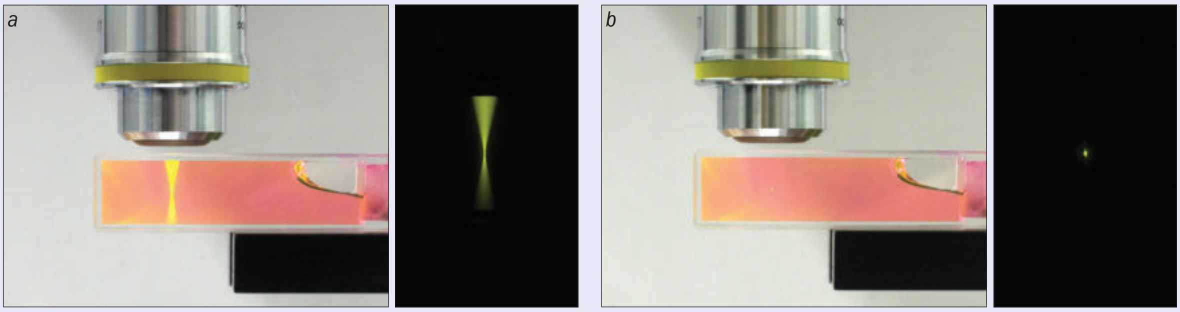
Pump-probe microscopy has recently been used to measure the 3D distribution of a pigment in Puccio Capanna's 14th-century masterpiece *The Crucifixion*. As **Martin Fischer** explains, this laser-based technique can give art conservators and historians information that is impossible to get by other means

Museum guards can get very nervous when inquisitive visitors step towards a work of art and lean in for a closer look. After all, someone crazy might want to attack the masterpiece with a knife or spray a load of paint over it. However, for true art lovers, getting right next to a work of art can offer a deeper appreciation of what the artist had in mind. Brushstrokes, colour composition and other detailed features can – once you step back and regard the artwork from its intended viewing distance – almost magically create a wealth of different impressions and emotions.

Quite simply, close-up views can reveal information about the artwork and its artist. Old Master paintings, for example, are very delicately layered objects with many features that are not immediately obvious. Our eyes mostly perceive the paint layers, which are a complex arrangement of coloured pigments, but these are embedded in "binders" that can alter the appearance of the pigments despite themselves being transparent. In fact, some Old Master painters used dozens of glaze layers to achieve the desired colour, gradient and even perceived depth.

Martin Fischer is an associate research professor in the Department of Chemistry, Duke University, US, and is part of the Center for Molecular and Biomolecular Imaging, e-mail martin.fischer@duke.edu

1 Hip to be square



Duke University

(*a*) In conventional fluorescence, one photon excites a fluorescent molecule, so that the amount of fluorescence is simply proportional to the intensity of incoming light. Here, a cuvette of dye is excited with continuous blue light and "linear" fluorescence can be seen throughout the entire cuvette, shown also in close-up. (*b*) But a fluorescent compound can also emit light if it absorbs two photons, each of roughly half the energy needed to excite the molecule. In this "two-photon fluorescence", the light emitted is proportional to the square of the laser intensity, which is why the same dye exposed to pulsed infrared light only fluoresces at the focus because only here is the light intense enough. This localized excitation can be used to image the 3D distribution of fluorophores by scanning the beam across the sample.

Leonardo da Vinci's *Mona Lisa* is a prime example of such a layering technique, although very few visitors to the Louvre are ever allowed to get close enough to fully appreciate it.

Careful examinations of paintings can also reveal preparatory layers, initial sketches or under-drawings, with the latter being particularly useful to establish the true identity of an unknown artist. Sometimes even entire new art works can be discovered underneath the surface. However, such close-up analyses are best left to professional art conservators and conservation scientists, both equipped with microscopes and other imaging techniques. These people are experts in obtaining highly detailed structural and chemical information, which is crucial in identifying, authenticating, preserving and conserving works of art. Their aim is to identify individual pigments and pigment mixtures, work out how they are layered in 3D and establish how the artist applied them.

Valuable clues about an artwork's authenticity can also come from checking if the pigments are really those that were used at the time the painting was supposed to have been created and/or seeing if the work has degraded in the manner expected for a painting of that age. Paints, glazes and varnishes all deteriorate naturally when exposed to light and humidity – in fact some early cadmium-yellow and lead-white paints react with each other and gradually turn black with age. Such degradation phenomena can be confined to a few microns of the surface but sometimes they can even encompass entire layers of paint. The challenge for conservators is to identify how much the painting has degraded, what products have been created and what can be done to stop things getting any worse. The specialists have several tools at their disposal, but our group at Duke University, led by Warren Warren, has been working on a new laser-based technique – pump–probe microscopy – that we think could help in that quest.

We think that our new kid on the block – pump–probe microscopy – could find its place in conservation science by circumventing some of the limitations of other mapping tools

Tools of the trade

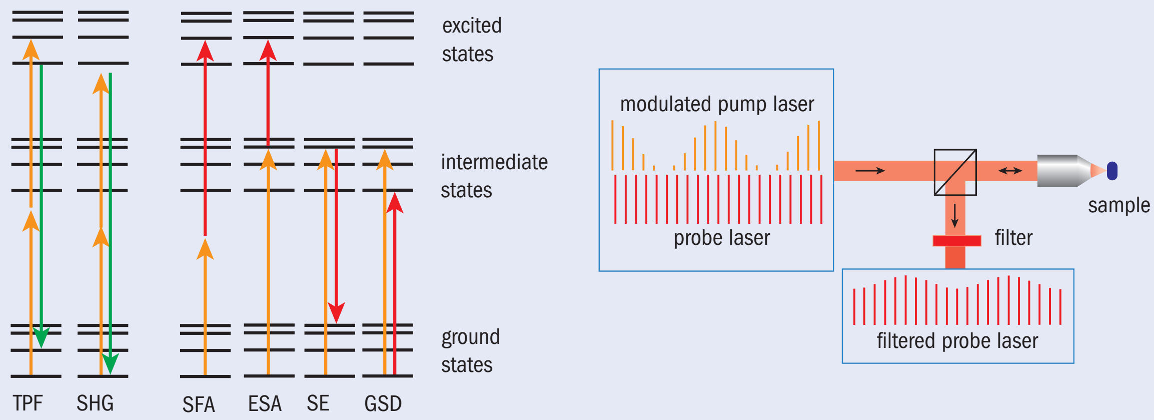
For art conservators, the easiest way to get detailed microscopic information about the composition and layering of pigments is to simply remove a small cross-sectional area of the art work with a scalpel. By laying this piece on its side, the layers can be seen and analysed, just like a sample extracted from an ice sheet or a tissue biopsy in medicine. However, sampling creates spots of damage and, although these marks are almost invisible to the naked eye, this technique should only be used sparingly, particularly on noticeable areas such as someone's face or with paintings of great value. And even when samples can be taken, they provide information on only a few selected areas of the entire artwork. For some types of art, such as decorated or illustrated manuscripts, sampling is impossible because the pages are much too thin and delicate.

There are, however, some imaging methods that do not leave visible marks on the painting, each having its own strengths and weaknesses. X-rays are a particularly powerful tool, but they can only identify atomic elements and they cannot determine the individual pigments in a mixture. In addition, most X-ray imagers shine radiation through a sample and do not provide information in 3D, although spatially resolved (confocal) versions are being developed that can sample selected points. As for studying larger areas with this technique, that requires access to synchrotron sources, which is costly and not easily obtained.

Cheaper and easier to use than X-rays is light. Infrared reflectography, for example, can reveal under-drawings beneath a whole painting, while ultraviolet fluorescence photography can reveal areas covered with certain varnishes. Selected spots can also be probed with Raman, Fourier-transform-infrared or reflectance spectroscopy, all of which are good at identifying specific pigments, even if they are generally restricted to imaging surfaces, rather than providing 3D information.

In fact, for all mapping tools there is a trade-off between having a high spatial resolution, a large field of view, a good chemical specificity, and the ease (and cost) of use. We think that our new kid on the block – pump–probe microscopy – could find its place in conservation science by circumventing some of these limitations.

2 Two are better than one



Nonlinear interactions between light and matter can be generated in many different ways, including two-photon fluorescence (TPF) and second-harmonic generation (SHG), which both involve a molecule absorbing two incident photons (orange) to create new colours of light (green) that are easy to detect. Also shown are four other powerful nonlinear two-photon interactions – sum frequency absorption (SFA), excited-state absorption (ESA), stimulated emission (SE), and ground-state depletion (GSD). Each interaction involves one photon from a pump laser (orange) and one photon from a probe laser (red). These interactions can yield more molecular information than TPF or SHG but because they do not produce a distinct colour they are harder to detect. We detect them by modulating the intensity of the pump laser and detecting synchronous variations in the reflected probe laser.

The art of being square

To see why pump–probe microscopy can be used in art imaging, it is worth first describing its precursor – a technique developed by physicists that was initially used in the seemingly unrelated field of biomedical imaging. Known as "two-photon fluorescence" (TPF), the technique involves shining infrared light onto a sample containing a fluorescent compound, which emits a photon only if it simultaneously absorbs two separate photons each of roughly half the energy needed to excite the molecule. As not one but two photons need to be absorbed for the molecule to fluoresce, the light emitted is not proportional to the intensity of the incoming light, but instead varies with the square of it. (This nonlinear effect was first predicted by the Nobel-prize-winning physicist Maria Göppert-Mayer back in the 1930s.)

For a physicist, a linear response is generally a good thing, as it often leads to simple, more easily predictable systems. But in optical microscopy, linearity comes with one big drawback. As shown in figure 1*a*, although the fluorescence is strongest at the focus, it is also generated by out-of-focus light. Even though the fluorescence in these other regions is much dimmer, much of it comes from layers above and below the point to which the light has been focused, making the signal hard to decipher.

But because the fluorescence scales more strongly with intensity in TPF microscopy than it does in linear techniques, the signal is mostly generated where the light is focused on a sample because here the intensity is at its highest (figure 1*b*). In fact, for good objective lenses, this region can be as small as $1\,\mu m^3$.

This localization sounds great, but it comes at a price, which is that nonlinear processes are generally harder to induce than linear ones. In fact, all things being equal, TPF would need a light source about a million times more powerful than those used with ordinary microscopy. But we can make TPF work by turning to ultrafast lasers, which essentially lump a beam's photons into very short but intense pulses, thereby creating large peak intensities without increasing the average power. Using this approach, in 1990 Watt Webb's group at Cornell University was the first to implement TPF in a microscope and observe biological samples without damaging them.

Making an object fluoresce while matter surrounding it stays dark is, however, just one way to create the contrast needed to form an image and other groups swiftly developed similar nonlinear mechanisms that can also produce image contrast in biological media. These include second- (or third-) harmonic generation, which involves adding the energy of two (or three) photons to create a single photon of twice (or three times) the energy. Another example is coherent anti-Stokes Raman scattering, in which a photon is inelastically scattered, increasing its energy an amount equal to one of the molecule's vibrational modes.

Pumping for information

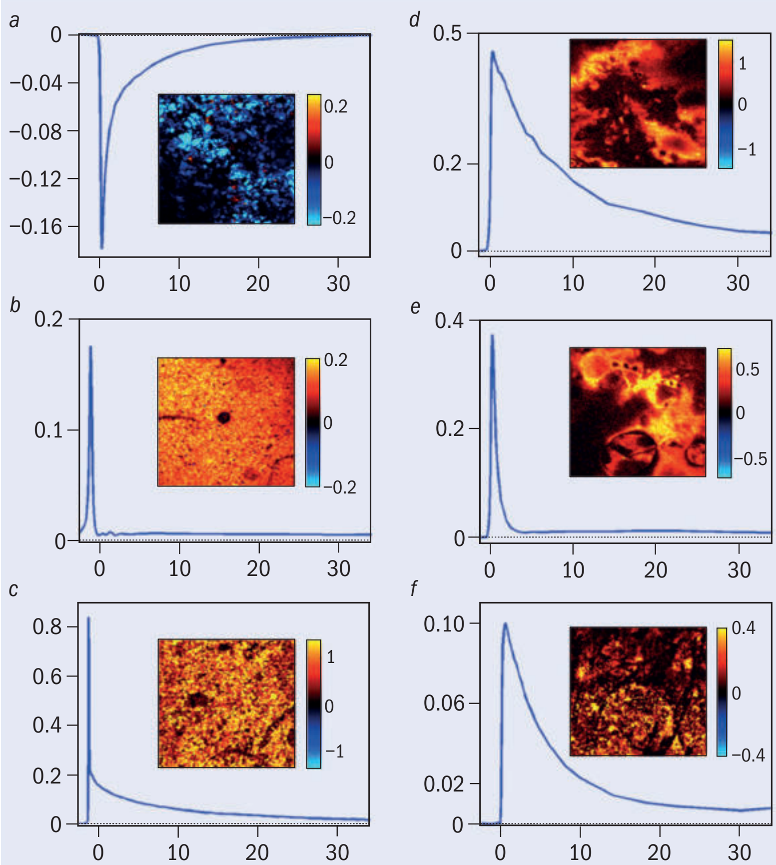
By demonstrating these nonlinear contrast mechanisms, researchers opened the door for nonlinear microscopy to be used to study biological tissue. However, its potential remained largely untapped as it is easier to use techniques that generate light of a different colour to the incoming beam because the emitted light can be detected fairly simply using colour filters. Unfortunately, most nonlinear interactions do not generate such distinct colours and so are harder to detect. While physicists and spectroscopists are familiar with these interactions, current measurement strategies use far too much power to be applicable to tissue (or art).

Nevertheless, some of these other nonlinear techniques can provide the contrast needed to create an image by measuring the intensity of light from different parts of a sample. These include sum fre-

Louise Barker/American Institute of Physics/Science Photo Library

Nonlinear thinking Nobel laureate Maria Göppert-Mayer predicted an effect that lies at the heart of two-photon fluorescence.

3 Dynamic probe



These graphs show pump–probe dynamics in test samples with the pigments (*a*) lapis lazuli, (*b*) vermillion, (*c*) caput mortuum, (*d*) quinacridone crimson, (*e*) phthaloblue and (*f*) indigo. Each trace is the signal from the amplifier measuring changes in the probe beam as a function of the time delay (in picoseconds) between the pump and probe pulses – positive signals are from interactions that reduce the probe intensity, negative from effects that increase it. These samples, which include various colours and pigment types (mineral and organic, synthetic and natural), reveal a wide range of dynamics. Some responses are almost instantaneous, but most involve one or more molecular states that decay over times from picoseconds to fractions of nanoseconds. The insets show false-colour images of the amplifier signal (positive signals in yellow, negative in blue). For these images we chose a fixed pump–probe time delay (by an amount differing for each pigment) and scanned the beam over the paint sample. The images highlight structural features in the paint samples.

quency absorption (SFA) and excited-state absorption (ESA), both of which involve a sample absorbing two photons of different wavelengths – one from a "pump" laser and the other from a "probe" laser (figure 2). In SFA both photons need to arrive at exactly the same time, while in ESA the molecule first rests in an excited state after absorbing a photon from the pump laser, before only later absorbing a photon from the probe. Another nonlinear process is ground-state depletion (GSD), in which a pump photon excites molecules, with those remaining in the ground state then absorbing a photon from the probe. In stimulated emission (SE), meanwhile, excited molecules provide extra photons that add to the probe beam.

In all of these cases, the nonlinear interaction couples the pump and the probe beam – in other words, turning the pump laser on or off alters the intensity of the probe. So, for example, when the pump beam in an ESA experiment is switched on, the intensity of the probe drops after passing through a sample because the molecule absorbs one photon from both beams. In an SE experiment, in contrast, the intensity of the probe beam rises as an extra probe photon gets generated. And if the incident pump beam is turned on and off periodically, we can use a lock-in amplifier to measure the resulting variation in the probe beam (either from transmitted or back-scattered radiation), with its phase giving information about the type of nonlinear interaction (loss or gain in the probe) and the amplitude relating to the strength of the interaction (or the concentration of a given molecule).

In all cases, this localized excitation can then be used to image the 3D distribution of molecules by scanning the beam across the sample. However, additional details about the molecules can be obtained by introducing a time delay between pump and probe pulse because when the pump pulse excites a molecule, the population in a particular state can relax back to the ground state(s) with a certain time constant that depends on the nature of the molecule. So by switching on the probe pulse a certain time after the pump pulse, we can map out how fast ground-state or excited molecules decay, thereby providing clues as to the composition and structure of the molecule.

Into the art world

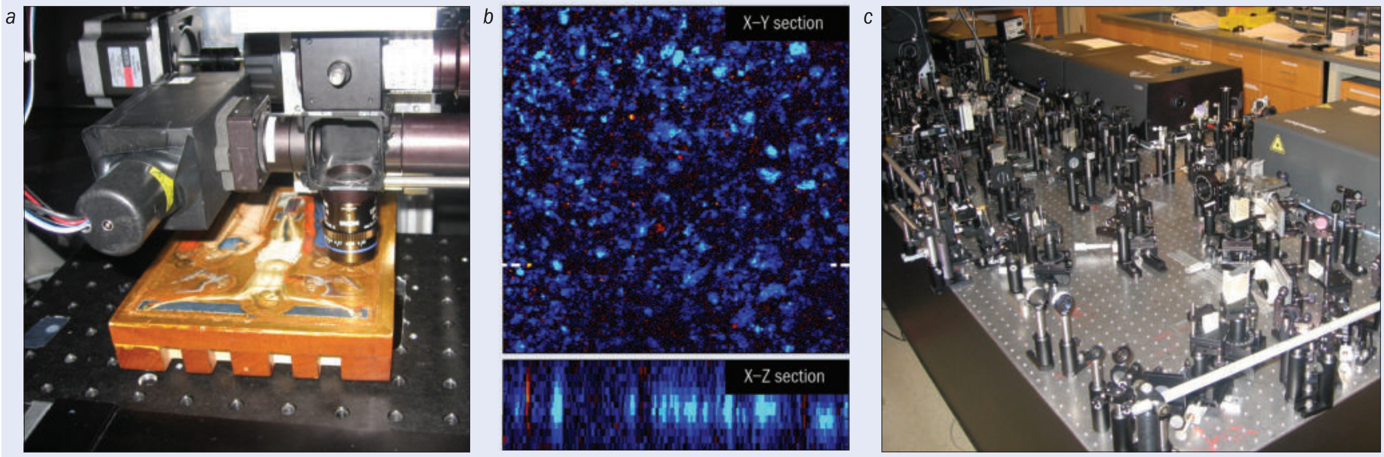
Laser spectroscopists have used such modulated pump–probe techniques for decades, but it is only recently, thanks to the development of highly stable, ultrafast dual-colour sources, that these methods have been used to image biological samples. In 2007 our group at Duke was the first to apply this technique to image melanin pigments in skin. Melanin is meant to protect the skin from Sun damage, but in melanoma – an extremely aggressive form of skin cancer – this pigment is involved in uncontrolled cell proliferation. The Duke team has since shown that pump–probe microscopy can provide valuable microscopic information on how this disease develops and spreads.

Although conventional, nonlinear contrast imaging is now widespread in biomedicine, it has been used much less in the art world because the inorganic pigments used in paintings rarely fluoresce. However, our group, which originally developed absorption-based contrasts for biomedical imaging of skin, later realized that these contrasts could also be applied to pigments in artwork. After all, pigments are rather good at absorbing light, which is why they are on a painting in the first place.

Biological tissue and paintings might seem very different objects, but they are in fact rather similar. Both are complex, delicate and microscopically heterogeneous arrangements that contain highly absorbing pigments that need to be identified and localized. In fact, the most obvious way to make a realistic-looking face is to make the paint structure match the absorption and scattering properties of skin – a point that Leonardo da Vinci understood empirically, even if he had no tools to measure those properties.

Armed with a biomedical microscope and tissue-imaging experience, our team therefore set out to test

4 Under the microscope



Duke University

(*a*) Puccio Capanna's historic 1330 painting *The Crucifixion* under Duke University's pump–probe microscope, with acquisition parameters tuned for lapis lazuli. (*b*) The distribution of this precious pigment shown (top) as a "virtual slice" – acquired parallel to the surface but at a depth of about 30 μm within the paint layer on the Virgin Mary's robe – and (bottom) as a "virtual cross-section" in the plane perpendicular to the surface. Image dimensions are 365 × 365 μm and 365 × 60 μm, respectively. (*c*) The lasers and associated optics of this research-grade microscope are bulky, but much more compact set-ups are under development.

the pump–probe microscope's capability to image paint pigments in 3D. Collections of paper strips with small paint samples from Kremer Pigments – a company specializing in the manufacture of historical pigments – provided a convenient testing ground for the new microscope application. To our surprise, about half of the tested pigments provided a signal strong enough for imaging, even with a pump and probe wavelength combination that was simply set to image melanin, rather than the pigments.

In fact, we showed that 3D images can be acquired, letting us extract "virtual optical cross-sections" – maps of the distribution of pigments – without optically or mechanically damaging the sample in any way (2012 *Optics Letters* **37** 1310). Figure 3 shows the pump–probe dynamics with a single-depth optical cross-section image for a representative selection of pigments, ranging from organic to mineral, and from synthetic to natural.

A leap of faith

After obtaining contrast in art-pigment samples and demonstrating non-invasive 3D cross-sectioning capabilities in lab-made test samples, the time was ripe for an actual demonstration with real artwork. But where does one get access to relevant historic works of art? Fortunately for our group at Duke, we are only a short drive away from the North Carolina Museum of Art (NCMA), which not only houses a world-class art collection but also has enthusiastic and exceptionally skilled conservators and curators. In what proved to be a truly interdisciplinary collaboration – and with a certain leap of faith! – the conservators agreed to bring Puccio Capanna's 1330 painting *The Crucifixion* (see p19) to our lab and let us test it with our pump–probe microscope. Figure 4 shows this Renaissance master painting undergoing the procedure, from which the painting emerged visibly unscathed.

In this demonstration, the lasers were tuned to map lapis lazuli, a precious blue mineral pigment. In the Renaissance age, lapis lazuli – being so rare – was actually more expensive than gold and was therefore used sparingly, primarily for iconic religious figures. Pump–probe microscopy was able to map the distribution of the pigment through the entire paint layer, which in this case was a surprising 60 μm thick, with micron-scale 3D resolution.

Being able to show that our microscope can non-invasively image a painting was naturally exciting. However, the current microscope system is bulky – requiring optics benches and other laser-lab paraphernalia – and was optimized for tissue imaging, rather than for works of art. Much more work remains to be done before pump–probe microscopy can be more widely used in the art world. In particular, the equipment would need to be portable so that it can be taken to conservation labs and easily adjusted so that it can be used to investigate many different parts of an artwork.

Fortunately, the Duke and NCMA collaboration has recently been able to secure funding from the National Science Foundation to bridge the gap between imaging skin and art. Among the aims of our research grant is to develop a much more compact microscopy system, which could provide conservation scientists and conservators with the opportunity to evaluate artworks, including not just painted or coloured works but also pottery and statues. One interesting possibility is to study iron oxide, the pump–probe signature of which seems to change permanently when heated – suggesting that firing history in terracotta could be measured. Nonlinear microscopy could also be used to detect paint fragments buried under the surface (for example, on Greek statues), or even read a delicate scroll without unrolling it.

Much work remains to be done, of course, yet the promise of pump–probe microscopy is genuine. What's more, it reveals an unusual but fabulous spin-off from society's investment in basic biomedical research. ■

Forecasting the fate of Arctic flora

With the effects of climate change on plant life a growing concern, researchers are examining threatened Arctic ecosystems to help predict the fate of the species in cold habitats. **Liz Kalaugher** travels to Finland to investigate

Liz Kalaugher is editor of *environmental researchweb* – a website produced by IOP Publishing to complement its open-access journal *Environmental Research Letters*, e-mail liz.kalaugher@iop.org. The article is based on a science journalism fellowship from the European Geosciences Union

As I walk across the curving slopes of the valley to the north of Saana – a fell in the far north-west of Finland – I'm greeted by an unexpected sight. Dotted against the blanket of low-lying shrubs are heaps of rusting metal. Despite its remote location – roughly 300 km north of the Arctic circle – this area was the scene of the last battle during the German army's retreat northwards in 1945. Now protected as a memorial, the twisted panels from the German defences are surprisingly well preserved; no doubt the winter temperatures here, which sink to an average of –13.4 °C in January, slow corrosion.

The German bunkers have left their mark in other ways too. Even a small change to the landscape, such as a hole or ridge, can affect its vegetation, as physical geographer and ecologist Miska Luoto from the University of Helsinki explained to me in August when I visited the village of Kilpisjärvi, now home to a university research station. Of course, it's not just war-time excavations that have moulded this area; the terrain is continually disturbed by processes such as frost, wind, late-lying snow and water flow.

The concern driving Luoto and his eight colleagues is that as temperatures rise, cold-tolerant plant species that are found only at high elevations or at Arctic latitudes could become extinct. These "Arctic–alpine" plants include species such as mountain avens and white Arctic mountain heather. "Where only the peak of a mountain is suitable for these alpine species, there's a lot of worry that as conditions warm and lowland species move up, they will essentially be squeezed off the top and lost," says Peter le Roux, Luoto's former colleague who is now at the University of Pretoria, South Africa.

Luoto and his team have spent the last three summers intensively studying the vegetation on and around Saana, with the aim of working out the factors, including disturbance, that affect which plants grow where. They intend to use this data to predict the vegetation mix over larger areas than they can study – both now, and in the future, based on projections of temperature and precipitation from climate models (see box on p26).

The project is unusual not only for looking at landscape processes as well as plant ecology, but also in the sheer amount of data it is collecting. By the time the researchers have finished, they will have around 500 different measurements of factors such as topography, geomorphological and hydrological disturbance, species presence, soil temperature and soil moisture, from each 1 m grid square in their study. With a grand total of 3360 grid squares, that's pretty impressive. What's more, Luoto has discovered that by including disturbance, such as frost churning the ground, or water flow, the models' predictive powers are improved.

Trek to the top

On a typical morning during my visit to this remote region I'd wake up with my fleece hat pulled down over my eyes in an attempt to stave off an early alarm call from the Sun, which became much brighter at about 3 a.m. after nominally "setting" at midnight. After breakfast, I'd head off with two or three members of the team and hike to the area they planned to study that day.

From our base at the Kilpisjärvi Biological Research Station, which had views across to Sweden

iStockphoto/ddes02

Snowy spectators Reindeer near Kilpisjärvi in north-west Finland.

on the other side of Lake Kilpisjärvi, we'd cross the main road – where reindeer like to stop traffic – and walk up through the mountain birch woods that hug Saana's lowest slopes. Occasionally we had to wave away from our faces one of the autumnal moths that were experiencing a population boom and stripping the birch trees of their leaves.

As we emerged from the forest and onto the mid-level slopes, a mix of low-growing perennial shrubs such as crowberry, dwarf birch and juniper took over. The juniper serves as a measuring device in its own right as it reveals the level of snow here in winter – branches sticking out above the snow blanket suffer repeated freezing and thawing and so do not thrive, limiting the height of the shrub to that of the snow. The crowberry, meanwhile, provided a tasty snack for the researchers, who took care, of course, only to sample berries from outside their survey areas.

To make sense of the mix of species on these mid-level slopes, it's essential to understand the effects of running water – indeed, a stream in the valley to the north of Saana demonstrated how much difference it can make. Grasses, sedges and herb species – plants that would normally only occur at lower altitudes – clustered in the boggy ground surrounding the stream. While it is standard for the mid-level slopes to have 8–15 plant species per square metre of ground, near water that figure can rise to 40. A few trees were even creeping up the river; their presence can shelter other plants and increase snow accumulation in winter, providing extra protection from the cold.

Grid by grid

Species per square metre is just one of the measurements made by the Helsinki team. So far they've surveyed 21 grids, each 8 m wide and 20 m long – about the size of a singles tennis court – and divided them up into 1 m squares. The grids are marked out using wooden barbecue skewers that, by happy accident, have the brand name Saana, which is also a Finnish girl's name. It's low-tech but the sticks do a good job – until inquisitive reindeer knock them over.

The sites are chosen to represent a range of aspects, elevations and topographies: there are six each on Saana's northern and southern slopes; and three each on the western slopes, near the top of the fell and in the valley to the north. Aspect is important because solar radiation can be as much as eight times higher on south-facing sites than on northern slopes.

This year the researchers also ventured further away from Saana and surveyed 1 m squares at points along transects (lines of measurement), enabling

The concern is that as temperatures rise, cold-tolerant plant species that are found only at high elevations could become extinct

The physics of climate change

Back in 1896, Swedish physicist Svante Arrhenius, who was interested in ice ages, was the first to calculate how carbon dioxide – or carbonic acid as it was known at the time – in the Earth's atmosphere affects temperatures on the ground. To do this he used measurements of infrared radiation from the full Moon. When the Moon was near the horizon, the radiation had to travel through more of the Earth's atmosphere than when the Moon was directly above. These different atmospheric path lengths meant greater or lesser contact with carbon dioxide and water vapour along the way. "A simple calculation shows that the temperature in the Arctic regions would rise about 8° to 9 °C if the carbonic acid increased to 2.5 or 3 times its present value," he wrote in the *London, Edinburgh and Dublin Philosophical Magazine and Journal of Science*.

Nowadays, instead of the Moon, physicists use sophisticated climate models that run on supercomputers. Put simply, the models, such as the UK Met Office's HadGEM3, split the Earth's atmosphere and ocean into small cubes. The contents of each cube obey the basic laws of physics and chemistry, including the rules of thermodynamics and the fluid dynamics principles that govern flow of air and water as the Earth rotates. The conditions in each cube affect the next.

To start the process rolling, modellers tend to use initial conditions such as observations of temperature at the Earth's surface as well as in the oceans and the atmosphere. They then let the model run as the clock ticks forward, projecting temperatures for many years into the future under the different conditions, such as increasing greenhouse-gas concentrations, that they impose. It is temperature and precipitation outputs from models like these, fed into regional climate models, that Miska Luoto and his team of geographers and ecologists are using to project the effects of climate change on vegetation such as Arctic–alpine species.

Liz Kalaugher

Bit by bit A University of Helsinki team painstakingly studies vegetation in Saana one square metre at a time.

them to assess how vegetation changes, for example, on a path that climbs straight up the hill or is parallel to the slopes.

For each square, whether it's in a grid or on a transect, the team has analysed the vegetation, noting all plant species present and the percentage of the ground that each type of plant covers. Luoto himself assessed the landscape topography and disturbance – those extra factors that he has found improve the predictive power of vegetation models. At several points across each grid, the team also sampled soil temperature, pH and biomass, while factors such as slope angle, altitude and aspect come from digital elevation models.

I spent two days with Luoto visiting a selection of transects near and on the fells of Korkea (High) Jehkas and Iso (Big) Jehkas. Luoto was the only person responsible for topography and disturbance assessments throughout the project, in order to keep the method consistent. He and other team members surveyed the vegetation independently from landscape factors to avoid biasing their results. At each transect point we reached – marked by coloured forestry tape that was hard to spot, making the GPS kit a godsend – Luoto assessed the surface shape of each of four 1 m squares by assigning a slope rating relative to the surrounding area, on a scale of one to 10.

Evaluating disturbance, meanwhile, required Luoto's keen eye for identifying the physical processes that have affected the ground. Much of the disturbance here is related to frost activity. The top couple of metres of soil freezes every winter, creating seasonal frost, while high up in the mountains – above 800 m – there is permafrost. Soil and bedrock is frozen all year round at depths of more than 5 m or so below the surface. Repeated freezing and thawing of the soil gradually squeezes stones to the surface as the ground contracts and expands – a process known as cryoturbation. Meanwhile, recurrently frozen ground can creep gradually downhill, creating characteristic "solifluction terraces".

Wind can play a role too – on the edges of small ridges, it blows away the fine soil particles leaving only gravel and rock behind. And then there's snow. Although it was gone by the time of my visit in August, signs of its presence remained. When the snow starts to melt in late May, new streams break out around the hills. These can wash nutrients into an area and play a direct role in vegetation growth, as well as disturbing the soil. Some resilient snow patches, generally in high-altitude hollows and dips shielded from the Sun, remain later into the year and create their own disturbance.

Troubled sanctuary?

While disturbance might sound undesirable, for Arctic–alpine plants it is a blessing. On those windswept edges, for example, the poor soil prevents the alpines' more vigorous lowland cousins, such as crowberry and dwarf birch, from taking hold. This means that species such as white Arctic mountain heather, mountain avens and *Diapensia lapponica* are able to thrive. Luoto and colleagues' analysis shows that the disturbances that affect plant growth the most, giving Arctic–alpines a greater advantage, are solifluction, water flow and late-lying snow.

Of course, the disturbance here is not just physical – there are biological influences too. The impact


All images: Liz Kalaugher


Under scrutiny Miska Luoto's team studies species such as white Arctic mountain heather (top left) and juniper (top right) in the region of Saana fell (bottom right). Arctic–alpine plants are affected by disturbances, including by animals such as reindeer (bottom left).

of humans is relatively low but reindeer, lemming and willow ptarmigan graze on the vegetation. The lemming population is cyclical; in a good year the animals can be bigger grazers of herbs than reindeer, which normally hog the number one spot. Two years ago there were so many of the rodents in this area that their corpses littered the roadside and you could stand on them by mistake. Now only their burrows are visible – small holes among the rocks with droppings by the entrance – and the occasional lemming track in grassy areas, presumably made in the winter when the animals tunnelled beneath the snow.

Onto the plateau

As we climbed up onto a plateau on Korkea Jehkas, the vegetation changed dramatically. The ground was almost barren, except for a few hardy specialists. The perennial shrubs that grow lower down don't do well at these higher altitudes, where colder temperatures mean a shorter growing season and strong winds blow away the winter snow, leaving plants less protected. It is here that Arctic–alpine species finally come into their own, along with lichens and mosses, as well as some grasses where it's wet. The white Arctic mountain heather was flowering; in a boulder field Luoto pointed out a glacier buttercup, the most northerly vascular (veined) plant in the world and the highest-growing in Europe, reaching altitudes of more than 4000 m in the Alps.

It's this type of habitat that is under threat of being forced off the top of the mountain as temperatures warm and perennial shrubs become able to survive higher up. There are glimmers of hope, in the form of small patches of land that happen to be relatively cold and disturbed – these could act as refuges for the Arctic–alpine species that would otherwise lose their homes. But it's not a great prognosis. "The outlook for these species is maybe not as bad as forecast, but it doesn't change the fact that the populations would be seriously affected by climate change," says Le Roux. For example, plants might end up less connected to other populations of the same species; that's bad news for their genetic diversity.

As I stand in the sunshine I can't imagine what Saana will look like in just a couple of months, when snow and darkness cloak the landscape once again, let alone what conditions will be like by the end of the century. Society's climate negotiations are arguably much harder to predict than the climate itself – ultimately it is likely to be the decisions we make about our greenhouse-gas emissions that will most drastically affect this area in years to come. ■

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Deadline: 2 February 2014

Christmas books

Len Fisher

Wrong turns and dead ends

iStockphoto/Hiob

Oops-a-daisy
The major errors of great scientists are the basis of this new book from Mario Livio.

Brilliant Blunders: From Darwin to Einstein, Colossal Mistakes by Great Scientists That Changed Our Understanding of Life and the Universe
Mario Livio
2013 Simon & Schuster £18.99/ $26.00hb 352pp

In his book *Brilliant Blunders*, Mario Livio offers a detailed and fascinating examination of major errors made by five great scientists – Charles Darwin, Linus Pauling, Lord Kelvin, Fred Hoyle and Albert Einstein – as they sought to understand the evolution of life on Earth, the evolution of the Earth itself and the evolution of the universe as a whole. The stories of how these blunders came about, and what happened next, are extremely well researched, and they shed a welcome, informative, entertaining and sometimes new light on science as a deeply human activity. They also pass my private test – that non-scientific friends and relatives should be able to read and enjoy them – with flying colours.

Livio's stories do not, however, always support his contention that blunders "acted as catalysts for impressive breakthroughs". In four of the five cases (Darwin is the exception, and Einstein is a partial exception), the scientist concerned simply dug his heels in, refused to accept that he had made an error and was overtaken by other scientists working along different lines. Far from catalysing progress, the errors were dead ends, and the views of their proponents became marginalized.

Pauling, for example, hung on to his abortive three-chain model for the structure of DNA and kept trying to rescue it with minor tweaks. Its obvious failings did not stimulate him to investigate substantive alternatives. Nor did Pauling's model really catalyse Watson and Crick's development of a two-chain model, except in the sense that it stimulated Watson's competitive instinct. The catalysts that really mattered were Rosalind Franklin's discovery of the "B" structure of DNA in the presence of a large amount of water, along with Crick's understanding of what its X-ray diffraction pattern meant. As Livio points out, both were necessary. By 1951, he writes, a rival team of researchers at Leeds, Elwyn Beighton and William Astbury, "had excellent X-ray photographs of the B form [but] unfortunately, neither of them was familiar with how a helix would appear in X-ray photographs. Just like that, the Leeds lab missed a chance to play a significant role in the DNA story."

The book is full of such informative sidelights on well-known stories. Fred Hoyle, for example, introduced the term "big bang" in a BBC radio broadcast, but according to Livio's research, he used it as a term of description, not of disparagement as is commonly supposed. Hoyle hung on stubbornly, however, to his belief in a "steady-state" model of the universe, and a consequent need for the continuous creation of matter at a rate that precisely compensates for the dilution caused by observed cosmic expansion. As evidence in favour of a "big bang" theory continued to accumulate, Hoyle used increasingly complex logical convolutions to try to fit the new data to his theory. As a result, he was sidelined by the mainstream cosmological community, and his opinions were no longer taken seriously.

The story of Lord Kelvin's calculation of the age of the Earth at around 100 million years, using Fourier's new theory of heat transfer, is also well known, as is Kelvin's ongoing argument with the biologist T H Huxley on the subject. Kelvin got it wrong mainly because he did not allow for convection in the Earth's mantle. When his former pupil, John Perry, introduced this factor into the calculations, he found that the calculated age could be as much as three billion years, which was much more in line with the geological evidence being adduced by Huxley.

The discovery of radioactive elements such as radium suggested another possible means of heat production in the Earth's core, but although their disintegration did not turn out to be a significant factor, radioactivity contributed to the debate in another way. Livio tells a nice story about an encounter between the Canadian geologist Frank Dawson Adams and Ernest Rutherford, who was, at the time, carrying a piece of black rock. "How old is the Earth supposed to be?" asked Rutherford. Adams answered that several methods had given an estimate of 100 million years. Rutherford commented quietly, "I know that this piece of pitchblende is 700 million years old," and walked on.

Kelvin stuck to his guns and, as with Hoyle, his opinions on the subject became marginalized. Nevertheless, Livio has a case when he argues that Kelvin's error (unlike Hoyle's or Pauling's) catalysed the advance of science, since it "completely transformed geochronology from vague speculation into an actual science, based on the laws of physics".

Livio is an astrophysicist at the Space Telescope Science Institute in Maryland, US, and his insights and knowledge are particularly apparent in the chapters on his own field. His meticulous research reveals, for example, that Einstein is unlikely ever to have said that the assignment of a non-zero value to the cosmological constant was his "biggest blunder". Most probably this widely quoted phrase was an invention of George Gamow, whose interaction with Einstein the author examines in some detail. Livio argues that, in any case, Einstein's real blunder was in returning to his initial assignment of a value of zero, whereas the discovery that the expansion of the universe is accelerating now suggests that a non-zero value is necessary.

The biggest blunder of all was made by Charles Darwin, who failed to see that his mechanism of natural selection was incompatible with the contemporary belief that inheritance occurs by blending the characteristics derived from *both* parents. As the Scottish engineer Fleeming Jenkin quickly pointed out, such a mechanism would swamp any advantageous variation within a few generations. Only when Mendelian heredity, and its genetic basis, were discovered and accepted many years later was this problem resolved. Even so, Darwin's proposed mechanism of natural selection prospered and survived.

The real message of this vastly entertaining book is that scientists often make major blunders when they try to reconcile new ideas with established paradigms. Scientific insight can be a fickle jade but, as Darwin's example shows, it can be best (unwittingly or otherwise) sometimes to have the insight to ignore such paradigms. But then, you probably need to be a Darwin to get away with it.

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Anja Skaar Jacobsen

A romantic scientist

TEK Image/Science Photo Library

Moved by physics
Hans Christian Ørsted identified the link between magnetism and electricity thanks to a compass needle.

Hans Christian Ørsted: Reading Nature's Mind
Dan Charly Christensen
2013 Oxford University Press
£39.99hb 768pp

While giving a lecture on electricity, electrochemistry and magnetism in the spring of 1820, the Danish scientist Hans Christian Ørsted noticed something remarkable: the magnetic needle he was using for one of his demonstrations was deflected by an electric current in a nearby wire. The discovery of this (at first sight) simple and feeble phenomenon came as a great surprise to the scientific community. According to established beliefs among leading scientists in Paris (then the centre of physics and chemistry research), an interaction between electricity and magnetism was not to be expected. Therefore, nobody in Paris was looking for such a connection. But as soon as its existence was realized, electromagnetism sparked a new and extremely fruitful area of physics research. Its discovery was a key step towards understanding the unification of the forces of nature, and it is hard to imagine what life would look like today were it not for the countless telecommunication inventions based on electromagnetism.

The discovery of electromagnetism made Ørsted's name, ensuring him instant immortality and a place in the history of science. But what is the story behind this important finding, and who was this great Dane whom the renowned British chemist, Humphry Davy, described as "a man of simple manners, of no pretensions and not of extensive resources; but ingenious, and a little of a German metaphysician"? The answers are provided in *Reading Nature's Mind*, Dan Charly Christensen's excellent biography of Ørsted and his times. It is the first complete biography of Ørsted ever written and will probably be the most comprehensive ever to appear.

The picture of Ørsted that emerges in Christensen's book is of an enterprising and innovative scientific polymath who had been engaged in such diverse intellectual ventures as science, philosophy, art and poetry long before his career-making discovery. Unlike his French colleagues, Ørsted expected a connection between electricity and magnetism to exist and had been looking for one for years. His research involved seeking connections between such phenomena as electricity, magnetism, chemical affinity, heat and light. In his view, the invention of the first chemical battery, the Voltaic pile, in 1800 and the fruitful field of electrochemistry that developed from it were the first important steps in this new programme. For Ørsted, the discovery of electromagnetism was therefore a culmination of his research project.

As citizens of a tiny country on the periphery of the European cultural, scientific and intellectual spheres, Danish intellectuals and scientists have always travelled abroad in order to enhance their qualifications, establish scientific liaisons and learn about research at the forefront of their fields. Ørsted was no exception: he undertook three major journeys around Europe and met and corresponded avidly with most of the leading scientists and scholars of the time. The international flavour of his life lends something extra to his biography, making it a revealing snapshot of the European scientific community and cultural life in the first half of the 19th century.

The narrative of Ørsted's life in the small but charming Copenhagen bourgeois scene is compellingly written, and Christensen deals with the personal aspects of his life as well as the scientific ones. For the first time Ørsted's rather innocent love life is analysed, thanks to Christensen's scrutinizing of Ørsted's original travel letters. During Ørsted's first journey abroad in 1801–1803, his fiancée Sophie Probsthein got tired of waiting for him and broke off their engagement, and in 1814 he married his father's housekeeper, Birgitte Ballum. We share Ørsted's happiness when he makes his famous discovery and his sorrow when he loses first his beloved sister-in-law Sophie and then, less than a year later, Ørsted's own daughter, Sophie's namesake. We follow the lifelong, close alliance between Ørsted and his brother Anders Sandøe Ørsted; although they moved in different intellectual spheres, both men became extremely influential in Copenhagen society, with Anders Sandøe eventually serving as the Danish prime minister. (Two of Ørsted's younger brothers led more dubious lifestyles, and there are stories about them as well.) We also learn about Ørsted's friendship with the fairytale writer Hans Christian Andersen and the tribulations experienced by the latter when he first settled in the Danish capital. Ørsted became a patron for the ambitious and vain young writer, and a close filial relationship developed between the "big and little Hans Christian", as Andersen called them. Ørsted's scientific epistemology is echoed in some of Andersen's fairytales, such as "The bell".

Christensen's aim is to make Ørsted visible in the history of science outside Denmark, and with this new English version (a more or less literal translation from the Danish original, published in 2009) his book seems likely to achieve that goal. The author's insight into the time period and Danish and European culture – as well as his sensitive description of the characters involved – are unmatched and his love for the topic permeates the text. The inclusion of many striking illustrations makes it a very beautiful book as well, although it is a somewhat heavy one; the Danish version was published in two volumes, but the author chose to squeeze the translation into just one, containing no less than 61 chapters in seven parts.

The title of the book, *Reading Nature's Mind*, is well chosen because it captures the essence of Ørsted's philosophy of nature. Throughout his career, he strove to develop qualitative explanations of phenomena in terms of opposing polar forces that balance each other through a "conflict," and in his scientific approach and belief he took inspiration from German idealist philosophy. This world-view may have made him more open to discovering electromagnetism, and many scholars (including myself) would call the way the intersection between art, poetry, philosophy and science guided his life "romantic". However, Christensen makes it clear throughout the book, and particularly in the last chapter, that he does not consider Romanticism an appropriate epithet for Ørsted's ideas. I disagree with the author on this point, but this did not impair my enjoyment of the book, which is overall a magnificent and superior biography of one of Denmark's most notable scientists.

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Margaret Harris

In search of the real Stephen Hawking

NASA/Science Photo Library

Freefall flight Stephen Hawking experiencing weightlessness on a modified Boeing 727 jet owned by the Zero Gravity Corporation.

My Brief History: a Memoir
Stephen Hawking
2013 Bantam Press £12.99hb 144pp

Hawking Incorporated: Stephen Hawking and the Anthropology of the Knowing Subject
Hélène Mialet
2012 University of Chicago Press $31.00pb 272pp

Stephen Hawking is famous for three reasons. The first is his reputation as a cosmologist. Back in the 1960s, when Hawking began studying singularities in black holes and the early universe, the field of general relativity was more or less in the doldrums. Hawking's work helped change that, and he deserves a substantial part (though by no means all) of the credit for the field's revival.

The second source of Hawking's fame is his role as a science communicator. Some people are sniffy about his first popular book, *A Brief History of Time*, calling it "the least-read bestseller in history", but I am not one of them. As a teenager, I lapped up every challenging word of it, and together with one of his later books, *Black Holes and Baby Universes*, it helped persuade me (and many other like-minded people) to study physics at university.

Like it or not, though, these achievements are overshadowed by the third component of Hawking's fame: his public image as the stereotypical disabled genius. Cut off from most human interaction by the effects of motor neurone disease, which have rendered him almost immobile and unable to speak except through a computer, Hawking – so the story goes – chooses instead to concentrate on loftier matters. Even as his body remains confined to a wheelchair, his mind is free to journey to the furthest reaches of space and time.

In his memoir *My Brief History*, Hawking strikes a balance between scientific contributions, communication and image. Writing in his characteristic clear, concise style, he describes how, after an idyllic childhood and some rather lazy undergraduate years, his devastating diagnosis spurred him to make something of his life using whatever abilities remained to him. What follows are short sketches of his research career, interspersed with accounts of his travels, his two marriages and his role as an advocate for people with disabilities.

Readers with no previous knowledge of Hawking will find these stories interesting. For everyone else, though, the book will feel disappointingly superficial, and perhaps also strangely familiar (more on that later). The tales from his childhood are pleasant enough, but unlike the biologist Edward O Wilson, whose memoir *Letters to a Young Scientist* seems sure to become a classic, Hawking mostly declines to draw the sort of connections to his later career that would give weight to these reminisces. There are also some curious inclusions, and one even more curious absence. Hawking devotes nearly a whole paragraph to the Roman heritage of St Albans, his boyhood home, but nary a word to Jacob Bekenstein, whose ideas about black holes and entropy helped precipitate some of Hawking's best work.

My Brief History is not entirely colourless, though. It does contain some moments of waspish humour, as when Hawking relates how his doctor told his then wife that he was coming home to die ("I have since changed my doctor," he adds drily). Less pleasant are the book's occasional brushes with sexism, as when he quips that "scientists and prostitutes get paid for doing what they enjoy" or grouses that the title of the television series *The Ascent of Man* would "not be allowed today" because it is not politically correct. And there is real heat in his gibes at particle physicists ("falling over themselves to latch on to the latest idea") and his repeated digs at the widely held view that theoretical physics can only progress with the help of experimental data.

For insights on Hawking the man, and especially Hawking the scientist, you would be much better off reading Hélène Mialet's book *Hawking Incorporated*. Mialet is an anthropologist, and her book is a densely-written "ethnographic study" of Hawking and the network of people and technologies that assist him. The existence of such a network, Mialet observes, is at odds with Hawking's public image, an entity she calls HAWKING. How, she asks, has "this man who cannot move a finger without his nurse's help…come to represent the mythical figure of the lone genius who can grasp the ultimate laws of the universe with nothing more than the strength of his reasoning"?

To find out, Mialet interviewed a dozen or so people, including her subject's nurses, personal assistants and students as well as several of his colleagues. These are the people who enable Hawking not only to travel and give talks, but also to do the research and writing for which he is famous. Mialet refers to them as Hawking's "extended body" and she reveals, in painstaking detail, how they transform Stephen Hawking – a 71-year-old man with a debilitating illness – into HAWKING, the world's most famous physicist.

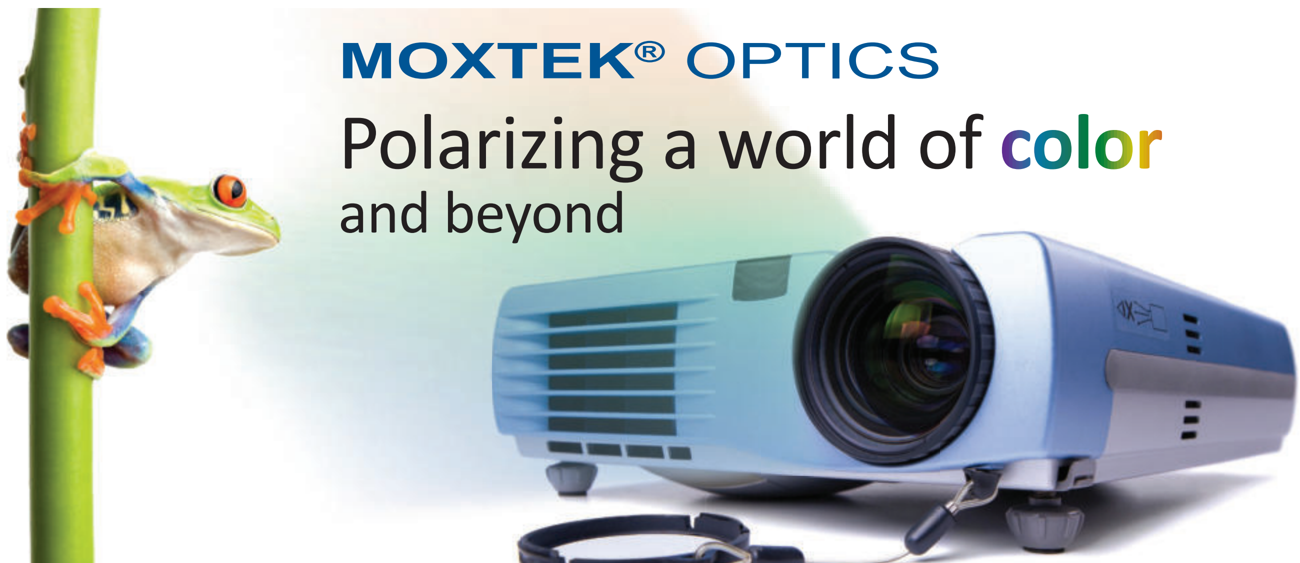
In his memoir (which came out after Mialet's book was completed), Hawking writes that he is glad he became a theorist, because his disabilities would have prevented him from succeeding in experiment. Even so, his illness has profoundly affected the way he works. Hawking alludes to this briefly when he writes that he thinks in pictorial terms instead of equations "partly because it is difficult for me to write them [equations] down". But Mialet, characteristically, probes deeper. For most people, she observes, doing mathematics is a very tactile process, and "one needs not only a head but also 10 fingers to write equations, draw diagrams and use a computer". Moreover, "far from being a discipline in which one can devote oneself to the joys of solitary thought, theoretical physics requires intense collaborative work". But Hawking cannot do any of these things easily, and some he cannot do at all. How has he managed it?

The answer, in a nutshell, is through his students. Because communication is so difficult for Hawking, his students learn to present their questions to him in such a way that he can give them maximum information with minimum effort. They also learn to translate his tiniest facial gestures and most cryptic comments into useful feedback. But this is an art, not a science. Although his students insist to Mialet that Hawking does help them, they often struggle to explain how. One is left with the impression that Hawking, even more than most senior scientists, relies on his students to do the intellectual grunt work.

More unsettling is the chapter on how the media and Hawking have collaborated to create HAWKING. In his public utterances, Hawking has repeated most anecdotes about himself many times; his assistants even keep an archive so he can call up previous comments as required. When he does this in interviews, journalists dutifully repeat his answers, treating each as a new revelation. But on the rare occasions when he deviates from the "script" – by, for example, expressing opposition to the Iraq war – Mialet shows that he is often ignored. Hence, regardless of whether he "plays the game and lets the media exploit his writings, or rebels and intervenes in the construction of his own myth", the result is much the same. The public gets the version of Hawking it expects, and maybe the version it deserves.

As an anthropologist, Mialet is interested in this process because each repetition helps to standardize HAWKING, the public image. As a reviewer, I am interested because it explains why Hawking's memoir gave me such a sense of déjà vu. Hawking is hardly the only prominent figure to engage in "recycling", and since he can only write a few words per minute, he has a better excuse than most. Even so, the extent of his repetition is annoying. Why should anyone buy Hawking's memoir when some of the most interesting stories in it have already been published – sometimes nearly word for word – in *A Brief History of Time*, *Black Holes and Baby Universes* or even, for heaven's sake, an interview he once gave to *Playboy* magazine? And does the identity he constructs by such recapitulation have anything in common with what Mialet calls "the real, unique Mr Hawking, the flesh-and-blood person"? These are good questions, but neither Hawking nor HAWKING seem prepared to answer them.

Margaret Harris is the reviews editor of *Physics World*



Robert P Crease

Making sense of Oppenheimer

CERN/Science Photo Library

Pause for thought
Robert Oppenheimer in the library at CERN in 1962.

Robert Oppenheimer: a Life Inside the Center
Ray Monk
2013 Doubleday/ 2012 Jonathan Cape
$37.50/£30.00hb
832pp

J Robert Oppenheimer has proven all but unfathomable to his biographers. It is not easy to craft a convincing portrait of someone who was alternately brilliant and obtuse, eloquent and shallow, arrogant and insecure, robust and fragile. Handsome and charismatic, the head of the Manhattan Project to build the atomic bomb cultivated friends in high places, but he could also be callous and even vicious toward friends and intimates. The range of reactions he inspired is as discordant as his character. Some people called him a secular saint, a "Gandhi stretched up to six feet", while others saw him as treacherous – a brutal, petty and often pretentious colleague.

Moreover, Oppenheimer was notoriously guarded. He left no personal diary, no autobiography. He repeatedly and deliberately frustrated efforts by interviewers to elicit personal feeling and reflections. A biographer has little to go on in figuring out what drove this driven man, despite the existence of years of now-public wiretaps and FBI surveillance. As Ray Monk puts it in his masterful new book *Robert Oppenheimer: a Life Inside the Center*, "Not revealing things about himself was something he was extraordinarily good at."

Monk is hardly the first scholar to try his hand at explaining one of the 20th century's most enigmatic scientists. Indeed, several biographies appeared around 2005 in the wake of the centennial of Oppenheimer's birth. These include the Pulitzer-prizewinning *American Prometheus* (2005) by Kai Bird and Martin J Sherwin; and Abraham Pais's *J Robert Oppenheimer: a Life* (2006), to which I contributed after Pais died with the manuscript unfinished. Yet all of these biographies managed to paint their respective portraits by adopting partial perspectives, whether historical, sociological or political.

Monk's biography improves on them by subtly shifting the focus away from the man to his interactions with his surroundings. It presents Oppenheimer as a man consumed by centres – social, scientific, political. Monk describes the dynamics of Oppenheimer's life as efforts to move towards these centres, to maintain his unstable presence at them and to avoid falling away from them.

In part one, for instance, Monk goes to some lengths to describe the German Jewish community on Manhattan's Upper West Side in which Oppenheimer was born and raised in the early 1900s. This community was struggling to fit in not only with its adopted country but also with more recent Polish and Russian Jewish immigrants who landed in the "Jewish Ghetto" on the city's Lower East Side. Monk describes the leaders of this centre-aspiring community and its institutions, including the Ethical Culture School, which Oppenheimer attended. He presents Oppenheimer as a youth whose German and Jewish background propelled him to seek to become a devoted American, and whose patriotism and assimilation into American life were unequivocal.

Monk also dwells on Oppenheimer's intense and formative personal relationships with classmates and teachers en route to his becoming a promising young theorist, one who managed to show up at the centre of theoretical physics (Göttingen) at a time (1926) of radical change: the quantum revolution. Yet for Oppenheimer, it was not enough merely to be at the centre of theoretical physics. He wanted that centre to be American, and after leaving Europe, he quickly set out to build the US's first school of theoretical physics.

In succeeding chapters, Monk portrays other kinds of centre-seeking movements, as Oppenheimer became the surprise choice to lead one of the riskiest military ventures ever, the Manhattan Project, and as he afterwards sought to play a key role in shaping US atomic policy, only to be expelled after a gruelling and humiliating series of security hearings. Monk enables us to understand why Oppenheimer was so determined to brave that ordeal, defending himself against charges of disloyalty, when he might have gracefully stepped back.

Strangely, Monk does not go into as much detail about Oppenheimer's later personal relationships as he does with his earlier ones. A lack of evidence may be partly to blame; Oppenheimer's wife and children, in particular, seem to have shared his reticence about putting personal feelings on paper. Even so, plenty of people knew his late wife and daughter, and his son is still alive, though elusive. Some sense could have been made of it.

Monk's care not to overstep the available evidence does pay off later in his treatment of Oppenheimer's possible Communist Party membership. "The question of whether Oppenheimer was a communist or not is thus rather like the question of whether he was or was not a German Jew," Monk writes insightfully. "He did not consider himself to be German, Jewish or communist and yet, as those words are commonly used, he was ethnically a German Jew and politically a communist. One does not have to accuse either Oppenheimer or common usage of being wrong here; one just has to be careful in distinguishing the sense in which he was and was not German or Jewish or a communist."

> One has to be careful in distinguishing the sense in which he was and was not German or Jewish or a communist

Only occasionally does Monk falls prey to Oppenheimer-mystique: the temptation to read deep meanings into the man's verbiage when more mundane explanations are likely. When Oppenheimer named a used car "Ichabod", Monk proposes that he was thinking of an obscure Old Testament priest – the son of Phinehas in the Book of Samuel – or a figure in an enigmatic Robert Browning poem. Oh, come on. The car's most probably named after Ichabod Crane, the itinerant schoolteacher famously chased by a headless horseman in Washington Irving's *The Legend of Sleepy Hollow* – a tale known to every New York schoolchild.

Unlike most other biographers, Monk takes Oppenheimer's scientific concerns seriously. Quantum electrodynamics, he notes, had an "extraordinary hold" on Oppenheimer in the 1930s, and he quotes a student's recollection about Oppenheimer's determination to make sense of the meson puzzle: "it bothered him, it tore at him". In her *New York Times* review of this book, the journalist Janet Maslin chides Monk for wasting so many pages on things like mesons, asking sarcastically: "Would anyone seriously interested in Oppenheimer seek out a biography for this?" Gosh, how small-minded! But Monk appreciates just how captivating science is to the true scientist. "I need physics more than friends," he cites Oppenheimer as saying.

Isidor Isaac Rabi once said that, while most physicists regard physics as simply a profession, Oppenheimer regarded it as a path to deeper truths; physics for Oppenheimer was therefore a means to the Centre. The towering achievement of Monk's book is that it finally makes this plausible. J Robert Oppenheimer has never made more sense.

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Fantastic foods

Nathan Myhrvold/Modernist Cuisine LLC

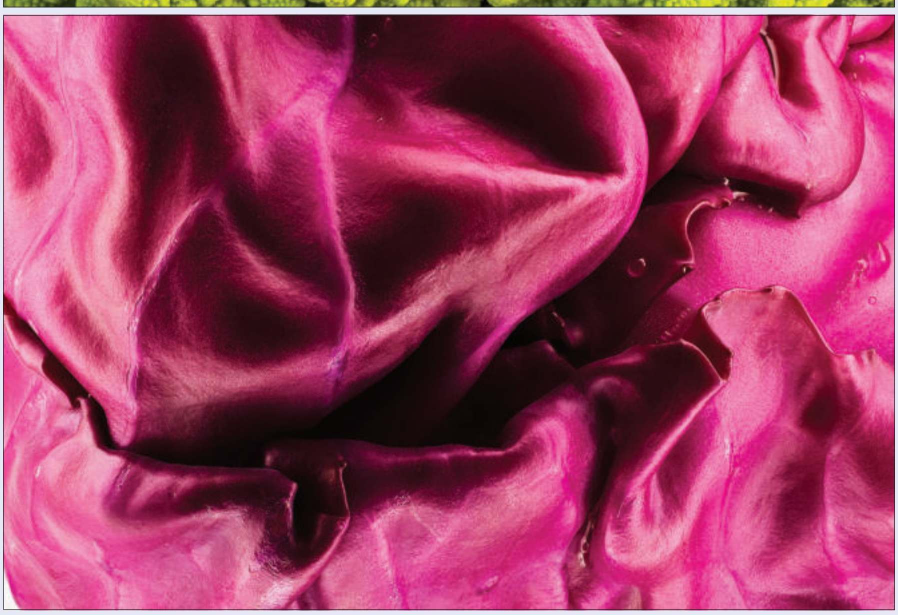
Ryan Matthew Smith/Modernist Cuisine LLC

The Photography of Modernist Cuisine
Nathan Myhrvold
2013 Cooking Lab £80.00hb 312pp

Two years ago, a six-volume paean to molecular gastronomy made a surprise appearance in *Physics World*'s annual list of the year's best physics books. Written by Nathan Myrhvold – a PhD-level physicist and a former Microsoft executive whose CV also includes a one-year stint as Stephen Hawking's postdoc – *Modernist Cuisine* made our list thanks to its descriptions of scientific cookery, including explanations of how to use standard laboratory equipment such as water bottles and centrifuges in food preparation (December 2011 pp35–36).

Myrhvold's follow-up effort, *The Photography of Modernist Cuisine*, lacks the scientific heft of its predecessor, but as these photos illustrate, it is breathtakingly beautiful and full of surprises. The image at top left, for example, may look like a distant planet viewed through the porthole of a spacecraft, but it is actually the bottom end of a blueberry: the "planet" is part of the berry's ovary, while the rough-edged lobes of the "porthole" are the remains of its blossom, or calyx. The middle image shows the fractal-like patterns characteristic of a romanesco cauliflower, while the delicate folds of bright-pink material in the bottom left image are found on the surface of a cabbage. In the final photo, below, oil is ignited as it bursts from an orange as it is peeled.

With a "wingspan" of more than a third of a metre, a mass of nearly 6 kg and a hefty price tag, *The Photography of Modernist Cuisine* is not the sort of book that can be tucked discreetly into a Christmas stocking. Still, the book – which includes a "how we did it" chapter that delves into the photographic techniques and the back stories of some of the book's 405 photos – is a visual feast, and we think it will appear under a few trees this season.



Nathan Myhrvold/Modernist Cuisine LLC

Ryan Matthew Smith/Modernist Cuisine LLC

Between the lines: Christmas special

20th Century Fox/The Kobal Collection/Matt Groening

iStockphoto/gschroer

The comic and the serious
Using *The Simpsons* to explore complex mathematics, and why increasing light pollution is not just a problem for astronomers.

Mmm...mathematics

For most people, mathematics and the animated TV show *The Simpsons* are not exactly synonymous. Yet as the British science communicator Simon Singh shows in his book *The Simpsons and their Mathematical Secrets*, the show's writers have stealthily inserted almost an entire PhD's worth of mathematics into its 500+ episodes. This is partly a reflection of the writers' backgrounds, since several of the show's most prolific contributors acquired advanced mathematical degrees before changing careers. Writers David Cohen and Jeff Westbrook, for example, have degrees in physics and computer science, while Al Jean has a BSc in mathematics and was described as a "maths whizz" while a student at Harvard University. The popularity of *The Simpsons* has spawned a number of books that purport to examine the show's psychology, politics, popular culture or religion; indeed, there is even a book devoted to the sometimes-impossible science of *The Simpsons* (*What's Science Ever Done for Us?: What the Simpsons Can Teach Us About Physics, Robots, Life, and the Universe* by Paul Halpern). But as Singh shows, the show's mathematical vein is actually quite deep. Its second episode, "Bart the genius", features some clever calculus jokes at Bart Simpson's expense, and from the offset the writers seemed keen to include high-brow hilarity in amongst the silliness and sight gags. Take, for example, the episode "The wizard of Evergreen Terrace", in which Homer Simpson has a mid-life crisis and is inspired by Thomas Edison to become an inventor. It would be easy to miss the four equations that appear scribbled on a blackboard in this episode, but Singh – who must have worn out the "pause" button on his remote control while researching this book – shows that they include the equation that predicts the mass of the Higgs boson, a (near-miss) solution of Fermat's last theorem and an equation for the expansion of the universe. Singh explains all of these concepts simply but clearly, and he also incorporates a set of five clever examinations so that you can test yourself. Undoubtedly, his book is the perfect Christmas present for both mathematical savants and Simpsons aficionados – not to mention anyone with a healthy interest in humour and maths.

● 2013 Bloomsbury Publishing £18.99/$26.00hb 272pp

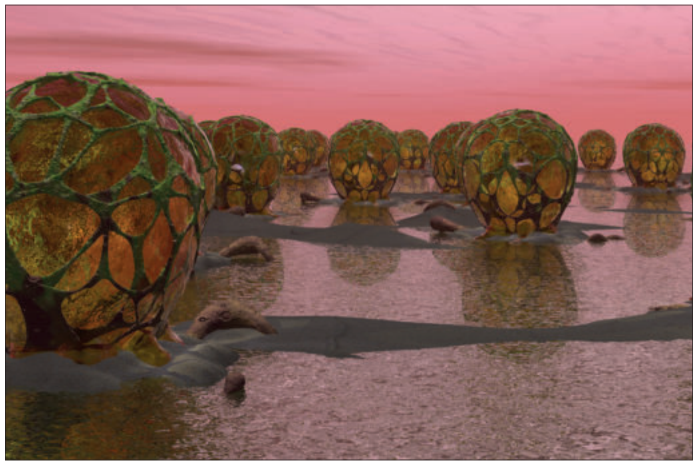
No more starry nights

On a clear night, how many stars can you see in the sky above where you live? For most residents of developed countries (and cities everywhere), the answer is likely to be less than 100 – a far cry from the thousands that our ancestors saw 150 years ago, and that people who live in the world's remaining dark-sky areas still experience today. Paul Bogard's book *The End of Night: Searching for Natural Darkness in an Age of Artificial Light* is both a lament for those vanished starry nights and a tirade against the things that have caused their disappearance, including unshielded street lights, billboards lit from below and even squid-fishing boats, which use daylight-imitating spotlights to attract their prey. Bogard, a journalist at James Madison University in the US, has travelled around the world speaking to people with an interest in darkness, including astronomers, park rangers, philosophers and lighting engineers. Astronomers, in particular, have long been in the vanguard of the fight against light pollution, but Bogard shows that their concerns are only a small part of the big picture. As one of his interviewees puts it, "The presence of an astronomer [is] the sign of a healthy ecosystem…when the sky grows too bright for astronomy and the astronomers go away, you know you have a polluted sky, and whatever has polluted that sky will eventually pollute other resources, given time." Accordingly, Bogard's argument goes well beyond astronomy and aesthetics, taking in elements of ecology (light pollution is bad for animals), public health (people are animals too) and even social justice (poorer people are disproportionately affected). The book never quite decides whether it wants to be a poetic lament or a practical call to arms, but its mixture of lyricism and activism still makes for fascinating reading.

● 2013 Fourth Estate/Little, Brown £16.99/$27.00hb 366pp

A medical history lesson

Most physicists are familiar with the role that physics-based techniques such as magnetic resonance imaging, endoscopy and radiotherapy play in healthcare, but the story of how physics came to be an integral part of medicine is perhaps less well known. In *Physicists and Physicians: a History of Medical Physics from the Renaissance to Röntgen*, retired medical physicist Francis Duck describes the birth of his discipline iStockphoto/arcoss



iStockphoto/Redemption

Mind-boggling The big questions, such as how to make our energy usage more "green" and what forms of life might exist beyond the Earth.

via the life stories of the scientists and physicians who brought physics out of laboratories and into clinical practice and medical training. Duck has packed his book with interesting facts, quotes and illustrations from an array of pre-20th-century archive sources, some of which were previously unpublished. The medical content is simple enough for non-specialists to understand, although some descriptions of early medical physics experiments are rather stomach-churning. In one particularly gruesome 19th-century example, the vocal functions of the human larynx were probed with the deceased's face still attached. Modern readers may also be startled by the many 18th-century attempts to use mild electric shocks for treating a wide range of conditions, including constipation, sprains and deafness – with varying degrees of success. Some of the medical-physics pioneers wrote popular-science books and, it seems, had a way with words; for example, an explanation of inertia in a book by the 19th-century British physician Neil Arnott included this delightful quote: "A horse at speed, stopping suddenly, often sends his cavalier over his ears." The book contains several unnecessarily repeated quotes and a handful of rather jarring jumps from one topic to another, while most of the non-English book titles and institution names are left frustratingly un-translated. But Duck has an engaging writing tone, and physicists keen on history will not be disappointed by the depth of research or wealth of fascinating material presented.

● 2013 IPEM Books £35.00pb 306pp

Pondering the big stuff

What is the universe made of? Will we ever cure cancer? And where should we put all the carbon we are generating? These are just a few of the queries that feature in *The Big Questions in Science: the Quest to Solve the Great Unknowns*. The subject matter of this beautifully illustrated book reflects the diverse interests of its three authors; while all are British-based science writers, Hayley Birch specializes in writing about energy and the environment, while Mun Keat Looi and Colin Stuart focus on biomedicine and astronomy, respectively. The book's 20 essays are written with clarity and verve, and the authors' decision to include occasional sub-sections written by active researchers lends them extra gravitas. On the down side, the essays are too short to cover everything, and a few of the expert-penned sub-sections give a rather one-sided view of topics (such as string theory) that are still the subject of active scientific debate. In most cases, though, both the authors and their contributors are unafraid to say "we don't know", and the result is a fine introduction to important questions from across the scientific spectrum.

● 2013 Andre Deutsch £14.99hb 192pp

The weirdness starts here

Since the turn of the new millennium, planets orbiting stars other than our own have been discovered at an astounding rate: about one per fortnight, on average. This proliferation of new exoplanets has sparked renewed speculation about what, if anything, might be living on them. David Toomey's book *Weird Life: the Search for Life That Is Very, Very Different from Our Own* offers an accessible and engaging survey of recent developments in the burgeoning field of exobiology. Toomey, a writer at the University of Massachusetts Amherst, US, begins by considering life that is "weird" in a biological sense. Our own planet, he explains, is home to numerous organisms that thrive in extremes of temperature, pressure, acidity or saltiness. So far, none of these so-called "extremophiles" has been shown to be truly weird (in the sense of having evolved independently from other terrestrial life), but research on them has nevertheless broadened our view of what constitutes a habitable planet. Next, Toomey contemplates the possibility of life that is based on substances other than carbon and liquid water – chemically weird life, in other words. This sort of life is extremely unlikely on Earth, but it might exist elsewhere in our solar system; in particular the icy worlds of Titan, moon of Saturn, and Triton, moon of Neptune, are regarded as good candidates for hosting it. With readers' imaginations thus primed, Toomey moves on to more speculative notions about physically weird life, such as Freeman Dyson's idea that life in the extremely distant future might exist in diffuse clouds of molecules, or in the atmospheres of white dwarf stars. In the latter, Toomey suggests, energy would be at such a premium that a sentient being "might take a thousand years to complete a single thought". Sounds like some of us after a big holiday dinner...

● 2013 W W Norton £16.99/$25.95hb 288pp

Careers

Applied knowledge

Jennifer King explains how group industrial projects can help physics students to build real-world skills within a university environment

Durham University

Teamwork Physics students from Durham University get stuck in to a group project at PII Pipeline Solutions.

When Ian Mullin began his undergraduate physics degree at Durham University, he did so hoping that he would eventually be able to apply his knowledge to practical problems. Soon, however, he realized that it was not always easy to see a route from learning to application. Fortunately, a solution was at hand: as part of his degree, Mullin did a team-based project with PII Pipeline Solutions, a pipeline-inspection firm that is part of the General Electric group of companies. The work he did as part of the project was "no longer theory", he says. "It wasn't even just a linear process of 'learn and apply' but a very creative process. The challenge of having control over the project – of having to interpret a brief and work towards the customer's goals – was very different to the normal part of the degree."

Participating in the project had a direct impact on Mullin's career: at the end of the project, PII invited the students to apply for a job with the firm. Mullin took them up on the offer, and he has now come full circle by serving as the company's industrial contact for projects with current Durham students. "It's still career development for me," he explains.

Building soft skills

Securing good employment after graduation has long been a motivating factor for students, but the global recession and the rise in tuition fees at English universities have increased the focus on employability. One of the ways that the UK physics community has responded is through projects like Mullin's, which was created under the auspices of the Group Industrial Project scheme – a programme that aims to help students develop "soft skills" while also training them to apply their physics knowledge. Backed by the Institute of Physics (IOP), which publishes *Physics World*, and using funding from the National Higher Education STEM Programme, the scheme is modelled on one that the physics department at Durham has run successfully for 20 years, and is now available at more than 20 physics departments across the country.

Projects in the scheme have involved a wide variety of external partners, ranging from small- and medium-sized businesses to multinationals and including not only government organizations but also more unusual partners, such as zoos and beekeeping associations. With such a wide range of external partners, students can often be given experience that is directly relevant to their career aspirations. At Cardiff University, for example, students with an interest in teaching participated in a project with eChalk, a Wales-based company that provides online education resources.

Benefits to employers

Undergraduates who get involved in projects associated with the scheme work in a small team and undertake research in conjunction with an industrial or other non-university partner. For example, a group of students at the University of York worked with the multinational firm Reckitt Benckiser (makers of products such as Lemsip and Cillit Bang) on a project related to understanding the physical characteristics of a surface, a liquid undergoing evaporation and the air surrounding the two. While the exact details of the students' work cannot be disclosed for commercial reasons, the Reckitt Benckiser employees who worked with them say they were impressed with the students' ingenuity as well as their hard work and dedication.

The opportunity to get some research done is not the only attraction for external partners. Grace Bramer, an illumination engineer at the automotive engineering firm Visteon, collaborates with the University of Bath, and she notes that industrial projects are also an opportunity to get to know an institution. This can be useful when looking to recruit staff or placement students and to expand into larger research partnerships in the future. James Benstead, a nuclear data physicist at the Atomic Weapons Establishment (AWE) who worked on a project with students at University College London (UCL), agrees. In their case, the initial link made by the project has since developed into a wider collaboration, with AWE sponsoring multiple PhD studentships at UCL and becoming involved in longer final-year projects for undergraduates.

Another benefit for external staff is, as Mullin suggested, the chance to develop their own careers. Employees who participate in projects gain experience of directing research, and may also sharpen their recruiting skills. Stephen Penney of Tyco Fire Protection found that he learned how the Lancaster University students he worked with developed their skills as the project progressed – something that he says gave him new insight into what to look for when recruiting science graduates.

Benefits for students

The fact that the projects involve research on real problems provided by the external partner, rather than a well-worn laboratory exercise, is one that students frequently cite as one of the scheme's most positive aspects. Working on a project often allows students who have lost enthusiasm for their courses to rediscover (or even to discover for the first time) why they decided to study physics. They realize that there is a point to what they have been learning and that real people are actually interested in the outcome. As a consequence, many middle-ranking students do better than expected in their projects. One institution was pleased to note that all of the project students had gone into graduate employment, despite some of them "not being the high-fliers" – a description that surprised the industrial partner involved, who had been impressed by the ability of the students he worked with.

At the beginning of projects, students often find the teamwork aspect of their work off-putting. This is true even though survey data shows that students invariably think that they are good at working in a team before they start out. Perhaps surprisingly, their assessment of their team-working abilities actually declines by the end of the project, which may indicate a more realistic view of the challenges involved. In any case, it does not appear to put them off, since exit surveys also show an increased enthusiasm for team working.

Industrial projects involve research on real problems rather than a well-worn laboratory exercise

But the biggest benefit seems to be that by working on an industrial project, students develop a much broader set of skills than they might have done if they had taken only the more traditional academic components of a physics degree. Skills in project management, communication, teamwork and budgeting are highly valued by employers, says Graham Wynn, a physicist at the University of Leicester who directs the group industrial projects there. "There are signs that the projects have had a significant impact on the employability skills, business awareness and confidence of the students taking part," he adds, pointing out that students often make their project experience a highlight of their CVs. As one student enthused to me during a visit to Leicester, "I am using the project for just about every question in job applications."

A student from the University of Exeter agrees. "From an employability point of view, it's nice to have a module that provides an evidence base of your skill development," the student wrote in an end-of-project assessment. "You can go to interview and you can say…I did this…we achieved this…and because it's already tied in to industry it shows you can abstract the skills from your degree and put them into the real world."

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Careers and people

Spotlight on: Thomas F Rosenbaum

The incoming president of the California Institute of Technology (Caltech), Thomas Rosenbaum, is a condensed-matter physicist who has previously served as an administrator at the University of Chicago. His move to the Pasadena-based institute comes after his predecessor, civil engineer Jean-Lou Chameau, accepted a position earlier this year as the new head of Saudi Arabia's King Abdullah University of Science and Technology.

After earning his PhD in physics at Princeton University, Rosenbaum had a brief career in industrial research, working at Bell Laboratories and IBM's Thomas J Watson Research Center before joining the faculty at Chicago in 1983. His research there focuses on quantum phase transitions that occur in materials at very low temperatures, including metal-insulator transitions and the development of exotic superconducting behaviour. In 2007 he became Chicago's provost – an administrative role akin to that of the pro-vice chancellor at many UK institutions – and he has also served as a member of the board of governors at Illinois' Argonne National Laboratory. Rosenbaum's wife Katherine Faber, a materials scientist at Northwestern University who studies polymer-based microstructures in ceramics, will join him in California as a member of the Caltech faculty.

Movers and shakers

Its researchers may have been snubbed by the Swedes this time round, but **CERN** – along with newly minted Nobel laureates **Peter Higgs** and **François Englert** – has won Spain's Prince of Asturias Award for the discovery of the Higgs boson.

Medical physicist **Roger Dale** of Imperial College London has received the British Institute of Radiology's Distinguished Service Medal.

Radiation oncology pioneer **Benedick Fraass**, director of medical physics at Cedars-Sinai Medical Center in the US, has won the American Association of Physicists in Medicine's highest honour, the William D Coolidge Award.

The British industrial scientist **Peter Jost**, a pioneer in the field of tribology (the study of friction and wear processes), has won the Royal Academy of Engineering's Sustained Achievement Award.

Geophysicist **Harry "Hap" McSween** of the University of Tennessee, Knoxville, US, has won the American Geophysical Union's Whipple Award for his work on the composition of Mars and meteorites.

Metamaterials expert **John Pendry** of Imperial College London has won the $5000 Julius Springer Prize for Applied Physics.

Two physicists are among 24 scholars and artists to receive so-called "genius grants" from the US-based MacArthur Foundation in 2013. Theoretical atomic physicist **Ana Maria Rey** of the University of Colorado, Boulder and astrophysicist **Sara Seager** of the Massachusetts Institute of Technology will each receive $625 000 over five years. Also among the honourees is **Vijay Iyer**, a physics graduate who became a renowned jazz pianist (April 2009 p46).

F Richard Stephenson of Durham University, UK, has won the American Astronomical Society's LeRoy E Doggett Prize for his work on ancient and medieval astronomy. A separate award for outstanding contributions to planetary science went to **Joseph Veverka** of Cornell University in the US.

The European Physical Society's first ever prize for research in laser science and applications has been awarded to **Thomas Udem** of the Max Planck Institute of Quantum Optics in Germany.

Soft-matter physicist **Julia Yeomans** of the University of Oxford, UK, has been awarded the Pierre-Gilles de Gennes Lecture Prize for her work on the behaviour of complex and active liquids in confined geometries.

Once a physicist: Caroline Harper

Caroline Harper is chief executive of the Sightsavers charity and was awarded the OBE for services to the gas industry in 2000

Why did you decide to study physics?
It was fairly straightforward. I did maths, physics and chemistry at A-level partly because they were my strongest subjects, and partly thanks to the influence of my father, who said that science would always get you a good job. Then, when it came time to move on to university, I was just better at physics – I can't say I had a huge desire to study the subject!

How did you get into the energy industry?
I had done a "science and society" project on future energy issues as an undergraduate at the University of Bristol, so when I saw that Cambridge's Cavendish Laboratory had a research group devoted to energy studies, it really attracted me. As part of my PhD in the group, I studied the residential energy market, so it seemed logical for me to move into the industry after I finished. Initially, I didn't get the right job – I misread a job advert and thought it was more senior than it was – but I tried some different ones and eventually I moved into commercial negotiation for British Gas. My career really took off from there.

You became the first managing director at Amerada Hess Gas. What was that like?
I'd been doing commercial negotiation around gas purchasing and transportation, so when I was headhunted to start Amerada's retail gas business from scratch, it was a big jump. Initially I was going to turn it down; I spoke to my father about it and he said he wasn't sure I could really do it. But then, just as I was about to say "no", my father died, and it was one of those moments where you think, "What am I afraid of, here?" So, oddly enough, his death sparked a flame of ambition in me, and I said yes.

How did you get to be chief executive at Sightsavers?
After we sold Amerada Hess Gas, I did some travelling and I decided that I would like to get into the not-for-profit sector. I thought it would be difficult to do that with my private-sector CV, so I applied to be a non-executive director of my local housing association in Notting Hill, London, because I thought it would give me useful experience (which it did). Then a few years later, Sightsavers advertised for a chief executive role and it was just one of those things where, very occasionally, you see something and you think, "That's what I want to do." I had blindness in my family (my father and uncle were both blind before they died), so it had some personal resonance for me. I didn't actually think I'd get the job because I had so little experience either in international development or in the charity world, so I was hugely pleased when I got it.

That's the second time you've mentioned feeling unqualified to do something. Are you prone to impostor syndrome?
I think so, occasionally. You sort of think, "My goodness, am I really doing this?" But since my father died, one of the things I have consciously done is that even if I think, "Oh, they won't want me, I couldn't possibly," I make myself do it and that's stood me in good stead. And I think women are particularly prone to it – there's that classic story of how women will look at a job advert where there are six requirements and think, "Oh, I can't do that because I only meet five of them," whereas a man will say, "I meet three out of six, I'll give that a go." I've seen that in some of the women I've worked with and I've encouraged them not to be held back by it.

What are you working on at the moment?
We've got a very big push on tropical diseases, particularly trachoma, which is actually chlamydia in the eye. People get infected as young children, over and over again, and their eyelids start turning inside out. Then the eyelashes scrape the cornea, which is absolutely agonizing, and they go blind. We are aiming to eliminate blinding trachoma from all the countries where we work by 2020. That's probably our most exciting project, and certainly for me, personally, the idea of helping to eliminate a disease from the world – and it's not just trachoma, there's several that we work on, including one called river blindness – I can't really think of anything more exciting in terms of a legacy.

Any advice for today's students?
Keep your options open and don't assume that you have to follow an obvious treadmill, or that the first job you get is the one you have to do for life. And there's one other thing, particularly for women. When I was studying physics, we were very much the minority, and I remember being really quite intimidated when some of my male classmates would go around saying, "Oh, these exams, they're so easy it's an insult to my intelligence." I found the exams quite difficult, and I remember being really worried – only to discover that a lot of the guys who had been going around boasting actually didn't do very well at all, whereas I did fine. So don't be intimidated if you're in the minority. You're just as good as they are.

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THEORETICAL CONDENSED MATTER AND STATISTICAL PHYSICS (CM&SP) POST-DOCTORAL POSITIONS AT THE ABDUS SALAM INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS (ICTP) TRIESTE, ITALY (ACADEMIC YEAR 2014-2015)

The current research areas of the ICTP CMSP Section include disordered quantum many-body systems, quantum Monte Carlo simulations of ultra-cold gases: BEC-BCS crossover in strongly interacting Fermi gases, low-dimensional and/or disordered Bose gases; physics of nano-devices; statistical physics of complex systems and interdisciplinary applications; random matrix theory and its applications; density functional theory based investigations of structural, electronic and optical properties of materials, in particular in the field of renewable energy storage and conversion; development of efficient algorithms for the computation of electronic excitations in nanoscale systems.

A limited number of post-doctoral positions for young CM&SP theoreticians will be available starting Fall 2014.

Appointments will be made for two years, with the possibility of renewal for one more year.

Applicants should be no more than 35 years of age at the time of application and should have obtained their Ph.D. after 2009. The application form can be accessed at the website: **https://onlineapps.ictp.it/ENTER/APPLICANT/CP13.mhtml**

Additional detailed curriculum vitae, list of publications and at least three recommendation letters (sent separately after submission of application) must all be appended on-line.

Deadline for receipt of applications: 12th January 2014.

Penn Nano Clusters Hiring

UNIVERSITY of PENNSYLVANIA

The School of Engineering and Applied Science (SEAS) at the University of Pennsylvania seeks to build interdisciplinary faculty clusters of eminence at the forefront of nanotechnology. The newly opened Krishna P. Singh Center for Nanotechnology is a $100M facility integrating state-of-the-art nanocharacterization and nanofabrication facilities. This second phase seeks numerous hires who will comprehensively span forefront measurement, novel phenomena, innovative devices, and integrated systems. Successful candidates will be expected to couple with existing resources to synergistically build new areas of international impact.

Broad themes of interest include:

- Emerging fields at the interface of nano and biotechnology,
- Advanced nanoprobes pushing the frontiers of multi modal interactions, in-situ control and/or ultra fast dynamics;
- Coupled phenomena providing new paradigms, particularly under extreme environments including ultrafast time scales, ultra-small dimensions and intense energy fluxes;
- Design and fabrication of multifunctional devices that exploit such coupled phenomena for novel applications;
- Integrated systems for application in nano-enabled computation, energy technologies and nanomanufacturing.

Candidates will be expected to robustly utilize and further contribute to the development of experimental capabilities in the Singh Center, as well as to acquire and develop their own innovative experimental platforms. Read more about the Singh Center at http://www.nano.upenn.edu/. Candidates will also be expected to advance our creative educational programs at both the undergraduate and graduate level. Applicants with industrial experience or collaborations, and track records that include successful translational research programs and technology transfer are particularly encouraged and should highlight thes accomplishments in their application.

Appointments in this second round of hiring will be at the Associate or Full Professor level and applicants must have research and educational track records to merit an appointment with tenure. Successful candidates will be invited to participate in recruiting future faculty at all levels to further contribute to this long-term cluster hiring initiative, which builds on Penn's exemplary record in interdisciplinary research that integrates knowledge at the forefront of discovery.

Applicants should submit their applications electronically at http://www.nano.upenn.edu/about/hiring-initiative/

Information about the School of Engineering and Applied Sciences is available at http://www.seas.upenn.edu/.

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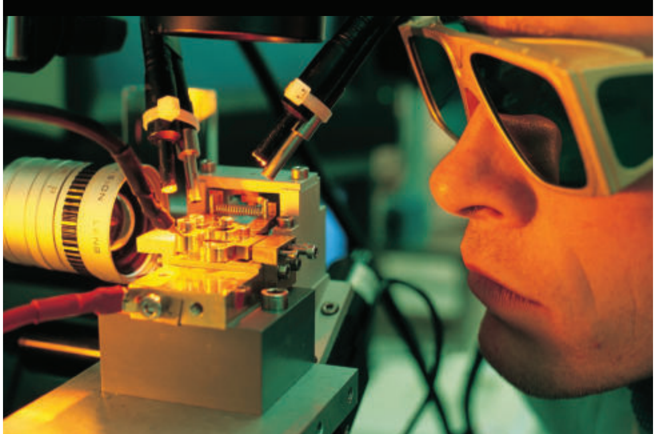

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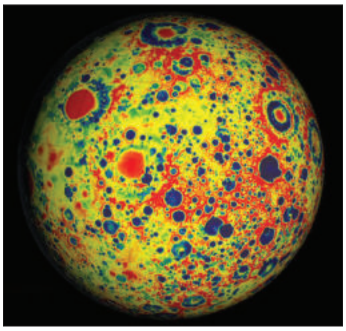
Quiz of the year 2013

It is time again for our annual quiz. As usual, all answers are based on stories that have appeared in *Physics World* this year. How many do you remember?



1. What property of the Moon is on display in this false-colour image?

2. This object was salvaged from the bottom of the ocean in April. What is it?

3. In this artist's impression, whose face has been superimposed on the tip of the silver indium-antimonide nanowire?

4. What is CERN director-general Rolf-Dieter Heuer helping to construct?

The year in physics silliness

5. In January which firm aired a television advert in which Stephen Hawking sent its spokesman into a black hole?
6. Also in January, the US-based fashion designer Holly Renee put together a collection inspired by which space mission?
7. According to a spoof article in the satirical magazine *The Onion*, what did former US energy secretary Steven Chu wake up next to in March?
8. In August the film distribution company Fox Searchlight announced that it was considering making a film about which physicist?
9. In September the Two Brothers Brewing Company produced a beer called Magnetic Moment to honour which scientific experiment?

Who said it? Part I

10. "Do the measurements indicate dark matter? Unfortunately the answer is yes, no and maybe."
11. "I had to practise wiping the blackboard in slow long strokes rather than short fast ones and thus avoid wiggling my bum comically."
12. "I never got into *Star Wars*, maybe because they made no attempt to portray real physics. At all."
13. "Early success pushes you into a scientific niche, making it hard to stay fresh and creative."
14. "Null results are hard to sell to newspapers, but they are really important to scientific progress."
15. "I occasionally get into discussions with astrologers but I don't want to be an arse about it."

A. Theoretical physicist Jim Al-Khalili
B. Comedian Dara Ó Briain
C. Neil deGrasse Tyson, director of Hayden Planetarium
D. Solid-state physicist Leo Kouwenhoven
E. Bill Murray, deputy physics co-ordinator of the ATLAS experiment at CERN
F. Astrophysicist John Wefel

Who said it? Part II (Nobel vs. ignoble edition)

16. "I attribute essentially all of my success to the very large amount of chocolate I consume."
17. "I was a swot, but I was allowed to be without any ill effects from my contemporaries."
18. "I am only interested in doing my research as much as possible, the where and how is irrelevant, frankly."
19. "Whether the Earth was created in seven days, or seven eras, I'm not sure we'll ever be able to answer that."
20. "I am a triumph of modern medicine, physics and chemistry."

A. US senator Marco Rubio
B. Rock musician Lou Reed, who died in October
C. Nobel laureate Konstantin Novoselov
D. Nobel laureate Peter Higgs
E. Nobel laureate Eric Cornell

Discoveries and breakthroughs

21. Physicists in Taiwan and Germany have developed a new technique for detecting blood-iron levels using which allotrope of carbon?
(A. diamond B. buckminsterfullerene C. graphene)
22. According to a group of University of Leicester physics students, how many seagulls would have been required to lift the house-sized fruit in Roald Dahl's book *James and the Giant Peach*?
(A. 501 B. 372 081 C. 2 425 907)
23. When the Nobel committee announced that Peter Higgs and François Englert had won the 2013 Nobel Prize in Physics, where was Higgs?
(A. on holiday in the Scottish Highlands B. out to lunch C. having a bath)
24. The Texas-based firm Systems and Materials Research Corp received a $125 000 grant from NASA to develop what technology?
(A. a satellite launcher called a "slingotron" B. a space toilet called a "lavotron" C. a 3D food printer)
25. *Physics World* was involved in the wedding of fashion designer Feng Ho and accelerator physicist David Kelliher. How?
(A. they met while collaborating on a *Physics World* video project B. the groom's speech was based on excerpts from our articles C. old copies of the magazine were cut up to make wedding decorations)

● Answers to the quiz will be published in the January issue. You can also try the quiz online, at physicsworld.com/quiz-2013.