CREATIVE AVALANCHE
Your brain is like a pile of sand

FOREVER YOUNG
The genetics of beautiful skin

CRASH-PROOF WEB
Building a better internet

NewScientist

WEEKLY June 27–July 3 2009

LAST CHANCE TO WIN! A piece of the moon

THE NEXT FOSSIL FUEL

A surprise successor to oil and gas

Science and technology news www.NewScientist.com US jobs in science

A paradoxical cure for fossil fuel junkies

A new source of carbon could curb greenhouse emissions, but only if it is used sensibly

ONE of the hallmarks of addiction is the inability to quit even when it becomes crystal clear that the craving is harming your health. By that measure, humans are dangerously addicted to fossil fuels.

Now, just as the world is waking up to the reality of climate change, preparations are being made to exploit a vast storehouse of energy that until now has been seen as too difficult and expensive to extract.

The fuel is methane, trapped in icy deposits called clathrates in permafrost and beneath the seabed. The energy in these deposits probably exceeds that of all the oil, coal and conventional natural gas left in the world. In fact, there is enough methane in clathrates to supply the entire world's energy needs for 100 years or more.

The existence of this bounty is not news. What is new is a growing international effort to extract it on a commercial scale. Japan, for example, plans to start doing so by 2016. The US, South Korea, Canada, China and Norway are also licking their lips at the prospect of a new energy bonanza (see page 30).

It is easy to understand the attraction of clathrates. Our civilisation runs on fossil fuel, and with oil prices rising inexorably and energy security far from guaranteed, the prospect of opening a deep freeze of hydrocarbons is impossible to resist.

Yet some would argue that we must resist. Adding yet another fix of fossil fuels to our already bloated consumption surely risks pushing us beyond a climate tipping point. Clathrates contain an estimated 3 trillion tonnes of carbon – more than is already in the atmosphere as carbon dioxide – and it will only take another 500 billion tonnes of the stuff in the air to cause irreversible climate change.

We won't be able to go cold turkey, of course. Assuming the most likely outcome is that we

"The prospect of opening a deep freeze of hydrocarbons is impossible to resist"

exploit clathrates alongside oil, coal and natural gas, it is imperative that we find ways to do it without wrecking the planet. One way would be to liberate methane from its clathrate cage and sequester CO_2 in its place.

If used sensibly, methane clathrates could ease the burden of our addiction: joule for joule, burning methane produces less CO_2 than coal. That is another reason why many countries are eyeing them. As a bonus, we also turn a potent greenhouse gas into less potent CO_2 (see page 24). Switching from coal to methane, however, would require international agreements to leave vast quantities of coal unburned. Does that sound like something political leaders and energy firms are capable of genuinely considering right now, let alone negotiating for? Like all addicts, we will need time to curb our cravings. ■

No hiding place for electoral cheats

MASSIVE displays of popular anger on the streets of Iran – not to mention an outpouring of tweets and blogs – leave no doubt that many Iranians suspect they were cheated of a fair result in this month's presidential election. While firm evidence is not easy to come by, this interconnected age makes wrong-doing impossible to hide completely. Statisticians around the world have been combing through the voting figures Iran has posted online, and then published their results on blogs and pre-print servers. While their "electoral forensics" have laid to rest some knee-jerk criticisms of the results, they have also highlighted areas where the Iranian protesters seem to have cause for real concern (see page 10). There are lies, damn lies – and lies that the sophisticated use of statistics can lay bare. ■

Pirates ahoy!

TO THE shock of its critics, Sweden's Pirate Party won a seat in the European Parliament with the promise of reforming copyright and patent law. Most of its votes came from the under-30s, showing that institutions and pricing structures that liberate digital knowledge are gaining support among the young (see page 28). As similar parties emerge around the world, mainstream politicians may be tempted to steal the pirates' ideas. Those who want to limit our access to knowledge had better get ready to walk the plank. ■

What's hot on NewScientist.com

ANIMAL BEHAVIOUR Honey, I ate the kids Some fathers shower their kids with affection. Male sand gobies value their offspring so much that the fish devour them rather than letting a predator do it

TECH Virtual worlds get real Improvements in computing power mean virtual reality simulations can now reflect real-world physics. See some examples of virtual animations with a firm grounding in reality

NEUROLOGY Brain activity lies on the edge of chaos Ever wondered why random thoughts pop into your head? New simulations that visualise thought patterns are providing an explanation

ASTROBIOLOGY Forget life on Mars – Titan has what it takes Saturn's giant moon has long been thought to be the most favourable place for extraterrestrial life in the solar system. Excitement has now been sparked by an experiment in Titan-like conditions that has created the building blocks of life

CLIMATE CHANGE Earth's coastlines, AD 4000 Even if we could keep the atmosphere as it is today, sea levels would still rise by 25 metres, says the latest study into the effects of climate change on ice sheets

ENVIRONMENT Animals that get cancer Cancer causes 20 per cent of deaths in some species, is slowing the growth of some animal populations and should be a concern for conservationists, say researchers

TECH 'Earthquake cloak' could protect buildings Minuscule objects in the laboratory are the only things that can be hidden by invisibility cloaks. But the same technology could one day help to "hide" large buildings from the effects of destructive earthquakes

For breaking news, video and online debate, visit www.NewScientist.com

Africa can feed the world

DOOM-MONGERS have got it wrong – there is enough space in the world to produce the extra food needed to feed a growing population. And contrary to expectation, most of it can be grown in Africa, say two international reports published this week.

The first, projecting 10 years into the future from last year's food crisis, which saw the price of food soar, says that there is plenty of unused, fertile land available to grow more crops.

"Some 1.6 billion hectares could be added to the current 1.4 billion hectares of crop land [in the world], and over half of the additionally available land is found in Africa and Latin America," concludes the report, compiled by the Organization for Economic Cooperation and Development and the UN Food and Agriculture Organization (FAO).

If further evidence were needed, it comes in a second report, launched jointly by the FAO and the World Bank. It concludes that 400 million hectares, straddling 25 African countries, are suitable for farming.

Models for producing new crop land already exist in Thailand, where land originally deemed agriculturally unpromising, due to irrigation problems and infertile soil, has been transformed into a cornucopia by smallholder farmers.

As in Thailand, future success will come by using agriculture to lift Africa's smallholder farmers out of poverty, aided by strong government measures to guarantee their rights to land, say both reports.

ANDY AITCHISON/CORBIS

Plenty to go round

Let's pay for eggs

IN A break from the US ethical consensus, the state of New York has decided that women can be paid to donate their eggs for research. The move should boost research into therapeutic cloning, which aims to create stem cells matched to individual patients.

Women who donate eggs must have hormone injections to persuade their ovaries to release a batch of eggs in one go. This is uncomfortable, can lead to complications, and the long-term risks remain uncertain.

Clinics in the US pay several thousand dollars to women who donate eggs for IVF. But most ethics bodies that have considered donations for research are against paying for eggs, given the health risks associated with donating – in 2005 the US National Academies issued guidelines discouraging the practice. As a result, stem cell biologists have struggled to find enough eggs for cloning experiments.

"Stem cell biologists have struggled to find enough eggs for cloning experiments"

Now the Empire State Stem Cell Board – which will award $50 million each year for stem cell research in New York over the coming decade – has decided that modest payments can be made. "We were unable to come up with an ethical reason for why we should pay for reproductive donations but not for research," says David Hohn of the Roswell Park Cancer Institute in Buffalo, New York, who sat on the ethics committee that advised the board.

Jonathan Moreno, a bioethicist at the University of Pennsylvania in Philadelphia who helped write the National Academies' guidelines, worries that there may be a public backlash against the decision, since so many Americans remain uncomfortable with cloning research.

Other states with stem cell initiatives will now be keeping a close eye on public opinion. But the hands of stem cell organisations in California are tied, after a 2006 state law banned payments other than direct expenses.

CERN's cable fix

THE Large Hadron Collider (LHC), possibly science's greatest ever project, was undone in September by one badly soldered join. With 10,000 such joins around the accelerator's ring, it is proving a struggle to check them all in time to restart this autumn as hoped.

A splice between two sections of superconducting cable melted when the current was turned up. As well as repairing the one that failed, engineers have so far found and fixed 20 slightly under-par splices. It is a slow process as each of the LHC's eight sectors must be gently warmed from its 1.9 kelvin operating temperature to about 300 K to be checked and repaired.

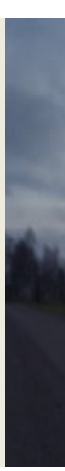
The repairers are now testing if they can check the splices at a moderately cool 80 K. "We'll know by Tuesday," says LHC technical director Steve Myers. If so, the last three sectors can be screened much more quickly. Any urgent repairs will delay the start-up, but less serious faults could be left and the LHC switched on anyway, perhaps at reduced energy.

Pets play role in superbug spread

ANTIBIOTIC-resistant bacteria such as MRSA tend to be associated with hospitals, but household pets are also helping superbugs to spread.

Richard Oehler of the University of South Florida in Tampa reviewed studies from the last decade of people who caught infections from their pets, either through bites or other contact. He found that a significant portion of infections were antibiotic-resistant, including some caused by the dreaded methicillin-resistant *Staphylococcus aureus*. One analysis found that 35 per cent of *S. aureus* samples taken from cats and dogs were MRSA (*The Lancet*, vol 9, p 439).

Oehler suggests that the rise in antibiotic-resistant infections in people means pets are also more likely to be infected. They then act as "reservoirs" that reinfect humans. "Finding MRSA in a pet doesn't mean the pet was the original source," says the US Centers for Disease Control and Prevention in Atlanta, Georgia.



Climate conflict

WANT to know what the weather will be like in a particular British town in 2080?

That's what the UK's Met Office offered last week, with climate

"We can be almost certain there will be big surprises, way outside what they say we should expect"

projections made for areas just 5 kilometres across. Trouble is, some climate scientists think such predictions are worthless or worse.

"By focusing on that sort of detail you detract from the solid science of climate change," says Leonard Smith, a mathematician at the University of Oxford. "At the local scale we can be almost certain that there will be big surprises, way outside what they say we should expect."

A key bone of contention is how the projections handle "blocking highs". These prevent the eastward spread of Atlantic weather to western Europe, leading to heatwaves and droughts in summer, and long cold spells in winter.

A review of the projections by outside researchers warns that flaws in the way the projections handle phenomena such as European blocking "cannot be compensated for by any statistical procedures, however complex".

MIKAEL ANDERSSON/NORDIC PHOTOS/GETTY

Catching more than mice

REUTERS/LUCY NICKOLSON

Turbo turbines

Feel the power

WIND patterns of the past are providing optimistic news about future energy supplies. It seems global winds are easily up to the job of supplying the world's electricity needs.

Previous projections for wind power simply rely on estimates of average annual wind speeds around the world today. Accurate predictions for future wind patterns are not available, so for more detailed information,

"This new approach has the best available wind information for the entire world"

Michael McElroy of Harvard University and colleagues turned to atmospheric models normally used by climate scientists and weather forecasters. They used these to recreate wind speeds and patterns from the past 30 years, using data from aircraft, balloons, rocket launches and surface measurements. "We have the best available wind information for the entire world, every 6 hours, with a spatial resolution of 50 by 66 kilometres," says McElroy.

The team's model suggests that the top 10 carbon dioxide-emitting countries, except possibly Japan, could generate all of their current and projected electricity needs from onshore wind turbines that are already commercially available.

In the US, for example, this would take a network of wind farms involving just 2 or 3 turbines per square kilometre over 13 per cent of the country (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0904101106).

No right to DNA test

US PRISONERS do not have a constitutional right to a DNA test that might prove their innocence, the Supreme Court has ruled.

Many inmates are seeking to take a DNA test in a bid to overturn a conviction. However, in some states there are no specific rules to grant access to such tests. The court ruled in a 5:4 decision that rules on who should be allowed DNA tests after conviction should be made by individual states and the US Congress, not federal courts.

The New York-based Innocence Project, which fought the case on behalf of William Osborne, an Alaskan inmate who maintains he did not kidnap and sexually assault a prostitute, described the ruling as "flawed and disappointing".

Most prisoners will not be affected by the ruling. Of 240 so far exonerated by DNA evidence, fewer than a dozen had to turn to a federal court to obtain the test.

60 SECONDS

Pigeon-headed

Homing pigeons often fly off in the wrong direction when first released, and now we know why. It's to sample local magnetic field strength and direction to find out where they are relative to their loft, say researchers from the University of Auckland, New Zealand. Once fully oriented, the pigeons can set a course for home (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2009.0872).

Want a free gene scan?

If you fancy having your genome scanned but don't want to pay, the company TruGenetics of Seattle may be for you. It is offering free scans to 10,000 people, provided they allow their genetic data and answers to a health questionnaire to be used anonymously in medical research.

Stone Age vulture flute

The discovery of a 22-centimetre-long flute made from the radius bone of a griffon vulture has pushed back the origins of music by 5000 years, to the middle Stone Age. The flute was found at the Hohle Fels caves in southern Germany and sports five holes for the fingers (*Nature*, DOI: 10.1038/nature08169).

HIV discrimination

HIV-positive migrant workers and refugees are being endangered by discriminatory laws, says a report by Human Rights Watch. About a third of countries limit the right of people with HIV to enter or stay – even if they are on antiretroviral therapy – while some restrict their access to healthcare.

Cocaine subs

Tighter land and air security are forcing cocaine smugglers to use fibreglass submarines to transport drugs to the US, says the Colombian navy. The 18-metre makeshift vessels are stuffed with 5 tonnes of cocaine and four people. Four rival gangs are now making the "narcosubs" – 11 of which have been seized this year.

A nuclear race worth winning

Treaties to curb weapons proliferation are gaining ground, but they cannot fly without new science

Debora MacKenzie

IN VIENNA, Austria, scientists are listening for clandestine nuclear tests. In Norway, other researchers are trying out a device that reveals the contents of a nuclear missile without betraying its deepest secrets. And 1000 kilometres east of Moscow in Votkinsk, 30 Americans who watch Russians make missiles to aim at other Americans may not be coming home at Christmas after all.

The world is in the midst of an unprecedented wave of negotiations aimed at saving global agreements to keep nuclear weapons in check. Few realise that this involves at least as much science as it does diplomacy. The weapons treaties involved are totally dependent on verification science: inspections, remote monitoring and other methods of ensuring that people do not build or conceal banned weapons.

The diplomats can only rescue the treaties if they convince sceptics that verification works, so scientists are launching a renewed research effort to enable verifiers to keep pace with the bomb makers. Keeping the world from blowing itself up now depends on which scientists win: the bombers or the verifiers.

The focus of attention is the 1968 Nuclear Non-Proliferation Treaty, due to be reviewed by its member states in New York in May 2010. The NPT was a three-part deal. The five existing nuclear powers vowed to "pursue negotiations in good faith" to reduce and abandon nuclear weapons. The non-nuclear countries promised not to acquire them. And everyone got the right to peaceful nuclear power so long as no material was diverted to bomb-making, as verified by the International Atomic Energy Agency (IAEA).

"It is a miracle the NPT was ever adopted," as it decrees a world of nuclear haves and have-nots, says Jose Goldemberg, the physicist and government minister who guided Brazil's retreat from nuclear weapons. The inequality of the deal kept some nations from ever signing. Israel's nuclear bomb is an open secret; India and Pakistan tested theirs in 1998 (see map, right).

Now countries in the NPT are defying and even leaving it. North Korea left and tested a bomb last month, and Iran is suspected of a clandestine programme. IAEA chief Mohamed ElBaradei fears that up to 20 more countries could remain non-nuclear within the NPT but covertly acquire the technology and materials to assemble a bomb at short notice – especially as many are planning their first nuclear power plants. North Korea is suspected of helping Syria do just that: this month, IAEA verification experts reported particles of uranium in Syria that were too enriched to be natural.

SSGT ALAN R. WYCHECK/DOD PHOTO

No peeking inside

The problem, says Goldemberg, is that the NPT requires countries to forgo nuclear weapons in return for the nuclear powers making genuine efforts to disarm completely, not just reduce their nuclear arsenals. There has been little sign of this happening. That is why US president Barack Obama and Russian president Dmitry Medvedev declared in April that their ultimate goal is indeed the complete abolition of nuclear weapons.

"Keeping the world from blowing itself up depends on which scientists win: the bombers or the verifiers"

To keep the deal alive, Obama spelled out what needs to be done in a speech he gave in April in Prague. First, the Comprehensive Test Ban Treaty (CTBT) must enter into force, or at least get closer to it. Second, the US and Russia must extend their 1991 Strategic Arms Reduction Treaty (START) to cut nuclear missiles before it expires in December this year – and with it the only ongoing verification in existence of the two countries' nuclear arsenals. And third, the world must negotiate a new treaty limiting the production of the fissile material used in bombs. Each of these depends critically on making governments believe the treaties can be verified.

The CTBT would be a serious step towards disarmament: no tests effectively means no new weapons. But it still requires ratification by all 44 countries that had nuclear plants when it was signed in 1996, and nine have not done this. The US Senate refused to ratify it in 1999: opponents feared that the treaty's verification network – hundreds of seismographs, radionuclide sniffers, infrasound and hydroacoustic monitors – would not catch small nuclear tests.

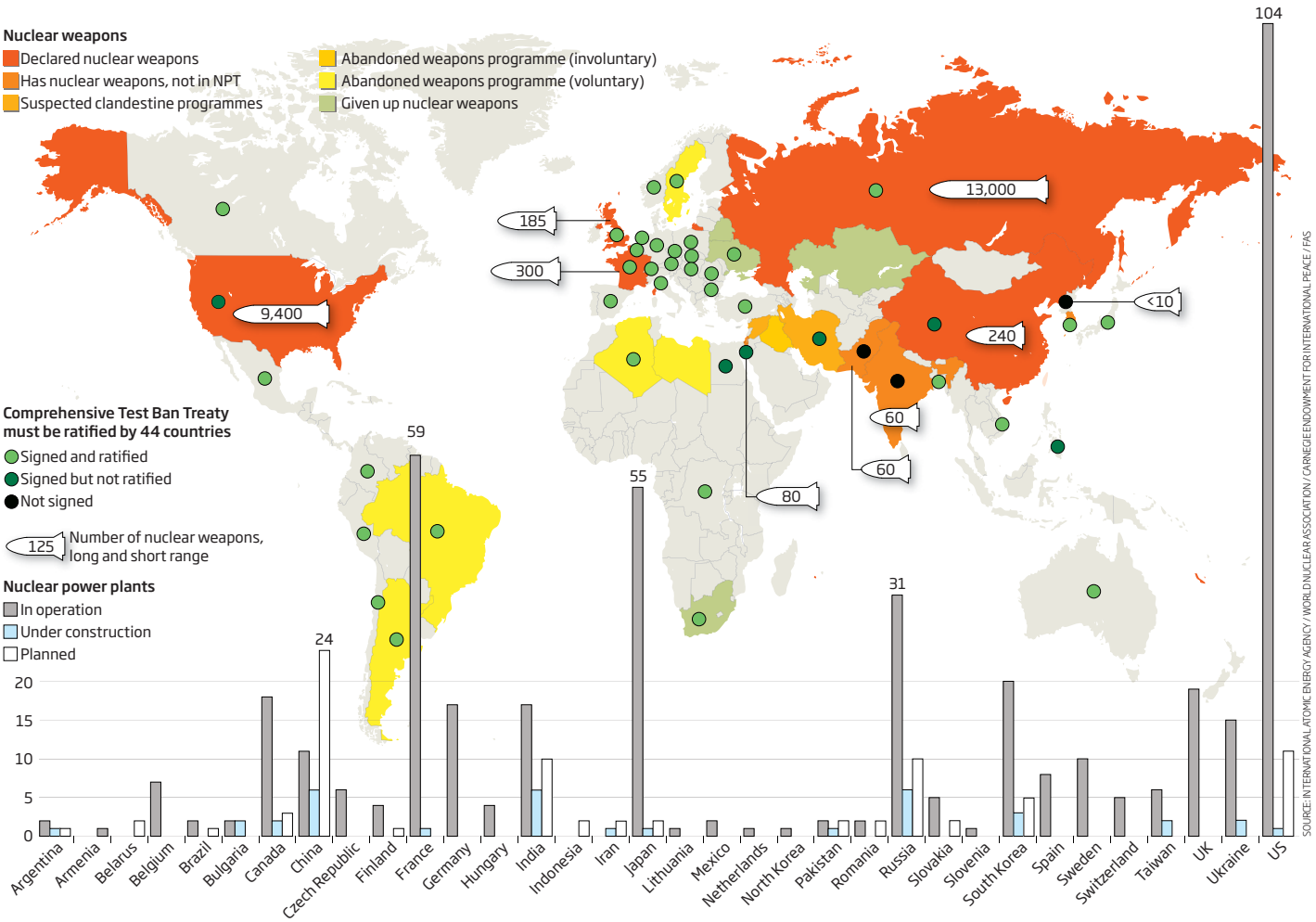
Last month, that network proved itself by spotting a test in North Korea. Partly as a result, "I think the US will ratify within a year," says Hans Kristensen of the Federation of American Scientists. That could break the logjam of remaining hold-outs, starting with China, says CTBT spokeswoman Annika Thunborg.

Meanwhile, the wide-ranging but cumbersome verification methods developed for START need refinement. In December, the US and Russia are expected to agree to cuts in each side's estimated 2000 to 3000 deployed long-range weapons to 1500 apiece, and to maintain current verification. This is based largely on inspections, remote sensing and detailed nuclear accounting. It includes the Americans in Votkinsk, and their Russian counterparts in Utah, ensuring each sticks to agreed limits on missile production.

For deeper cuts, the two powers need better verification. One problem is missiles with multiple warheads. Inspectors must verify how many warheads are inside sealed tubes, says Andreas Persbo of VERTIC, a pro-verification organisation in London, but they cannot just look inside – the missiles hold secrets their owners are obliged to keep.

Last week, VERTIC and British and Norwegian scientists ran the first field trials of a device that could solve the problem: a gamma ray detector linked to a hand-held "information barrier". The detector picks up the full spectrum of gamma radiation emanating from a missile, "but looking at that would reveal more than we need", says Persbo, such as what metals were alloyed

The nuclear world



with plutonium to make the "pit" of the device, or how and when the fissile material was made. "If two radiation energies common to all plutonium are there, the information barrier will just say 'yes' or 'no'," says Persbo. The first trial run of the system in Norway last week successfully verified a test object containing cobalt-60.

Verifying the US-Russia arms agreements will be such a big job, says Joan Rohlfing of the arms control group Nuclear Threat Initiative, that "it creates a new research agenda".

It will require even more to verify a new treaty on the production of fissile material. In 1995, the United Nations voted to negotiate a treaty to ban the making of fissile material that can be used in bombs, but negotiations have been deadlocked since then, partly because the US refused to accept the inspections required.

That changed in April when Obama called for a "verifiable" Fissile Material Cut-off Treaty: negotiations started this month. Such a treaty should extend verification measures to the military enrichment and reprocessing plants that are not now covered by international monitoring, and prohibit unmonitored production. Many of the accounting methods now used to check what flows through civilian nuclear fuel plants will be applicable. Efforts to put fuel enrichment and reprocessing into international hands would also help, although IAEA member states were unenthusiastic at meetings this month.

"Lessons from weapons inspections in Iraq will be very powerful, especially in environmental monitoring"

To detect covert enrichment, says Kristensen, "what we learned from weapons inspections in Iraq will be very powerful", especially the wide-area environmental monitoring that the IAEA used in Syria. This means sampling air and water for particles containing enriched uranium, plutonium or other telltale isotopes. Yet this technology will have to improve: modellers have calculated that for a network of detectors to be reliable, for instance in a country like Iran, its samplers must be no more than 10 kilometres apart. Putting such a grid everywhere is not feasible.

Not all, and possibly not any of these treaties, and their accompanying verification, will be complete by the NPT meeting in May next year. At best, they will show the nuclear powers are serious about their promises on disarmament. The world will have to wait to see if that convinces the nuclear have-nots. ■

ATTA KENARE/AFP/GETTY

Every vote should count

Stats hint at fraud in Iranian election

Stephen Battersby

ALLEGATIONS that Iran's presidential election on 12 June was rigged are being followed up by statisticians in the US and elsewhere who are studying published voting figures for signs of irregularities. They say they have found "moderately strong" evidence that the figures are not genuine, though all are careful to emphasise that maths alone can't prove fraud.

Opponents of the incumbent, Mahmoud Ahmadinejad, who was declared to have won by a landslide, have pointed to his wide margin of victory, the speed of the announcement and some unexpected results, such as Mehdi Karroubi's poor showing in his home state of Lorestan.

One suggested anomaly – that Ahmadinejad's proportion of the vote remained almost constant as the results were announced in six stages – was soon debunked by New York-based statistician and political pundit Nate Silver. He says this is not surprising when votes are reported in large slabs, and that the same effect would have occurred during last year's US presidential election if the results had been reported this way.

To dig deeper, Boudewijn Roukema of Nicolaus Copernicus University in Torun, Poland, used a mathematical tool called Benford's law. In many random sets of data, numbers are more likely to begin with 1 than any other digit. The next most frequent starting digit is 2, then 3 and so on, in a precise relationship. The law applies to any set of numbers scattered randomly on a logarithmic scale.

Any deviation from this pattern could suggest that figures have been manipulated. This has been used to uncover tax fraud and false expenses claims, and Roukema now says it points to fraud in the Iranian election. He analysed the vote counts reported for the four candidates in 366 districts. Votes for three of the candidates fit expected patterns, but Karroubi has an unexpectedly large number of counts beginning with the digit 7. The chance of such a large deviation from Benford's law happening without foul play is only 0.7 per cent, Roukema says. "The simplest interpretation would be that someone interfered in the overall counts per district."

"Statistics can show where there may have been fraud, and prompt more rigorous investigation"

Political scientist Walter Mebane of the University of Michigan, Ann Arbor, has found another anomaly. Based on figures from Iran's presidential election in 2005, when Karroubi was also among Ahmadinejad's rivals, he built a statistical model to predict how each would be expected to do in various districts in 2009.

The model assumes that the 2005 votes were based on regional differences in policy preferences, ethnicities and demographics that should still show up in 2009. Yet in around 200 of the 366 districts voting numbers were inconsistent with the model – and in two-thirds of these, Ahmadinejad's vote was higher than predicted. "It is moderately strong evidence in favour of the idea that there was fraud," says Mebane.

This is far from proof, however. "It is also compatible with the idea that the model is no good," Mebane admits. "I've never said that statistics alone can prove fraud." What it can do is identify places where there may be fraud, so that other investigations – such as studying the ballot papers themselves – can follow. ■

SOUNDBITES

"It's gorgeous! And it's not even real!"

Blogger **Phil Plait** gets excited about the first 3D computer-generated image of a sunspot's magnetic field (Discovermagazine.com, 22 June)

"The physics of the first kiss were off. I knew where I needed to be, but it was hard to reconcile the differences."

Noah Fulmor on getting married on board a parabolic flight – reported as the world's first wedding in zero gravity (Reuters, 20 June)

"The markets will be reacting if he looks awful."

Technology analyst **Van Baker** speculates about Apple boss Steve Jobs's scheduled return to work this month, following a reported liver transplant (BBC Online, 22 June)

"The giant dinosaurs probably were only about half as heavy as believed."

Gary Packard of Colorado State University finds a flaw in the algorithm used to estimate the weight of large extinct animals from their fossils (*The Sunday Times*, London, 21 June)

"We've got to get rid of the green noise. Vague and misleading terms should not be allowed."

Urvashi Rangan of the Consumers Union on the finding that the claims supporting more than 98 per cent of products in US stores labelled "natural" or "green" may be false or misleading (*The Guardian*, London, 21 June)

"If every US dairy farmer reduced emissions by 12 per cent it would be equal to about half a million cars being taken off the road."

Nancy Hirshberg of yogurt producer Stonyfield Farm, on cutting methane emissions from their cows by feeding them alfalfa, flax and hemp (Reuters 22 June)

How genes make our skin look older

GENETIC analyses of human skin are revealing more about what makes us look old. As well as throwing up ways to smooth away wrinkles, the studies may provide a quantifiable way to test claims made for skin products.

In the past , cosmetics companies relied on subjective assessments of skin appearance, and changes in its thickness, colour and protein composition, to evaluate the effectiveness of their products and work out the quantities of ingredients needed to get the best results. "It was totally hit and miss," says Rosemary Osborne of Procter and Gamble in Cincinnati, Ohio.

Now skin researchers, including those at P&G, are starting to use DNA microarrays, common in the drugs industry, to measure the expression of thousands of genes in skin of different ages. "It's a way of finding mechanisms that were not known before," says Fernand Labrie, who studies skin genomics at Laval University in Quebec City, Canada.

P&G recently compared gene expression in skin samples from the buttocks and forearms of 10 young and 10 older women. In older skin, they found a decrease in the expression of genes involved in cholesterol and fatty acid synthesis. More surprisingly, the opposite was true for genes associated with inflammation and other components of the immune system, suggesting that the immune system may play a role in ageing.

Treating the older skin with niacinamide, which helps skin retain moisture, damped down expression of genes related to inflammation. "We believe that improving the barrier results in a 'resignalling' of key molecular components of the skin," says Jay Tiesman of P&G. Targeting this inflammation might one day help to keep wrinkles at bay. The findings will appear in the *Journal of Drugs in Dermatology* in July.

Identifying a "genetic signature" of younger skin should also provide a benchmark for testing existing skin products. For example, P&G is measuring the effects on gene expression of a skin cream ingredient called pal-KT. Previous approaches suggested it increased production of structural skin proteins like collagen and laminin. Gene analysis indicates it also affects the expression of genes involved in wound healing.

"In older skin there was an increase in the expression of genes associated with inflammation"

P&G isn't alone, cosmetics firm L'Oréal claims to have identified differences in the way genes in old and young skin respond to physical damage: changes in gene expression began just 6 hours after damage in young skin but took around 30 hours to kick in with older skin. What's more, around 25 genes differ in their response to skin damage in young and old skin, says L'Oréal.

Rigorous studies in people are needed to confirm that changing gene expression in older skin to match younger skin improves skin quality. "You could find that a molecule is up or down-regulated, but whether that relates to a consumer noticing a difference is a big jump," says Diona Damian at the University of Sydney, Australia.

If new tools become available for assessing skin products, this could force cosmetics companies to back up claims about their products with hard evidence.

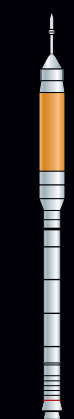
"If you really want to bring cosmetics into the field of rigorous scientific evidence, genomics may be the best and most quantitative way of doing it," says Labrie. **Linda Geddes** ■

LAURENCE MOUTON/PHOTO ALTO/JUPITER

Can we turn the clock back?

Which one is NASA's next rocket?

Ares I — NASA



NASA's own design, uses modified versions of space shuttle and Saturn V rocket components

Lift capacity
25 tonnes to low-Earth orbit

Cost per flight*
<$130 million

Pro
Shared hardware with larger Ares V saves development costs

Con
Prone to violent vibrations, straining to reach desired lift capacity

Delta IV — United Launch Alliance

Satellite launcher developed by Boeing with US military funds

Lift capacity
23 tonnes to low-Earth orbit

Cost per flight
$300 million

Pro
Cheap to develop since cargo version already flying

Con
Up to 7 years to make safety upgrades for crewed flights

Falcon 9 — SpaceX

Contracted for cargo flights to the International Space Station starting in 2010

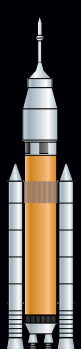
Lift capacity
10.5 tonnes to low-Earth orbit

Cost per flight
<$140 million

Pro
SpaceX claims could start flying astronauts in 2 years

Con
Newcomer status leaves some sceptical it will be ready so soon

Jupiter group — DIRECT project



Designed by anonymous NASA engineers in their spare time as alternative to Ares I

Lift capacity
39 to 96 tonnes to low-Earth orbit

Cost per flight
$100 million (39-tonne version)

Pro
Shared hardware with space shuttle simplifies development; heavy version can carry out moon missions

Con
Even heavy version less powerful than NASA's planned Ares V, requiring more manoeuvring and assembly in space for moon missions

Atlas V — United Launch Alliance

Satellite launcher developed by Lockheed Martin with US military funds

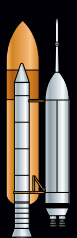
Lift capacity
13.6 tonnes to low-Earth orbit

Cost per flight
$130 million

Pro
Cheap to develop since cargo version already flying

Con
Rocket engine built outside US, complicating safety certification process

Heavy Launch Vehicle — NASA



Uses space shuttle rockets, but the shuttle orbiter is replaced by a lighter Apollo-like crew capsule

Lift capacity
72 tonnes to low-Earth orbit

Cost per flight
Not given

Pro
Off-the-shelf space shuttle components, quick to build

Con
May be difficult to eject crew capsule in emergency

10 metres

*Cost per flight to International Space Station, estimates given by each team, Ares 1 figure inferred

David Shiga

NASA's plan to return to the moon by 2020 is looking shaky – rather like Ares I, the rocket it hopes will carry astronauts to space.

The agency's Constellation project aims to replace the retiring space shuttle with Ares I, which will fly the Orion crew capsule to near-Earth orbit, and Ares V to carry a rocket and lunar lander. But to do this, NASA needs tens of billions of extra dollars over the next decade (*New Scientist*, 25 April, p 6).

Ares I has also been beset by technical problems and its advocates now find themselves struggling to defend it against rival spacecraft. What were fringe alternatives a few months ago are now being seriously considered.

Representatives argued for their concepts (see above) last week in Washington DC at the first public meeting of an expert committee tasked by the White House to recommend future spacecraft and mission options for NASA (*New Scientist*, 16 May, p 7).

An emissary from a group of rebel NASA engineers promoted a family of rockets called Jupiter. Executives from several aerospace companies pushed for various commercially built rockets. Even the NASA space shuttle manager, John Shannon, suggested an alternative, the Heavy Launch Vehicle, in which space shuttle rockets boost a light Apollo-like capsule to orbit.

All the rockets have enough muscle to take a crew capsule to the International Space Station, which is in low-Earth orbit, but only a few can handle more distant missions. The most powerful are the largest of the Jupiter group and the Heavy Launch Vehicle, each of which could provide the lift needed for moon missions. The Jupiter rocket could even bring Mars within reach, its backers claim.

NASA's current plan involves developing both Ares I and its more powerful companion, Ares V. The two rockets would rendezvous in low-Earth orbit, transferring a crew capsule from Ares I to a rocket and a lunar lander carried by Ares V. These then combine and fly to the moon, leaving the Ares rockets behind.

However, many now doubt that Congress will be willing to fund more than one new rocket, so if the agency continues with Ares I, it may be the only rocket it gets. The committee will report at the end of August. ■

Language may be the key to theory of mind

HOW blind and deaf people approach a cognitive test regarded as a milestone in human development has provided clues to how most of us deduce what others are thinking.

Understanding the mental states of others, and realising they can differ from our own, is known as theory of mind. It underpins empathy, communication and the ability to lie. But we don't acquire ToM until around the age of 4, and how it develops is a mystery.

You can test for ToM via the false-belief test, in which two children are shown playing. One puts a toy under the bed and leaves the room. The second then removes it and puts it in the toy box. On returning, where will the first child look for the toy? Those under the age of four choose the box, while older children correctly say under the bed.

Where does this leap in understanding come from? According to one hypothesis, children deduce that other people have internal experiences that are different from their own by observing the facial expressions and gestures of others over time.

To test this idea, neuroscientist Rebecca Saxe at the Massachusetts Institute of Technology and colleagues scanned the brains of 10 adults who had been blind from birth as they answered questions about the beliefs of people described to them. While most blind adults have a mature ToM, it wasn't clear whether they used the same parts of their brain as sighted people do to reason about the mental states of others.

Saxe's team showed that the same brain regions were indeed activated in the blind adults as in 22 sighted volunteers (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0900010106). They conclude that the way the brain reasons about the beliefs of others does not depend on visual observation.

Another suggestion is that ToM comes from language, which allows children to listen to people talking about their beliefs and emotions. This is backed up by the fact that language fluency and the ability to pass the false-belief test emerge at around the same age. However, previous studies have not teased apart whether language makes understanding false beliefs easier, or is a "necessary prerequisite", says Jennie Pyers, a psychologist at Wellesley College in Massachusetts.

Enter a community of deaf people in Nicaragua, who only developed a sign language in the 1970s and hence provided Pyers's team with a unique opportunity to compare two sets of people with very different levels of language ability: the first generation of signers, who created the rudimentary sign language, and adolescent signers who had worked out a more complex system of signs.

"Adults who later learned the more complex language got better at the false-belief test"

Pyers's team showed both groups videos of false-belief tests and asked them to answer by pointing at one of two images. The adolescent signers were more likely to show an understanding of false belief than the older generation (*Psychological Science*, DOI: 10.1111/j.1467-9280.2009.02377.x). What's more, adults who later learned the more complex language from the youngsters got better at the false-belief tests. The researchers say this suggests that language contributes to a mature theory of mind. Anil Ananthaswamy ■

RÜDIGER LUBRICHT/BILDERBERG/CAMERAPRESS

Soon to be green and pleasant?

Biofuels could clean Chernobyl badlands

Fred Pearce

CONTAMINATED lands, blighted by fallout from the Chernobyl nuclear disaster, could be cleaned up in a clever way: by growing biofuels. Belarus, the country affected by much of the fallout, is planning to use the crops to suck up the radioactive strontium and caesium and make the soil fit to grow food again within decades rather than hundreds of years.

A 40,000 square kilometre area of south-east Belarus is so stuffed with radioactive isotopes that rained down from the nearby Chernobyl nuclear power station in 1986 that it won't be fit for growing food for hundreds of years, as the isotopes won't have decayed sufficiently. But this week a team of Irish biofuels technologists is in the capital, Minsk, hoping to do a deal with state agencies to buy radioactive sugar beet and other crops grown on the contaminated land to make biofuels for sale across Europe.

The company, Greenfield Project Management, insists no radioactive material will get into the biofuel as only ethanol is distilled out. "In distillation, only the most volatile compounds rise up the tube. Everything else is left behind," says Basil Miller of Greenfield. The heavy radioactive residues will be burned in a power station, producing a concentrated "radioactive ash". This can be disposed of at existing treatment works for nuclear waste, he says.

The UN's International Atomic Energy Agency is not so sure, however. Its head of waste, Didier Louvat, told *New Scientist* that, while the biofuels process should be safe, neither Belarus nor Ireland has an adequate way of disposing of the radioactive residues at present. "The disposal facilities Belarus set up after the Chernobyl accident are not acceptable, so they will need safe storage until they have something better."

Belarus has been tight-lipped about the project, though it is clearly keen to tackle the problem. Last September Andrei Savinkh, Belarus representative at the UN in Geneva, called decontamination of the soil "the number one priority for the Belarus government".

Chernobyl is in Ukraine, close to the Belarus border. But prevailing winds meant 80 per cent of the fallout from the burning reactor fell in Belarus. Both were then part of the Soviet Union. The accident left vegetation and soils heavily contaminated with strontium-90, caesium-137, plutonium and americium. The most heavily polluted areas remain evacuated but 8 million people live in a much wider contaminated zone.

Farmers grow some grain crops here. The radioactive material concentrates in roots and stalks, which they plough back into the soil after harvesting. So the soil is almost as contaminated now as it was after the accident. The Belarus government hopes that by growing biofuels and using the whole plant, it can cleanse the soil. "Instead of centuries of natural decay [of the radionuclides] this process will cut the time to 20 to 40 years," Savinkh says.

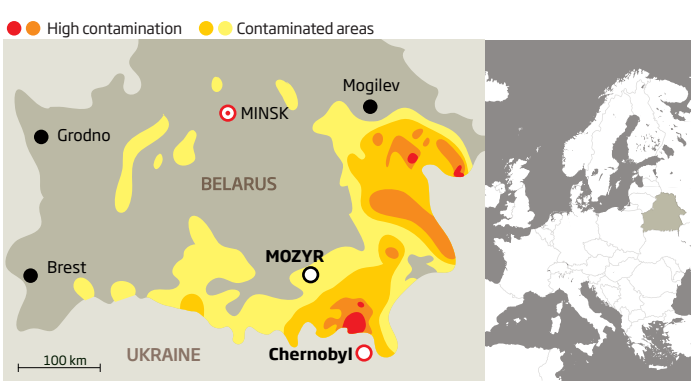
Greenfield plans to build the first biofuels distillery next year at Mozyr, close to one of the most contaminated areas (see map). The €500 million plant will turn half a million cubic metres of crops a year into 700 million litres of biofuels, starting in 2011. As many as 10 more plants will follow provided funding can be raised, says Miller. The European Union reckons it will need about 25 billion litres of bioethanol by 2020 to meet green fuel targets.

One of Greenfield's partners will be Belbiopharm, a state biotech company that wants to develop genetically modified crops able to clean the soil more quickly.

The hope is that in the long run these measures will make life safer for local people. A study in 1999 by Nick Beresford of the Centre for Ecology and Hydrology in Lancaster, UK, found that tens of thousands of people in the contaminated region are consuming dangerous levels of radioactivity in their food. ■

Contamination in Belarus

Planting biofuel crops in areas contaminated by fallout from Chernobyl could help "clean" the land within decades




KEREN SU/CORBIS

Great white sharks are the serial killers of the ocean

GREAT white sharks have more in common with serial killers than just their fearsome reputation. Unlike most predators, their hunting strategies are far from random. When deciding where to launch their attacks, they balance prey availability with factors such as finding a good hiding place – just as serial killers do.

Little was know about great whites' hunting strategies except that they are more successful in low-light conditions. So Neil Hammerschlag of the University of Miami, Florida, and his colleagues used geographical profiling, a tool more commonly used by police tracking down serial killers, to investigate how sharks hunt for Cape fur seals off Seal Island in South Africa. The team used the locations of 340 shark attacks to determine whether they were striking at random or setting out from particular "anchor points".

When the team fed their results into a computer model, it suggested that great whites don't attack at random but from well-defined anchor points or lairs (*Journal of Zoology*, DOI: 10.1111/j.1469-7998.2009.00586.x). "This wasn't where the seal concentration was greatest," says Hammerschlag. He suspects it was a balance between prey detection, competition with other sharks and environmental conditions that allow them to launch a quick vertical attack where the water is clear enough to see the seals.

Sun leaves Earth wide open to cosmic rays

THE sun provides ideal conditions for life to thrive, right? In fact, it periodically leaves Earth open to assaults from interstellar nasties in a way that most stars do not.

The sun protects us from cosmic rays and dust from beyond the solar system by enveloping us in the heliosphere – a bubble of solar wind that extends past Pluto. These cosmic rays would damage the ozone layer, and interstellar dust could dim sunlight and trigger an ice age. However, when the solar system passes through very dense gas and dust clouds, the heliosphere can shrink until its edge is inside Earth's orbit.

In a paper to appear in *Astrobiology*, David Smith at the University of Arizona in Tucson and John Scalo at the University of Texas, Austin, calculated the squeezing of various stars' protective "astrospheres". They found Earth is exposed to between one and 10 interstellar assaults every billion years. Habitable planets around a red dwarf, which account for three of every four stars, are never exposed. That's because they need to be close to these dim stars to be warm enough to be habitable. "The bottom line is that habitable planets around red dwarfs are better protected from climate catastrophes than Earth is," says Smith.

Gangster leaning is in your genes

MEN with gene variations linked to aggression are more likely to join a gang.

About one-third of men have the low-activity version of the gene *MAOA*. This has previously been shown to increase aggression in men who were abused as children.

Kevin Beaver, a criminologist at Florida State University in Tallahassee, and colleagues looked at the version of *MAOA* present in about 2000 people, and asked about their involvement with gangs. They found that men with low-activity *MAOA* were twice as likely to have joined a gang as those with the normal version. Among gang members, men with low-activity *MAOA* were four times more likely to have used a weapon. No correlation was found for women, who are less likely to have this variant (*Comprehensive Psychiatry*, DOI: 10.1016/j.comppsych.2009.03.010).

Giant sperm have long history

THERE'S sperm, and then there's super sperm – many times longer than the minute crustaceans that produce them. Now it seems that ostracods, or seed shrimp, have been producing giant sperm for at least 100 million years.

Renate Matzke-Karasz at Ludwig Maximilian University in Munich, Germany, and colleagues produced 3D images of 100-million-year-old fossil ostracods by firing X-rays through them. The images show two large sperm pumps called Zenker's organs, resembling those found in living giant-sperm-producing ostracods (*Science*, DOI: 10.1126/science.1173898).

Such a long history of giant sperm points to intense sexual competition between males, says Matzke-Karasz.

Mars may have secret water table

THE Red Planet could have a water table hidden underground, despite satellite data suggesting otherwise.

Today the small amount of water detected on the planet is locked in the polar ice caps, but recently discovered geological features suggest liquid water once flowed on its surface. This could now be hiding beneath the rocky crust.

The European Space Agency's Mars Express satellite has used ground-penetrating radar in some areas to look for a water table but found no evidence for one, despite research that concluded any water would be found within 9 kilometres of the surface – well within the reach of the probe's instruments.

Planetary scientist Bill Farrell of NASA's Goddard Space Flight Center in Greenbelt, Maryland, and colleagues will argue in *Geophysical Research Letters* that we shouldn't give up the search just yet, however. The satellite's radar signal should bounce back from shiny surfaces like water. But the team calculates that if the layer of rock and icy soil above the water table is particularly conductive, it could be absorbing enough energy from the radar to obscure a telltale signal.

Farrell says the work will be useful for missions to other icy bodies too: "We don't want future geologists to look at their radar data and say no reflectance means no aquifer."

(G. NEUKUM) FU BERLIN/DLR/ESA

Transplant drug turns traitor to boost vaccines

IT'S the biological equivalent of a turncoat. A drug used to stop immune cells from gobbling up transplanted organs and bone marrow has been caught boosting the immune response to a virus in mice and monkeys. It might now be used to enhance vaccines against cancer and other diseases.

Transplant recipients take rapamycin because it blocks the production of a range of different immune cells. But when Rafi Ahmed and colleagues at Emory University School of Medicine in Atlanta, Georgia, gave the drug to mice infected with a virus, to probe its effects on specific parts of the immune system, they found it can have another effect. The mice produced more memory T-cells, which kick in when bugs come back, than mice not given the drug. "We were completely surprised," says Ahmed.

The mice treated with rapamycin also ended up with better quality memory T-cells than the control mice. These cells could respond faster and more effectively to a future infection with the same virus (*Nature*, DOI: 10.1038/nature08155). Rapamycin had the same effect in mice and rhesus macaques when given alongside a vaccine.

Although the team did not measure it specifically, Ahmed suspects that the drug was also suppressing parts of the immune system in the mice and monkeys, just as it does in transplant recipients. To use rapamycin as a vaccine booster in people will mean finding a dose that raises memory T-cell count and quality but keeps immunosuppression to a minimum, says Ahmed.

Exit dinos, pursued by elephants

YOU wouldn't have recognised *Eritherium* as an elephant when it was roaming Morocco 60 million years ago. It weighed only 5 kilograms, and its canines were nothing like tusks. But detailed study of the newly discovered fossil's teeth, jaws and skull shows it to be the oldest member yet found of the order Proboscidea, of which elephants are the only living survivors.

The new find may shed light on the origins of elephants and other mammals, says Emmanuel Gheerbrant of the French National Museum of Natural History in Paris (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0900251106). It shows elephants were making evolutionary progress 5 million years after the dinosaurs died out. "The discovery of *Eritherium* supports an explosive radiation of placental mammals" in that period, he says.

This contrasts with the idea that the evolutionary roots of most modern groups go back long before the dinosaur extinction. Analysis of the DNA of living mammals supports that timetable, but palaeontologists say that fossil evidence is lacking.

ROY MCMAHON/CORBIS/JUPITER

Brain sees tools as limb extensions

WHEN you brush your teeth, the toothbrush may actually become part of your arm – at least as far as your brain is concerned. That's the conclusion of a study showing perceptions of arm length change after people use a mechanical tool.

The brain maintains a physical map of the body, with different areas in charge of different body parts. Researchers have suggested that when we use tools, our brains incorporate them into this map.

To test the idea, Alessandro Farnè of the Université Claude Bernard in Lyon, France, and colleagues asked 14 volunteers to use a mechanical grabber to pick up distant objects. Shortly afterwards, the volunteers perceived touches on their elbow and fingertip as further apart than they really were, and took longer to point to or grasp objects with their hand than before they used the tool.

The team say that their brains may have adjusted the areas that normally control the arm to account for the tool and not yet adjusted back to normal (*Current Biology*, DOI: 10.1016/j.cub.2009.05.009). "This is the first evidence that tool use alters the body schema," says Farnè.

OWEN FRANKEN/CORBIS

Close your eyes

Halt or we'll dazzle you

THE Pentagon is working on a laser dazzler that will force drivers to stop without harming their eyes.

When a vehicle approaches a checkpoint at speed, ignoring warning signs to slow down, troops do not know whether the driver is simply careless or a suicide bomber. They need a clear and harmless way of forcing drivers to stop.

Green laser dazzlers designed to temporarily blind drivers were sent to US forces in Iraq and Afghanistan for just this purpose. But at short range they can damage the eye, and a number of US troops and civilians have ended up in hospital with eye injuries after "friendly fire" incidents.

Now the US Department of Defense's Joint Non-Lethal Weapons Directorate (JNLWD) in Quantico, Virginia is developing a pulsed laser designed to prevent eye damage. Its wavelength means a portion of the light is absorbed by the vehicle windscreen, vaporising the outer layer of the glass and producing a plasma. This absorbs the rest of the

"US troops and civilians have been sent to hospital with eye injuries after 'friendly fire' incidents"

pulse and re-emits the energy as a brilliant white light that is dazzling but harmless.

Because the light is emitted from the windscreen, the effect on the driver's eyes should be the same regardless of the vehicle's distance from the laser.

Scott Griffiths of the JNLWD says it hopes to have a working prototype ready by next year.

Taxibot could save airlines billions

ROBOTIC tractors could one day be used to tow aircraft between the airport gate and the edge of the runway. This could save airlines $7 billion a year in fuel costs and cut 18 million tonnes of carbon dioxide from aviation's annual emissions.

Jet engines run at their most inefficient when used to propel planes around the taxiways. To get around this problem, the European aircraft manufacturer Airbus and the military robot maker Israel Aerospace Industries are working together to create a "taxibot" that docks with an aircraft's nose landing gear to tow the plane.

Pilots would guide the taxibot using their regular joystick and pedal controls. "To the pilot it would feel no different to normal taxiing with the engines," says Airbus engineer Marc Lieber.

494

The quantity of data in exabytes (10^{18} bytes) sent round the world on 15 June

Source: *Digital Britain* report, published by UK government last week

Feathers hold hydrogen promise

NEED a cheap way to store hydrogen? Put chicken feathers in your tank. The unlikely material may one day compete with more high-tech solutions such as carbon nanotubes for storing hydrogen for fuel-cell-powered vehicles.

Hydrogen is difficult to store safely in a tank because it is potentially explosive. So researchers are looking for materials that can stabilise hydrogen by weakly bonding with it. Richard Wool's team at the University of Delaware in Newark heated chicken feather fibres to 400 °C without burning. The process resulted in stable, porous carbonised fibres. When cooled to -266 °C, the material could store almost 2 per cent of its weight in hydrogen – almost as much as carbon nanotubes. While still shy of the US Department of Energy's target of 6.5 per cent, the feathers' abundance and price hold promise: chicken feathers are a huge waste problem in Delaware.

"You can afford carbon nanotubes if you want to go to the moon, but if you just want to go to the grocery store, you need something cheaper," says Wool, who presented the results last week at the Technologies for a Hydrogen Economy symposium at the University of Maryland University College in Adelphi.

"Another month for me!"

Japanese astronaut **Koichi Wakata**, who is on board the International Space Station, reacts favourably to the news that a fuel leak has prevented the launch of the space shuttle Endeavour, delaying his ride home until at least 11 July (NASA Twitter feed, 17 June)

When consoles and convalescence collide

Hand-amputee "guitar heroes" and people with Parkinson's playing virtual bowling and tennis – all in the name of physical therapy

Jim Giles

BOB ROHRMAN has never had much time for computer games. He was given a console a year ago, but stopped using it after a few weeks. It's not surprising: Rohrman is 67 and suffers from tremors caused by Parkinson's disease. "The only thing I knew how to play was solitaire," he says.

But in January, Rohrman got gaming again, thanks to Ben Herz, an occupational therapist at the Medical College of Georgia in Augusta. Herz had the retired truck driver play sports games on the Nintendo Wii, a console controlled by a hand-held wand that detects movement and gestures. In tennis games, for example, players swing this "Wiimote" as they would a racket. That meant Rohrman was getting a regular workout.

After playing 3 hours a week for about a month, he claimed he was a changed man. "I can move better, walk better, coordinate better," he said.

The benefits of exercise are well known, but active console games have several advantages over traditional workouts. Video games are designed to be engaging but not too challenging – players should spend most of their time in the sweet spot between too easy and too hard. And unlike jogging or swing-ball, video games can be played in the living room, where bulging waistlines and appalling skill levels can be kept safely from public view.

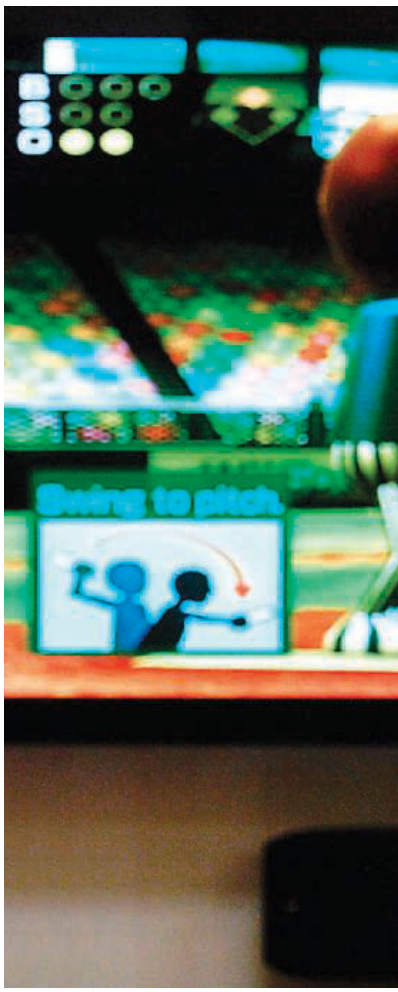
"After playing tennis on a Nintendo Wii 3 hours a week for about a month, he was a changed man"

Now physical therapists are starting to think that devices like the Wii, which are relatively cheap and come with addictive games, can help patients fight disease and speed rehabilitation. There have not been any large-scale trials of the consoles, but several published case studies suggest that the technology has big therapeutic potential. "It's transforming the kind of interactions patients can have with a computer," says Bob Hone, a software engineer who has developed Wii applications to help people with Parkinson's.

Herz has begun to assemble the data that could prove the idea. In a study of about 20 subjects, he has showed that playing bowling, tennis and baseball games improved the performance of people with Parkinson's on a range of physical tests, such as the ability to stand up and walk a short distance. The participants also got a boost to their mental health: about three-quarters showed at least a 10 per cent improvement on a standard assessment for depression.

This effect may be due to changes in levels of the brain chemical dopamine. Parkinson's disease is caused by a lack of the chemical, and both exercise and computer games have been shown to increase levels. "My hope is that this will slow the progression of the disease," says Herz, who presented his results at the Games for Health conference in Boston this month.

Other researchers are modifying games in a bid to expand the range of patients who can be helped. Jacob Vogelstein at Johns Hopkins University in Baltimore, Maryland, and Jonathan Kuniholm of Duke University in Durham, North Carolina, are developing a new kind of prosthetic limb. Many hand amputees retain muscle function in their forearms, and Vogelstein's prosthetics can be controlled by the electrical signals generated by these muscles. But these artificial limbs are not due for completion until 2010, so he needed a way of keeping his patients' muscles from



SARA D. DAVIS/GETTY

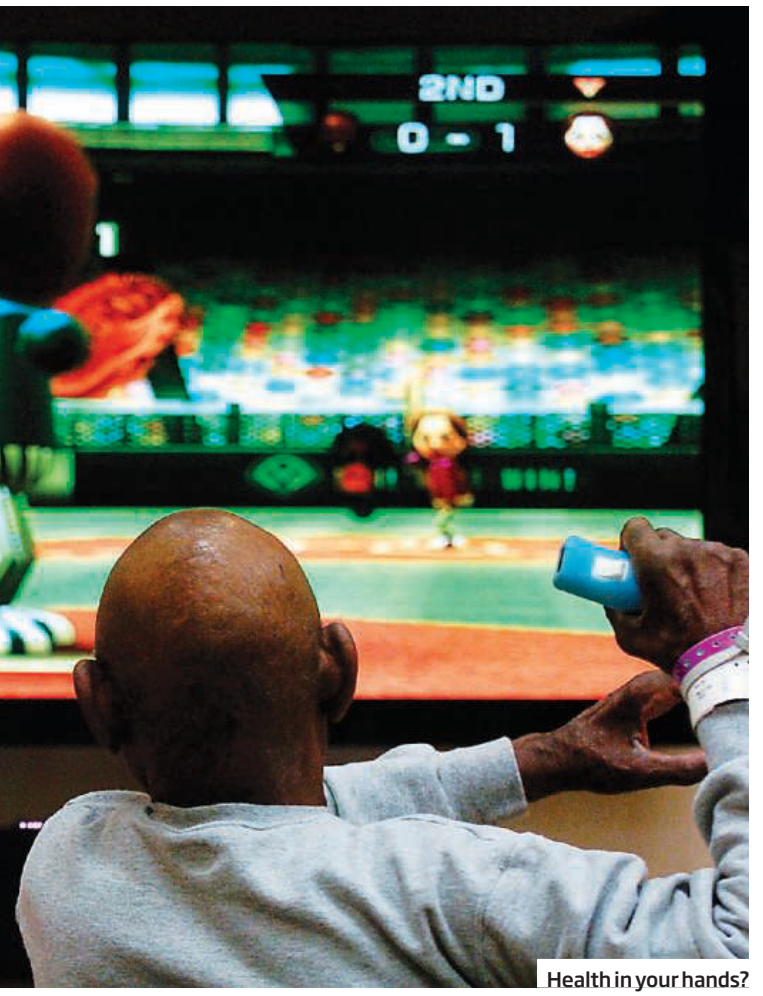
Whole-body gaming

The gaming industry sat up this month as Microsoft unveiled Project Natal – a device that turns a player's body into a game controller. Two cameras monitor the player and map their movements onto an on-screen avatar. In a demonstration at the E3 gaming conference, held in Los Angeles, a player kicked and batted virtual balls as they bounced towards her virtual self.

It is not just the gaming community that is hanging on the release date for this new device. Software engineer Bob Hone of Red Hill Studios in Larkspur, California, says that Project Natal could be used to help Parkinson's patients with their balance. He imagines a game in which players assume different poses and receive real-time feedback from the console as they close in on their target position.

And there is certainly more to come. The video games market is intensely competitive and Microsoft's announcement is in part a response to Nintendo's successful "Wiimote" controller. If Project Natal is a hit, Nintendo and Sony will aim to make even more sophisticated controllers.

Since console makers sell new controllers relatively cheaply, they are always within reach of physical therapists and their patients. So every new launch brings with it a potential therapeutic benefit. "We're just at the beginning," says Hone.



Health in your hands?

atrophying in the meantime.

The solution: a hacked controller from Guitar Hero, a game that challenges players to tap out a melody using five buttons on the neck of a mock guitar. Vogelstein modified the device so that it could be driven by signals picked up by electrodes placed on the arms of amputees instead. The same signals will be used to control the prosthetic limb. Guitar Hero is more compelling than any "gimmicky rehab game", says Vogelstein, and amputees quickly learn how to use the modified controller.

Promising case studies abound, but the field is still short on hard evidence. Herz, Hone and Vogelstein are all planning large-scale clinical trials, but no game has undergone rigorous testing yet. As a result, almost nothing is known about how long patients should play for, or which types of game bring the most benefit.

Boredom with the games may also be an issue. In 2005, Brock Dubbels at the University of Minnesota in Minneapolis started studying the potential fitness benefits of Dance Dance Revolution, a game in which players copy on-screen dance moves on a touch-sensitive mat. He could not get enough children to play regularly enough to produce meaningful results.

These questions will be addressed in upcoming clinical trials, but Rohrman is not waiting on the results. His Wii console is no longer mothballed: "When I saw what it could do for me, I thought I should stick with it." ■

Bloodhound on the trail of land speed record

WHEN the supersonic car Bloodhound SSC streaks across the desert sometime in 2011 in its bid to break the land speed record, it will be powered by no fewer than three different types of engine.

A rocket will boost the car to around 1200 kilometres per hour, (Mach 1) while a Eurofighter jet engine will provide more controllable thrust to coax it up to 1600 km/h. Finally, the car is equipped with a V12 petrol engine to pump the fuel and provide electrical and hydraulic power to the jet and rocket.

The car is being developed by a team led by Richard Noble whose Thrust SSC has held the land speed record of 1221 km/h or Mach 1.02 since 1997. Bloodhound SSC is designed to break the 1600 km/h barrier.

While the jet and petrol engines are well-established technologies, the team is building the rocket motor from scratch. The engine is a hybrid design that uses liquid hydrogen peroxide as an oxidiser to burn solid polyethylene, the same stuff that plastic bags are made of. Hydrogen peroxide is squirted into one end of a hole running down the centre of a cylinder of polyethylene, burning the plastic from the inside out. This creates a supersonic flow of exhaust from the other end of the cylinder, which pushes the rocket forward. Changing the flow of hydrogen peroxide alters the thrust.

Last week, Noble announced that his team had completed the first tests of a ⅓-scale prototype rocket engine at a test site in the Mojave desert in California. One way to judge the performance of a rocket engine is to examine the telltale diamond patterns in its exhaust which are formed by reflected supersonic shock waves. "This first engine looks to be functioning very efficiently from the shape of the flame and the distinct Mach diamonds," says Adam Baker, an expert on hybrid rocket engines with Surrey Satellite Technology, a space technology company in Guildford, UK.

"The Bloodhound supersonic car is designed to go faster than 1600 kilometres per hour"

The next stage of the project may be more challenging. "Scaling up hybrids can be difficult because the fluid flow inside the engine can change significantly as the size of the port in the fuel goes up," says Baker. Tests of a larger hybrid engine are scheduled to start on 2 July. Robin Hague ■


CURVENTA
Rocket plus jet equals speed

BEN BIRCHALL/PA

Don't let the trail go cold

Cryogenic ID chips could put an end to IVF mix-ups

AN ELECTRONIC ID tag that works even when cryogenically frozen could help prevent some of the mix-ups in IVF clinics that can cause heartbreak for would-be parents.

Last week, a couple from south Wales, UK, made headlines worldwide when they revealed that their last viable embryo had been taken from cryogenic storage at an IVF clinic in Cardiff and mistakenly implanted into another woman. The recipient, on learning of the bungle, terminated her pregnancy.

There were eight similar "class A" IVF mix-ups in 2008 in the UK fertility industry, according to its regulator, the Human Fertilisation and Embryology Authority. Class A means the wrong eggs, sperm or embryo were used in an IVF procedure. Such mix-ups occur when eggs, sperm or embryos are mislabelled due to slips in a lab's verification procedures.

Part of the solution is a system called IVF Witness, which constantly monitors the identity of the gamete and embryo containers that are brought near to each other on the IVF lab bench – sounding an alarm if eggs about to be introduced to sperm, say, have come from the wrong woman.

The system, made by Research Instruments (RI) of Falmouth, UK, is installed in 16 of the nation's 90 IVF clinics. It uses 15-millimetre-square, sticky-backed plastic radio-frequency identification (RFID) tags to label any dishes or vials that eggs, sperm or embryos are placed into. The tags house a memory chip and a coiled copper radio antenna. Each tag's memory is programmed with a unique ID code that is transmitted by its antenna when an ultra-low-power radio pulse interrogates the chip.

As a sample moves through the IVF process, the ID code of every container it is placed in is logged, providing a secure ID audit trail. So, in theory, only sperm and eggs from the right couples can be brought together, and the resulting embryos will be implanted into the right woman.

There's just one problem: the RFID tags do not work at -196 °C – the temperature of liquid nitrogen – and so cannot be used with gametes and embryos that are cryogenically stored.

The reason is twofold, says RI's technical director David Lansdowne. The low temperature raises the conductivity of the copper antenna, shifting its working frequency beyond that of the RFID reader. And as the temperature drops, the voltage needed by the RFID chip's transistors to switch on and off (to "squawk" out its ID code) increases until it cannot draw enough power from the field generated by the reader's signal.

So RI has developed a new type of tough plastic RFID tag that works at cryogenic temperatures. Its antenna – a copper coil wrapped around a piece of ferrite – maintains its low-temperature frequency in the readable range. And the chip is built from novel, enlarged transistors with many more charge carriers, enabling it tap enough wireless power from the reader's signal.

"Their last viable embryo was taken from cryogenic storage and implanted in the wrong woman"

Andy Glew, director of embryology at the Herts and Essex Fertility Centre in Cheshunt, Hertfordshire, UK, welcomes the idea: "By tracking the gametes and embryos through every step of the process, the risk of disaster can be avoided." **Paul Marks** ■

Methane first, OK?

Reducing carbon dioxide emissions will be vital in the long run, but we should start by tackling methane, says **Kirk Smith**

WHEN the UN Framework Convention on Climate Change came into force in 1994, climate change's impacts seemed distant. Not any more. With daily reports of changes to glaciers, ice sheets, oceans and ecological systems, climate change seems upon us.

As a result, the debate over what to do is changing. Geoengineering schemes, once considered nearly science fiction, are now discussed seriously. Most attention, though, has focused on reducing emissions of carbon dioxide.

There is no question that to stop climate change in the long run requires a substantial reduction in CO_2 emissions. However, significant opportunities exist to slow warming over the next few decades by reducing emissions of other greenhouse gases.

Only about half the warming that has occurred up to now is due to CO_2. The rest is caused by other greenhouse gases, particularly methane (*Proceedings of the National Academy of Sciences*, vol 97, p 9875). Similarly, less than half of the total warming expected over the next 20 years will be caused by CO_2. Methane, along with other gases such as carbon monoxide, volatile organic compounds (VOCs) and black carbon particles, will cause most of the changes.

Recent modelling shows the way to have the biggest impact on warming over this century is to immediately reduce emission of these gases, and keep them low (*International Journal of Climate Change Strategies and Management*, vol 1, p 42).

Methane is a much more powerful greenhouse gas than CO_2. A tonne of methane is responsible for nearly 100 times more warming over the first five years of its lifetime in the atmosphere than a tonne of CO_2. Methane is removed from the atmosphere much more rapidly than CO_2, with a half-life of 8.5 years compared with many decades for CO_2, but a tonne of methane eventually turns to 2.75 extra tonnes of CO_2 in the atmosphere. Even without taking this into consideration, a tonne of methane emitted today will exert more annual warming than a tonne of CO_2 emitted today until 2075. Not until the year 7300 will the cumulative warming exerted by the two become equal. It is truly carbon on steroids.

This makes methane a good target for emissions reductions. Indeed, methane's shorter lifetime means that atmospheric levels are much more responsive to reduction by emissions cuts.

Another important consideration is the impact on human health. Of all the greenhouse gases, CO_2 is one of the least damaging. Methane, on the other hand, is a precursor of ground-level ozone, which is a toxic air pollutant. Carbon monoxide, VOCs and black carbon particles are also directly harmful to human health.

"For the first five years, methane causes nearly 100 times the warming of the same weight of CO_2"

The global health burden from these air pollutants exceeds that of any other environmental risk and even that of some major diseases, including malaria and TB. Cutting methane emissions and those of other health-damaging greenhouse pollutants would thus save many lives.

More serious attention to methane would also change the terms of climate change negotiations, possibly for the better. Taking methane into account would shift some of the burden of responsibility onto developing countries. It may seem unfair to make developing countries more accountable for warming than they are now. But on the other hand, a range of new opportunities would arise for them to participate in tackling global warming. They could therefore benefit from schemes that reward progress in reducing emissions.

Why, then, are methane and the other non-CO_2 greenhouse gases not more prominent in discussions over global warming? One reason is that the official weighting scheme to assess the relative impacts of greenhouse gases is out of date and too focused on long-term warming.

According to this scheme, a tonne of methane is equivalent to 21 tonnes of CO_2 over a 100-year period. This is out of date – current estimates put the ratio at 25 or more. More importantly, the timescale is all

wrong given the urgency we now face. It gives equal weight to measures that will reduce warming in 2109 and warming next year. This is a rather odd perspective: surely reducing next year's warming should be the priority.

Reducing methane levels in the atmosphere would arguably be less painful than reducing CO_2. The technology already exists, and reductions would be politically and economically easier to implement. Methane is also easier to handle in international negotiations than black carbon, the next most important non-CO_2 greenhouse pollutant, because its impacts are better understood.

Global methane emissions are divided roughly equally between the energy sector (coal mine emissions and leaks from oil and gas wells), waste management (landfill, waste water and animal manure) and agriculture (mainly rice paddies and emissions from livestock).

Reducing livestock and rice production would require changes in consumption, but that is not the case with waste handling and leaks from fossil-fuel systems. Fixes for these do not directly threaten lifestyles and are amenable to direct regulation; no need for controversial carbon taxes or cap-and-trade schemes.

We urgently need measures that can help keep Earth from overheating while we work to control CO_2 emissions. Doing all we can to reduce methane emissions makes more sense than embarking on risky geoengineering schemes.

This fruit is low-hanging, ripe and heavy with immediate benefits. Helping to pick it also means I can tell my grandchildren that, yes, I did do something to directly protect the planet. ■

Kirk Smith is professor of global environmental health at the University of California, Berkeley

Viewfinder

Opinions from around the world

"If you sold strawberry jam that contained not a trace of strawberry you'd be in trouble."

Pharmacologist **David Colquhoun** of University College London in the medical journal *BMJ*, slamming the UK authorities over their decision to license homeopathic treatment for bruises

"The unrest unfolding in Iran is the quintessential 21st-century conflict. On one side are government thugs firing bullets. On the other side are young protesters firing tweets."

Editorial in *The New York Times*

"The current debate about global warming is clearly harmful. I believe that it is time we demanded that the media stop scaring us and our kids silly. We deserve a more reasoned, more constructive, and less frightening dialogue."

Self-styled "sceptical environmentalist" **Bjørn Lomborg** in *The Guardian*, London

SHADISHD173/AFP/GETTY

Good week for...

The Science Museum The popular London attraction celebrates its 100th birthday on 26 June

Bad week for...

Nuclear fusion (again) ITER, the international project to build a revolutionary energy source, is mired in rising costs and technical problems, pushing the prospect of commercial nuclear fusion even further into the future

In the polls

1 in 3

Proportion of American children aged 6 to 11 who are afraid that the Earth will cease to exist before they grow up because of global warming and other problems

Open letter to all UK chiropractors

From Edzard Ernst, Complementary Medicine Group, Peninsula Medical School
This is an invitation to all UK chiropractors to stop the confusions, misunderstandings and animosities that arose during the recent debate about the effectiveness of chiropractic for non-spinal conditions such as asthma and otitis. I herewith invite all of you to state clearly where you stand.

Many of your websites promote chiropractic as a treatment of these conditions, and the General Chiropractic Council's own survey of 2004 shows that 57 per cent of you believe that asthma can be "treated or managed by chiropractors".

For other non-spinal conditions, the figures are similar. I have seen no convincing evidence that chiropractic or chiropractic spinal manipulation is effective for these conditions. For asthma, the evidence I have seen is even squarely negative (*Journal of the Royal Society of Medicine*, vol 99, p 192).

However, the same survey demonstrates that 90 per cent of chiropractors support evidence-based practice principles and that 99 per cent of you use spinal manipulation – producing a somewhat contradictory overlap.

I therefore invite you to let the British public know, through your professional organisations, which of these three possible explanations is correct: you no longer hold that chiropractic is an effective treatment for non-spinal conditions like asthma, you admit that the inclusion of treatment of non-spinal conditions in chiropractic means that it can no longer be considered an evidence-based profession, or you can provide good evidence that chiropractic can treat non-spinal conditions.

I await your response with interest.
Exeter, UK

Ancient secrets

From Elizabeth Young
Andrew Robinson tells us the Etruscans were a "prehistoric civilisation that arose in western Italy – in what is now Tuscany and parts of Umbria" (30 May, p 24). In fact, the great Etruscan civilisation – the Etruscan Federation – arose in today's northern Lazio, including Rome itself, as my husband and I detail in our book *Northern Lazio: An unknown Italy*.

The Etruscans' great towns and infrastructure were remarkable. The Romans, who might have been an Etruscan tribe that overpowered the others, built on Etruscan technologies, but always bypassed the old Etruscan centres where they could.

Their language remains inscrutable but the old local language might provide some helpful clues to its comprehension, as is the case in other parts of Italy. "Lingua Toscana in bocca Romana" (the Tuscan tongue in a Roman mouth), seen as the ideal for spoken Italian, has long been recommended for the educated in an Italy full of local languages. What was the "lingua romana" that the educated should avoid: was it something which might still resemble Etruscan? Or did it resemble Romanesco, the dialect still used in Rome today?

I was taught Italian in the Roman market place of San Cosimato. I was firmly told never to name vegetables in other markets: "always point, the names would probably be obscene". Perhaps they were Etruscan?
London, UK

From George Louridas
Andrew Robinson's article on decoding antiquity does not mention the Lemnian language (30 May, p 24).

The inscription found on a funerary stela on the Greek island of Lemnos and fragments of inscriptions on local pottery are indicative of a spoken language. The inscriptions portray an alphabet similar to the Etruscan language. According to Robinson's classification system, this ancient script should fall into the category of a known script of an unknown language.

Does the author consider Lemnian similar to Etruscan, or is it just a simple omission in this vast field?
Thessaloniki, Greece

From Duncan Cameron
We have some interesting undeciphered texts in the UK. The Ogham alphabet was developed in the post-Roman period in Ireland for writing inscriptions in Goidelic, the ancestor of modern Irish.

However, there are around 30 Ogham inscriptions from Scotland that seem to be in an unknown language. The language may be Pictish, which was spoken by tribes that lived in Northern Britain after the late Roman period, but subsequently disappeared after the Viking invasions.
Brighton, UK

Andrew Robinson writes
■ The field of undeciphered scripts is huge. The inscription from Lemnos is indeed written in an alphabet and language akin to Etruscan, but it is not the same. I would have liked to include Ogham, although it cannot be considered one of the world's great undeciphered scripts.

Circus cruelty

From Craig Redmond, The Captive Animals' Protection Society
You report on a study of animal

Enigma Number 1551

The same chance

RICHARD ENGLAND
Harry and Tom each had a set of 15 red and six coloured snooker balls. Each of them had a bag, into which he put one or more of the red balls and four or more of the coloured balls from his set. Although Tom put more balls into his bag than Harry put into his bag, each of them calculated that if he picked four balls out of his bag simultaneously at random there was a 1 in X chance that all four would be coloured.

X represents the same number for each of them. What number?

WIN £15 will be awarded to the sender of the first correct answer opened on Wednesday 29 July. The Editor's decision is final. Please send entries to Enigma 1551, New Scientist, Lacon House, 84 Theobald's Road, London WC1X 8NS, or to enigma@newscientist.com (please include your postal address).
Answer to 1545 Dressed up to the nines: The numbers were 413, 568 and 927
The winner Johan Uys of Bellville, South Africa

circuses by the University of Bristol, UK (23 May, p 5). The British government is still stalling over a pledge made three years ago to stop wild animals appearing in circuses. This timely study shows why it must follow through on its commitment.

It shouldn't really take a scientist to make it obvious that a travelling circus, by its very nature, cannot meet the needs of animals. The inconstant conditions, brought about by weekly relocation, mean that animals often don't have access to exercise or grazing and are confined to cages or small stalls. A few minutes in the ring will not provide sufficient enrichment, particularly if training is carried out with force or cruelty.

UK circuses still use elephants, tigers, lions and even a red fox. A ban can't come soon enough for these animals. The same ethical objections apply to domesticated animals used for entertainment; they endure the same welfare and confinement problems as the non-domesticated species.

The Captive Animals' Protection Society, working with other charities, is lobbying hard for the government to bring animal use in circuses to an end. In the meantime, we encourage people to visit only those shows that rely entirely on the skills of human performers.
Manchester, UK

Flat Earth

From Mark Brandon
In discussing whether the universe is flat, Eugenie Samuel Reich compares this premise to the myth that once upon a time, we believed the Earth was flat (16 May, p 15).

However, if the BBC's *QI* programme is correct, and its entire stall is set out on reporting the truth, there is no evidence whatever that people ever believed the world was flat. Chaucer didn't, and Columbus

believed it was pear-shaped. It quotes "leading Medievalist" Terry Jones as pouring cold water on the theory, and where Jones goes, I tend to follow. So, the gauntlet is down: can you cite any evidence that our forebears believed in a flat Earth?
London, UK

The editor writes:
■ Terry Jones specifically addresses what was known in the Middle Ages. Many ancient cultures, such as that of ancient China, did indeed think the Earth was flat.

The two vectors

From David Gilbert
C. P. Snow correctly identified the self-segregation of our intellectuals into two mutually isolated cultures (2 May, p 26), but he did not understand the reason behind their mutual contempt, which is their "vector disparity".

Any thought process can be classified into one of two modes, either analytical/investigative or creative/constructive. Both cultures include examples of both modes of thought, but they differ in the vector relationships between them.

In science, we have analytical activities such as chemistry and physics, and constructive activities such as engineering and medicine. The creation of a building depends on the underlying physics, and achieving a medical cure depends on the underlying biology.

In the humanities we also have analytical activities, such as history and musicology, and creative activities such as composition, performance, statesmanship and military command. But here the vector operates in the opposite direction. For example, the historian is dependent on the actions of politicians and generals.

Unconsciously, each culture has developed a yardstick for its own activities and then applied it inappropriately to the other. In science the yardstick says that analysis is primary (creative, good) and construction is secondary (derivative, less good). In the humanities, on the other hand, construction is primary (imaginative, good) while analysis is secondary (pedantic, less good).

It is the inappropriate use of these yardsticks that has caused Snow's "two cultures" to drift into mutual incomprehension. A physicist, for example, may think of a sculptor as a "mere manufacturer" while the sculptor may think of the physicist as a "mere dismantler".

Perhaps if our educators were to teach this disparity in vector relationships, the two cultures might learn to get along with each other a little better.
Weston-super-Mare, Somerset, UK

Ballast buoyancy

From David Hobday
I think Feedback and Paul Spicker took a poorly aimed shot at the advertisement for "5 star Luxury European River Cruises" when remarking on its assertion that the cabin windows don't sink below water level "even when passing under low bridges" (30 May).

Our vintage paddle steamers on the Murray river often need to adjust their ballast water to ensure safe clearance under the lowest bridges. I suspect that the cruisers in the ad also have such a facility. The fuel saved by keeping the vessel as light as possible outweighs the cost of increasing the draught occasionally.
Bateau Bay, New South Wales, Australia

Black Sea life

From Pamela Kemp
In his review of Alanna Mitchell's *Seasick*, Fred Pearce states that the Black Sea "has been lifeless for thousands of years" (9 May, p 45). This is not true: the upper levels of the Black Sea have lots of aquatic life. It is only the lower level which is anoxic.
Mauzac et Grand Castang, France

For the record

■ **In our story on premature babies' posture and IQ, we should have said that researchers filmed the babies 11 to 16 weeks after their expected birth date, had they reached full term, rather than after their actual birth date (13 June, p 12).**

■ **The correct link to the work by Mark Bulmer of Towson University, Maryland, on using glucose to combat termite troubles is DOI: 10.1073/pnas.0904063106 (13 June, p 14)**

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Knowledge wants to be free too

When technology makes knowledge globally available, reshaping the economics of buying and selling it becomes crucial, argues **Peter Eckersley**

TEN years ago, a piece of software called Napster taught us that scarcity is no longer a law of nature. The physics of our universe would allow everyone with access to a networked computer to enjoy, for free, every song, every film, every book, every piece of research, every computer program, every last thing that could be made out of digital ones and zeros. The question became not, will nature allow it, but will our legal and economic system ever allow it?

This is a question about the future of capitalism, the economic system that arose from scarcity. Ours is the era of expanded copyright systems and enormous portfolios of dubious patents, of trade secrecy, the privatisation of the fruits of publicly funded research, and other phenomena that we collectively term "intellectual property". As technology has made a new abundance of knowledge possible, politicians, lawyers, corporations and university administrations have become more and more determined to preserve its scarcity.

So will we cling to scarcity just so that we can keep capitalism? Or will capitalism have to evolve into some new kind of digital economics? The question underlines many things – from music piracy to the woes of the newspaper industry to Google's efforts to scan all the books in the world.

This fragile scarcity has a purpose: to make things expensive. Water is plentiful and essential; diamonds are rare and useless. But diamonds are much more expensive than water because they're much rarer. People in the business of selling information have good reason to want a future where knowledge is valued like diamonds rather than water. Here pharmaceutical giants, Hollywood, Microsoft, even *The Wall Street Journal* speak with one voice: "Keep expanding copyright and patent laws so our products remain expensive and profitable." And they pay lobbyists worldwide to ensure this message reaches governments.

The irony of the battle between advocates of abundance and advocates of scarcity is that both sides are right. It makes no sense to limit and control access now we have technologies to give information to everyone. But it is also foolish to pretend we do not need incentives to help produce and publish that information.

While financial incentives are a very complicated business, two simple points hold true. First, even without payment, some folk will always record music, write software, make their feature films, do their own investigative journalism, occasionally even test their own drugs. You couldn't stop them if you tried. Second, we will all be better off with more, not fewer, professional careers available for knowledge producers. Not having to stick with a day job allows creative workers to be more creative and productive, for the benefit of all.

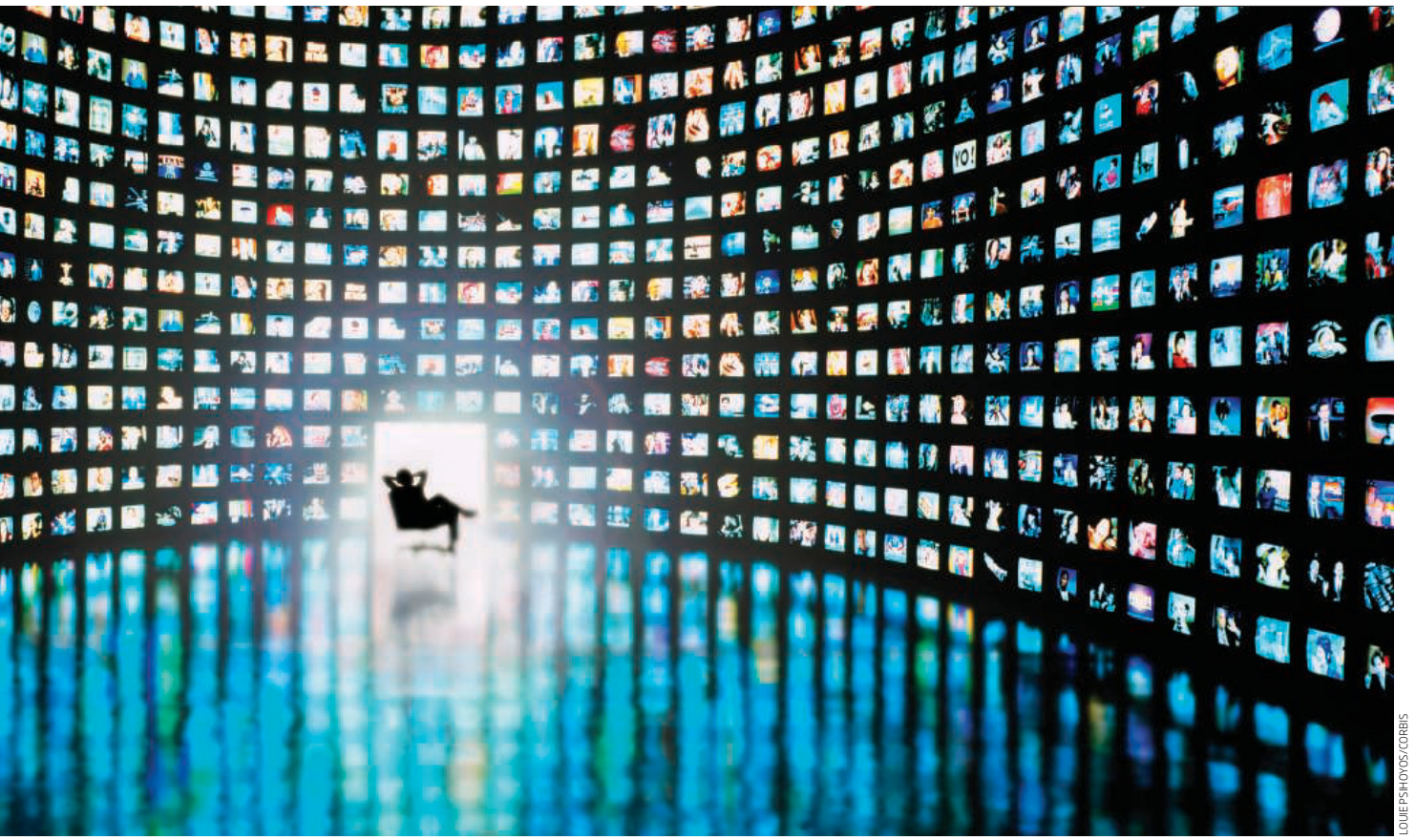
Crucially, though, if we really want to end scarcity, we will have to build institutions that promote knowledge-sharing, while at the same time ensuring that there are incentives for creative and technical minds to contribute.

Science, and the universities that support it, is the grandest example of a system that has evolved to promote the abundance of knowledge. Universities offer incentives in the form of tenure, promotion and prestige to researchers who can discover and share the information which their peers consider most valuable. Academics are human: they are as greedy, short-sighted and treacherous as everyone else, but the academic environment encourages them to focus those vices and impress their colleagues with their cleverness and cool discoveries published in fancy journals. Sometimes those cool discoveries are imagined or incomplete, but then others get ahead by pointing this out, and when the whole process works, the result is science.

In recent years, however, science has become another front in the conflict over scarcity. As any biologist will tell you, patents, secrecy and commercialisation have become a way of life. At the same time, science has inspired new institutions and movements that promote its ideals and its liberty.

Take the open access movement, which has campaigned to ensure that scientific articles are freely available to the public, who ultimately paid for the research with their taxes. Historically, most scientific writing was confined to expensive scholarly journals and essentially available only to people with

PROFILE
Peter Eckersley is a staff technologist at the Electronic Frontier Foundation in San Francisco, which sets out to defend digital civil liberties . His doctoral research at the University of Melbourne is on alternatives to digital copyright. He can be contacted at pde@eff.org



LOUIE PSIHOYOS/CORBIS

university affiliations. Some publishers resisted the open access movement, but trends are against them. In March this year, for example, the US Congress made permanent a requirement that all research funded by the National Institutes of Health be openly accessible, and other countries are following. Within a decade or two, it is safe to say that all scientific literature will be online, free and

"People are pirates... there are still 10 songs copied for each one bought on iTunes"

searchable. Journal publishers will still be paid, but at a different point in the chain.

Outside the universities we have some even more remarkable developments. Fifteen years ago, who would have predicted that teenagers would be allowed to edit the world's primary reference source from their homes? Twenty years ago, who would have predicted that teams of volunteers would succeed in writing and giving away software that produces many billions of dollars of economic wealth?

Wikipedia and the free and open-source software movements have produced stores of knowledge while trying to insulate themselves from the old institution of copyright, which is inherently unsuited to their processes of authorship. But that's not enough: we urgently need institutions to liberate knowledge produced under the old rules, too.

The music industry, for example, is slowly realising it cannot win the war on copying. People are pirates, and there are still 10 songs copied for every one bought on iTunes. Soon, the record labels will start to experiment with alternatives to copyright, such as licences that allow unlimited, restriction-free file sharing in exchange for flat fees, maybe a $5 or $10 voluntary payment with your monthly internet provider bill. This kind of system will not be perfect, but it will allow us to have wonderful libraries of legal MP3s, and it may help more independent professional musicians to flourish.

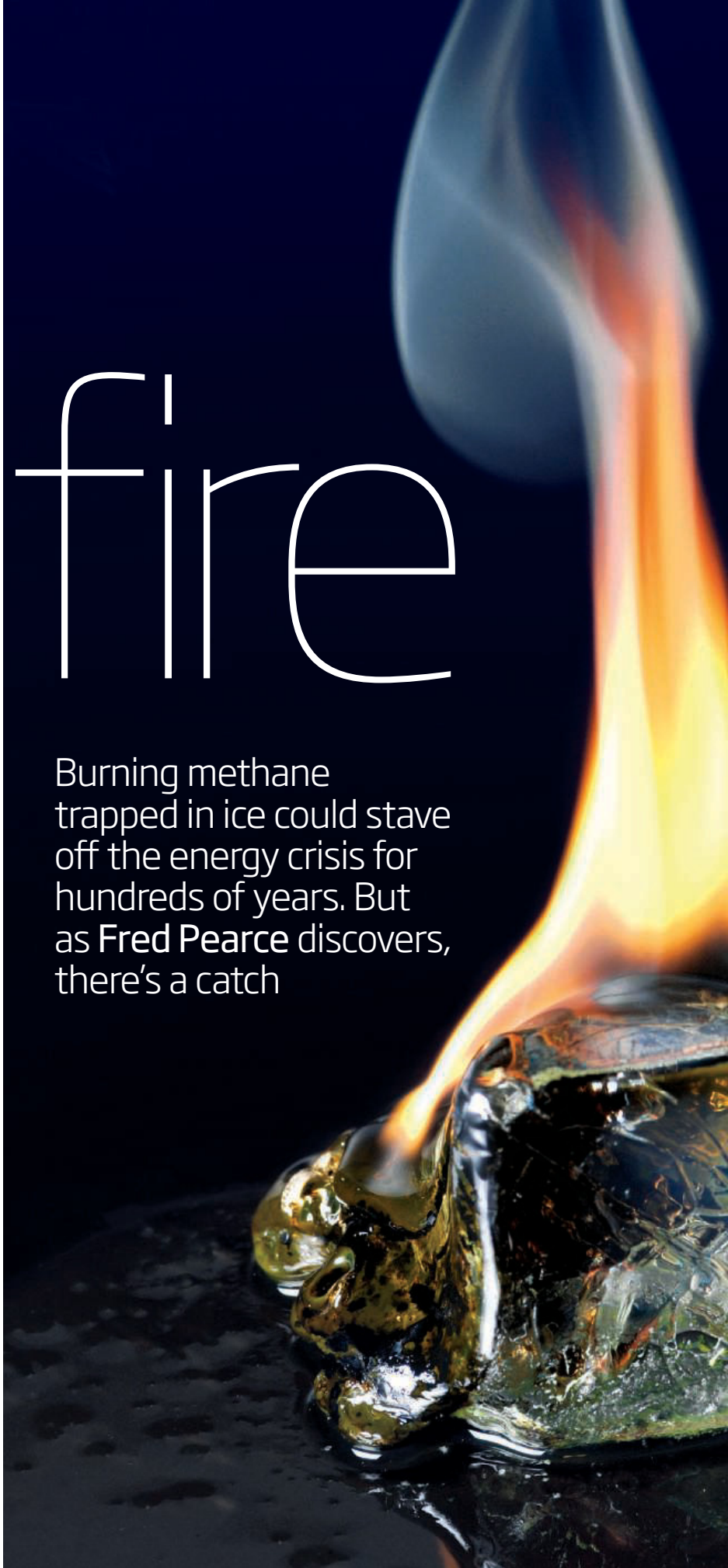
Another experiment in post-scarcity capitalism concerns the digitisation of the world's books. One draft of the rules for access to scanned books is currently being written in the US courts as Google settles a class action over its scanning projects. This settlement will make books more searchable and improve access to both out-of-print and "orphaned" books whose copyright holders can't be found. Under the current version, books will only be available in snippets and sections. Some out-of-print books will be available through institutional and individual subscriptions, but we don't yet know whether the prices will be inviting to most of the public, thus making Google Books a true post-scarcity project.

So here's a challenge to the governments of countries that want to lead the way, whether rich or poor: sit down with Google (or one of its competitors), authors and publishers, and work out a deal that offers a complete, licensed digital library free to your citizens. It would cost taxpayers something, but less than they currently spend on buying scarce books and supporting large paper collections. It would be great news for publishers and authors, who would receive most of the funds and would no longer need to fear piracy.

It's time to recognise that when we build institutions to promote the abundance of knowledge, everybody wins. When it comes to knowledge, you can never have too much of a good thing. ■

ice on fire

Burning methane trapped in ice could stave off the energy crisis for hundreds of years. But as **Fred Pearce** discovers, there's a catch



BLICKWINKEL/ALAMY

DEEP in the Arctic Circle, in the Messoyakha gas field of western Siberia, lies a mystery. Back in 1970, Russian engineers began pumping natural gas from beneath the permafrost and piping it east across the tundra to the Norilsk metal smelter, the biggest industrial enterprise in the Arctic.

By the late 70s, they were on the brink of winding down the operation. According to their surveys, they had sapped nearly all the methane from the deposit. But despite their estimates, the gas just kept on coming. The field continues to power Norilsk today.

Where is this methane coming from? The Soviet geologists initially thought it was leaking from another deposit hidden beneath the first. But their experiments revealed the opposite – the mystery methane is seeping into the well from the icy permafrost above.

If unintentionally, what they had achieved was the first, and so far only, successful exploitation of methane clathrate. Made of molecules of methane trapped within ice crystals, this stuff looks like dirty ice and has the consistency of sorbet. Touch it with a lit match, though, and it bursts into flames.

Clathrates are rapidly gaining favour as an answer to the energy crisis. Burning methane emits only half as much carbon dioxide as burning coal, and many countries are seeing clathrates as a quick and easy way of reducing carbon emissions. Others question whether

that is wise, and are worried that extracting clathrates at all could have unforeseen and perilous side effects.

If countries and companies are exploring the potential of clathrates only now, that's not for lack of scientific interest over the years. Research over the past two decades has shown that the energy trapped in ice within the permafrost and under the sea rivals that in all oil, coal and conventional gas fields, and could power the world for centuries to come. Oil and gas companies have been slow to catch on, however, believing methane clathrates to be unreliable and uneconomical. Feasibility studies and the diminishing supplies of conventional natural gas are changing that, making commercially viable production realistic within a decade, says Ray Boswell, who heads the clathrates programme at the US Department of Energy.

"Just a few years ago no one was thinking about clathrates as an energy source," Boswell says. "Now there is a great deal of interest in them." It is not just the US. Canada, China and Norway are entering the race too. The governments of Japan and South Korea have given the green light for full-scale production. The first intentional commercial exploitation may come as early as 2015.

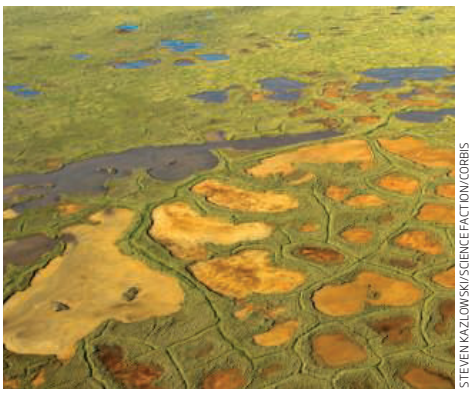
So what are methane clathrates, and where do they come from? As with all natural gas, the story starts with rotting plants. As these plants decay, they release methane, which permeates through porous rocks underground. If the conditions where the methane ends up are just right – temperatures close to 0 °C and pressures of roughly 50 atmospheres – ice crystals form that trap the gas in place.

In practice, these conditions mostly occur within and underneath permafrost and beneath the seabed on continental shelves, usually at ocean depths of 200 to 400 metres, although clathrates have also been known to appear on the seabed. In 2000, a 1-tonne chunk of the stuff was scooped up by fishermen off Vancouver Island in British Columbia. They hastily dumped the hissing mass back into the ocean.

Until recently, these deposits escaped the serious attention of energy companies. Engineers stumbled on clathrates from time to time while drilling for conventional reserves of oil and gas, but they were mostly viewed as an irritant that caused blowouts or blocked pipelines.

"Fishermen scooped up a hissing mass of the stuff – and hastily dumped it back in the ocean"

That view changed with studies showing that the gas is often present at a given site in concentrations of 50 per cent or more in ice's pore space – values similar to the prevalence of natural gas in traditional sources – in layers of clathrate hundreds of metres thick. What's more, in its constricted surroundings the gas is compressed to 160 times its density at atmospheric temperature and pressure, making for vast quantities of it when released.



STEVEN KAZLOWSKI/SCIENCE FACTION/CORBIS

Frozen deposits of energy-rich clathrates could make the Siberian wilderness the new Gulf

These revelations made clathrates a potential gold mine that countries and energy companies are now eagerly prospecting. In 2007, a US project found clathrate reserves in Alaska with 80 per cent of the ice's pore space packed with methane. Tim Collett, a clathrate specialist at the US Geological Survey who was part of the team, says there may be reserves all along the Alaska north slope, including beneath existing oil installations at Prudhoe Bay and, alarmingly for environmentalists, the Arctic National Wildlife Refuge.

Collett estimates there is between 0.7 and 4.4 trillion cubic metres of methane clathrate in Alaska alone. Even the low end of that range could heat 100 million homes for a decade. "It's definitely a vast storehouse of energy. But it is still unknown how much of the volume can actually be produced on an industrial scale," he told a meeting of the American Chemical Society at Salt Lake City, Utah in March this year.

That's not the only reserve of interest. In 2004, a German and Chinese team found methane venting from the seabed off the coast of Taiwan in the South China Sea, and in 2006 Indian researchers found a layer of methane clathrates 130 metres thick off its east coast in an area known as the Krishna-Godavari ›

basin. Collett calls these "one of the world's richest marine gas clathrate accumulations".

Estimates vary, but conservative figures place global reserves at roughly 3 trillion tonnes of previously untapped carbon – more than is trapped in all the other known fossil fuel reserves put together, says Klaus Wallmann of the Leibniz Institute of Marine Science in Kiel, Germany.

That would last about 1000 years if we continue to use natural gas at the current rate, estimates Collett. Even if the methane from clathrates replaced all fossil fuels, and not just gas, it would still last for at least 100 years. But with this methane held in fragile ice crystals and buried deep within the Earth, can it be exploited safely and economically?

Until recently, there were two methods of extracting methane from clathrates that were considered feasible. One is to drill a hole into the clathrate deposit to release the pressure, allowing the methane to separate out from the clathrate and flow up the wellhead. The second is to warm the clathrate by pumping in steam or hot water, again releasing the methane from its icy matrix.

In 2002, Canadian, American, Japanese, Indian and German researchers tested both techniques in the field, at a drill site called Mallik on the outer extremity of the Mackenzie river delta in the Canadian Arctic. Both were successful, but the energy costs of the heating method nearly outweighed the energy gained from the methane released, making depressurisation the more attractive option.

The potential of depressurisation was confirmed in March 2008, when Canadian engineers led by Scott Dallimore of the Geological Survey of Canada used the technique to tap 20,000 cubic metres of methane gas over six days from a deposit located 1 kilometre beneath Mallik.

"Disturbing the clathrates' delicate balance might unleash an uncontrollable 'methane burp'"

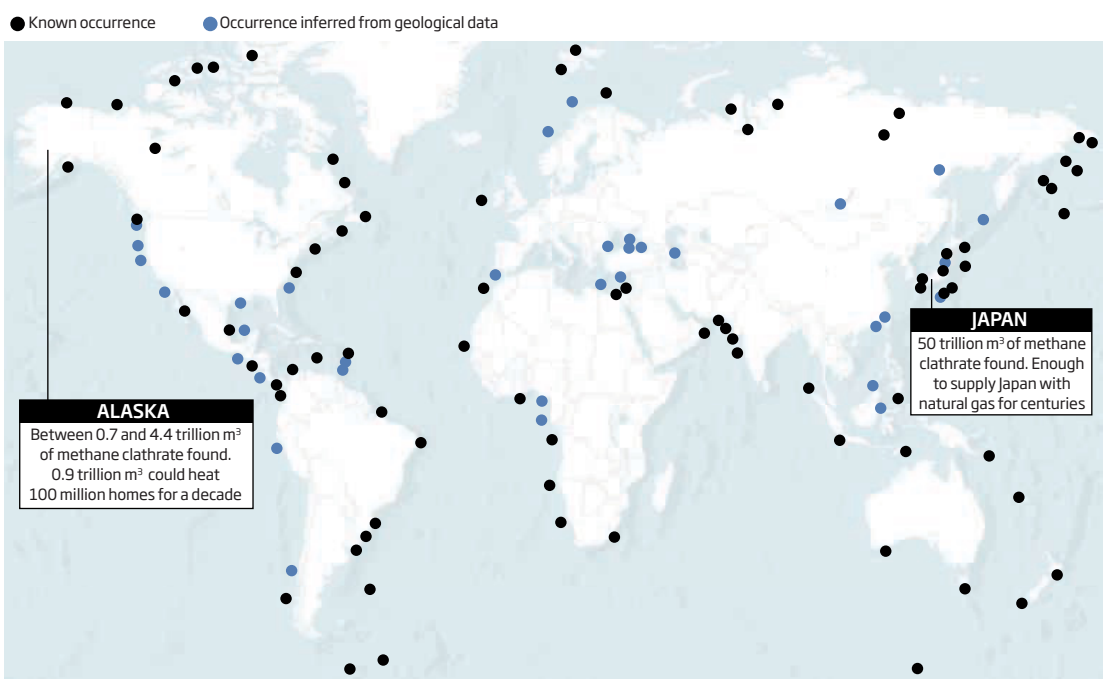
Similarly, in 2007, South Korea exploited depressurisation to extract methane clathrate from the Ulleung basin in the Sea of Japan. Officials believe reserves there could meet the country's gas needs for up to 30 years, and they plan to begin production by 2015. Meanwhile Japan, another country with limited fossil fuel reserves, has found up to 50 trillion cubic metres of clathrate south-east of Honshu Island in the Nankai trough – enough to supply the country with natural gas for centuries. In March 2008, the Japanese cabinet pledged to begin production by 2016.

So methane clathrate extraction seems to be imminent, in Asia at least. Whether it is desirable is another matter. Some argue that the world shouldn't be tapping a new fossil fuel while we are pledging to build a low-carbon economy. Methane might be less carbon intensive than fuels such as coal, but switching to methane would not help countries to reach ambitious targets for reducing carbon emissions of up to 80 per cent by 2050.

To make matters worse, the methane itself could exacerbate global warming if it starts leaking from the reserves. Methane is, molecule for molecule, 20 times as powerful at warming the air as CO_2. Rising sea temperatures could melt some undersea clathrate reserves even without extraction projects disturbing them, triggering a release of this potent greenhouse gas. A decade ago, Peter Brewer of the Monterey Bay Aquarium Research Institute in Moss Landing, California, showed how clathrates on the seabed just off the coast of California disappeared after an El

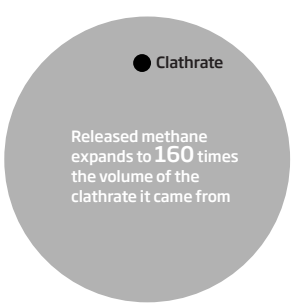
Global reserves of methane clathrates

Ice deposits containing natural gas within their crystals are found both under the sea and in permafrost. Globally, more carbon may be trapped in these methane clathrates than in all the traditional sources of fossil fuel



One way of releasing the methane is to pump another gas, such as CO_2, into the clathrate to take its place. The methane then shoots up the wellhead to the surface to be collected

If uncontrolled, a release could trigger explosions within the clathrate reserves that might cause landslides or tsunamis



SOURCE: USGS

MARC STEINMETZ

Burning bright, but are clathrates compatible with a low-carbon global economy?

Niño event raised ocean temperatures by 1 °C.

Exploitation of clathrate reserves might exacerbate this problem, but it could also have far more immediate adverse effects. Clathrates exist in a delicate balance, and the worry is that as gas is extracted its pressure will break up neighbouring clathrate crystals. The result could be an uncontrollable chain reaction – a "methane burp" that could cascade through undersea reserves, triggering landslips and even tsunamis. "Extraction increases the risk of large-scale collapses, which might have catastrophic consequences," says Geir Erlsand from the University of Bergen in Norway.

Evidence that such events have happened in the past comes from the Storegga slide, a landslip on the seabed off western Norway about 8000 years ago. A 400-kilometre stretch of submarine cliff on the edge of the continental shelf collapsed into the deep ocean, taking with it a staggering 3500 cubic kilometres of sediment that spread across an area the size of Scotland. The result would have been a tsunami comparable to the one that devastated parts of south-east Asia in 2004.

The naval researchers who first discovered the remains of the slide in 1979 assumed it was the result of an earthquake. Perhaps it was initially, but Jürgen Mienert of the University of Tromsø in Norway has found that the slumped area was also a hotspot for methane clathrates. The sheer number of cracks and giant pockmarks on the seabed, carbon-dated to the time of the slide, suggest billions of tonnes of methane must have burst out of the cliff along with the sediment, a possible trigger for the landslip. The resulting explosions would have turned even a minor slip into a major disaster.

Sinking carbon

The Storegga slide is not the only incident of this kind. The ocean floor from Storegga to Svalbard is full of pockmarks that might have been caused by similar clathrate-driven landslides, says Mienert. He says we will see more of these events in the future. "Global warming will cause more blowouts and more craters and more releases," he warns.

Other engineers believe claims that clathrate extraction poses a risk are little more than scare stories with little supporting evidence. Wallmann claims that the Chinese and Indians in particular are "afraid that the west wants to prevent them from rapid extraction of methane clathrate".

There might in fact be a safer way of tapping clathrates which, if successful, could quash the criticisms. Since other gases can also form clathrates, it should be possible to pump one of these gases into the crystals to displace the methane. Carbon dioxide would be an ideal candidate, says Ersland – the resulting crystal is even more stable than methane clathrate, meaning another greenhouse gas would be stored out of harm's way.

Ersland has already demonstrated his technique in the lab. In joint research with the energy company ConocoPhillips based in Houston, Texas, he replaced methane with CO_2 in artificial clathrate crystals. The exchange was rapid and did not damage the clathrate structure, making it the safest way to extract the methane yet found (*Chemical Engineering Journal*, DOI: 10.1016/j.cej.2008.12.028). Substituting methane with CO_2 "will increase the stability of the reservoir sediments as well as maintaining the clathrates in their solid state", Ersland says.

The acid test will be an experiment planned for January next year. ConocoPhillips intends to pour liquefied CO_2 down a borehole into the Alaskan north slope's clathrate deposit. If all goes well, the CO_2 will fill the clathrate crystals and the displaced methane will shoot up the wellhead to the surface. The method could be both a safe way of capturing the methane and an environmental argument for pursuing the goal – the clathrate structures would be acting as a carbon sink.

It is an intriguing possibility. Sooner rather than later, burning fossil fuels like coal and natural gas will only be acceptable if the CO_2 emissions are captured and stored. Right now, there is a rush to develop a practical system for capturing and burying billions of tonnes of CO_2 underground per year.

So far, the focus has been on old oil wells, salt deposits and even old coal mines. The big problem is that the huge infrastructure required to dispose of the CO_2 may quickly make burning fossil fuels uneconomic compared with alternatives like solar, wind or nuclear power. Disposing of CO_2 down the same pipe used to bring up more fuel could be the answer. ■

Fred Pearce is an environment consultant for *New Scientist*

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Your brain is like a pile of sand. That's why it has such remarkable powers, finds **David Robson**

Disorderly genius

HAVE you ever experienced that eerie feeling of a thought popping into your head as if from nowhere, with no clue as to why you had that particular idea at that particular time? You may think that such fleeting thoughts, however random they seem, must be the product of predictable and rational processes. After all, the brain cannot be random, can it? Surely it processes information using ordered, logical operations, like a powerful computer?

Actually, no. In reality, your brain operates on the edge of chaos. Though much of the time it runs in an orderly and stable way, every now and again it suddenly and unpredictably lurches into a blizzard of noise.

Neuroscientists have long suspected as much. Only recently, however, have they come up with proof that brains work this way. Now they are trying to work out why. Some believe that near-chaotic states may be crucial to memory, and could explain why some people are smarter than others.

In technical terms, systems on the edge of chaos are said to be in a state of "self-organised criticality". These systems are right on the boundary between stable, orderly behaviour – such as a swinging pendulum – and the unpredictable world of chaos, as exemplified by turbulence.

The quintessential example of self-organised criticality is a growing sand pile. As grains build up, the pile grows in a predictable way until, suddenly and without warning, it hits a critical point and collapses. These "sand avalanches" occur spontaneously and are almost impossible to predict, so the system is said to be both critical and self-organising. Earthquakes, avalanches and wildfires are also thought to behave like this, with periods of stability followed by catastrophic periods of instability that rearrange the system into a new, temporarily stable state.

Self-organised criticality has another defining feature: even though individual sand avalanches are impossible to predict, their overall distribution is regular. The avalanches are "scale invariant", which means that avalanches of all possible sizes occur. They also follow a "power law" distribution, which means bigger avalanches happen less often than smaller avalanches, according to a strict mathematical ratio. Earthquakes offer the best real-world example. Quakes of magnitude 5.0 on the Richter scale happen 10 times as often as quakes of magnitude 6.0, and 100 times as often as quakes of magnitude 7.0.

These are purely physical systems, but the brain has much in common with them. Networks of brain cells alternate between periods of calm and periods of instability – "avalanches" of electrical activity that cascade through the neurons. Like real avalanches, exactly how these cascades occur and the resulting state of the brain are unpredictable.

> "Disorder is essential to the brain's ability to transmit information and solve problems"

It might seem precarious to have a brain that plunges randomly into periods of instability, but the disorder is actually essential to the brain's ability to transmit information and solve problems. "Lying at the critical point allows the brain to rapidly adapt to new circumstances," says Andreas Meyer-Lindenberg from the Central Institute of Mental Health in Mannheim, Germany.

The idea that the brain might be fundamentally disordered in some way first emerged in the late 1980s, when physicists working on chaos theory – then a relatively new branch of science – suggested it might help explain how the brain works.

The focus at that time was something called deterministic chaos, in which a small perturbation can lead to a huge change in the system – the famous "butterfly effect". That would make the brain unpredictable but not actually random, because the butterfly effect is a phenomenon of physical laws that do not depend on chance. Researchers built elaborate computational models to test the idea, but unfortunately they did not behave like real brains. "Although the results were beautiful and elegant, models based on deterministic chaos just didn't seem applicable when looking at the human brain," says Karl Friston, a neuroscientist at University College London.

In the 1990s, it emerged that the brain generates random noise, and hence cannot ›

DARREL REES

"The balance between stability and instability in the brain has been linked with intelligence, at least as measured by scores on an IQ test"

STR NEW/REUTERS

be described by deterministic chaos. When neuroscientists incorporated this randomness into their models, they found that it created systems on the border between order and disorder – self-organised criticality.

More recently, experiments have confirmed that these models accurately describe what real brain tissue does. They build on the observation that when a single neuron fires, it can trigger its neighbours to fire too, causing a cascade or avalanche of activity that can propagate across small networks of brain cells. This results in alternating periods of quiescence and activity – remarkably like the build-up and collapse of a sand pile.

Neural avalanches

In 2003, John Beggs of Indiana University in Bloomington began investigating spontaneous electrical activity in thin slices of rat brain tissue. He found that these neural avalanches are scale invariant and that their size obeys a power law. Importantly, the ratio of large to small avalanches fit the predictions of the computational models that had first suggested that the brain might be in a state of self-organised criticality (*The Journal of Neuroscience*, vol 23, p 11167).

To investigate further, Beggs's team measured how many other neurons a single cell in a slice of rat brain activates, on average, when it fires. They followed this line of enquiry because another property of self-organised criticality is that each event, on average, triggers only one other. In forest fires, for example, each burning tree sets alight one other tree on average – that's why fires keep going, but also why whole forests don't catch fire all at once.

Sure enough, the team found that each neuron triggered on average only one other. A value much greater than one would lead to a chaotic system, because any small perturbations in the electrical activity would soon be amplified, as in the butterfly effect. "It would be the equivalent of an epileptic seizure," says Beggs. If the value was much lower than one, on the other hand, the avalanche would soon die out.

Beggs's work provides good evidence that self-organised criticality is important on the level of small networks of neurons. But what about on a larger scale? More recently, it has become clear that brain activity also shows signs of self-organised criticality on a larger scale.

As it processes information, the brain often synchronises large groups of neurons to fire at the same frequency, a process called "phase-locking". Like broadcasting different radio stations at different frequencies, this allows different "task forces" of neurons to communicate among themselves without interference from others.

The brain also constantly reorganises its task forces, so the stable periods of phase-locking are interspersed with unstable periods in which the neurons fire out of sync in a blizzard of activity. This, again, is reminiscent of a sand pile. Could it be another example of self-organised criticality in the brain?

In 2006, Meyer-Lindenberg and his team made the first stab at answering that question. They used brain scans to map the connections between regions of the human brain and discovered that they form a "small-world network" – exactly the right architecture to support self-organised criticality.

Small-world networks lie somewhere between regular networks, where each node is connected to its nearest neighbours, and random networks, which have no regular structure but many long-distance connections between nodes at opposite sides of the network (see diagram, below). Small-world networks take the most useful aspects of both systems. In places, the nodes have many connections with their neighbours, but the network also contains random and often long links between nodes that are very far away from one another.

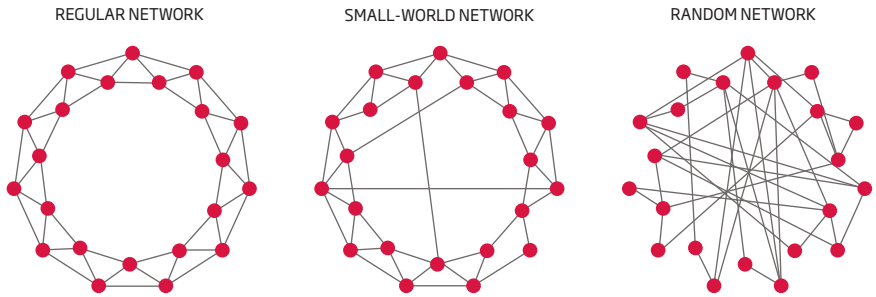
For the brain, it's the perfect compromise. One of the characteristics of small-world networks is that you can communicate to any other part of the network through just a few nodes – the "six degrees of separation" reputed to link any two people in the world. In the brain, the number is 13.

Meyer-Lindenberg created a computer simulation of a small-world network with 13 degrees of separation. Each node was represented by an electrical oscillator that approximated a neuron's activity. The results confirmed that the brain has just the right architecture for its activity to sit on the tipping point between order and disorder, although the team didn't measure neural activity itself (*Proceedings of the National Academy of Sciences*, vol 103, p 19518).

That clinching evidence arrived earlier this

Well-tangled webs

The brain is organised as a small-world network, placing it at the very edge of chaos



Snow avalanches have a surprising amount in common with your brain

year, when Ed Bullmore of the University of Cambridge and his team used brain scanners to record neural activity in 19 human volunteers. They looked at the entire range of brainwave frequencies, from 0.05 hertz all the way up to 125 hertz, across 200 different regions of the brain.

Power laws again

The team found that the duration both of phase-locking and unstable resynchronisation periods followed a power-law distribution. Crucially, this was true at all frequencies, which means the phenomenon is scale invariant – the other key criterion for self-organised criticality.

What's more, when the team tried to reproduce the activity they saw in the volunteers' brains in computer models, they found that they could only do so if the models were in a state of self-organised criticality (*PLoS Computational Biology*, vol 5, p e1000314). "The models only showed similar patterns of synchronisation to the brain when they were in the critical state," says Bullmore.

The work of Bullmore's team is compelling evidence that self-organised criticality is an essential property of brain activity, says neuroscientist David Liley at Swinburne University of Technology in Melbourne, Australia, who has worked on computational models of chaos in the brain.

But why should that be? Perhaps because self-organised criticality is the perfect starting point for many of the brain's functions.

The neuronal avalanches that Beggs investigated, for example, are perfect for transmitting information across the brain. If the brain was in a more stable state, these avalanches would die out before the message had been transmitted. If it was chaotic, each avalanche could swamp the brain.

At the critical point, however, you get maximum transmission with minimum risk of descending into chaos. "One of the advantages of self-organised criticality is that the avalanches can propagate over many links," says Beggs. "You can have very long chains that won't blow up on you."

Self-organised criticality also appears to allow the brain to adapt to new situations, by quickly rearranging which neurons are synchronised to a particular frequency. "The closer we get to the boundary of instability, the more quickly a particular stimulus will send the brain into a new state," says Liley.

It may also play a role in memory. Beggs's team noticed that certain chains of neurons would fire repeatedly in avalanches, sometimes over several hours (*The Journal of Neuroscience*, vol 24, p 5216). Because an entire chain can be triggered by the firing of one neuron, these chains could be the stuff of memory, argues Beggs: memories may come to mind unexpectedly because a neuron fires randomly or could be triggered unpredictably by a neuronal avalanche.

The balance between phase-locking and instability within the brain has also been linked to intelligence – at least, to IQ. Last year, Robert Thatcher from the University of South Florida in Tampa made EEG measurements of 17 children, aged between 5 and 17 years, who also performed an IQ test.

He found that the length of time the children's brains spent in both the stable phase-locked states and the unstable phase-shifting states correlated with their IQ scores. For example, phase shifts typically last 55 milliseconds, but an additional 1 millisecond seemed to add as many as 20 points to the child's IQ. A shorter time in the stable phase-locked state also corresponded with greater intelligence – with a difference of 1 millisecond adding 4.6 IQ points to a child's score (*NeuroImage*, vol 42, p 1639).

Thatcher says this is because a longer phase shift allows the brain to recruit many more neurons for the problem at hand. "It's like casting a net and capturing as many neurons as possible at any one time," he says. The result is a greater overall processing power that contributes to higher intelligence.

Hovering on the edge of chaos provides brains with their amazing capacity to process information and rapidly adapt to our ever-changing environment, but what happens if we stray either side of the boundary? The most obvious assumption would be that all of us are a short step away from mental illness. Meyer-Lindenberg suggests that schizophrenia may be caused by parts of the brain straying away from the critical point. However, for now that is purely speculative.

Thatcher, meanwhile, has found that certain regions in the brains of people with autism spend less time than average in the unstable, phase-shifting states. These abnormalities reduce the capacity to process information and, suggestively, are found only in the regions associated with social behaviour. "These regions have shifted from chaos to more stable activity," he says. The work might also help us understand epilepsy better: in an epileptic fit, the brain has a tendency to suddenly fire synchronously, and deviation from the critical point could explain this.

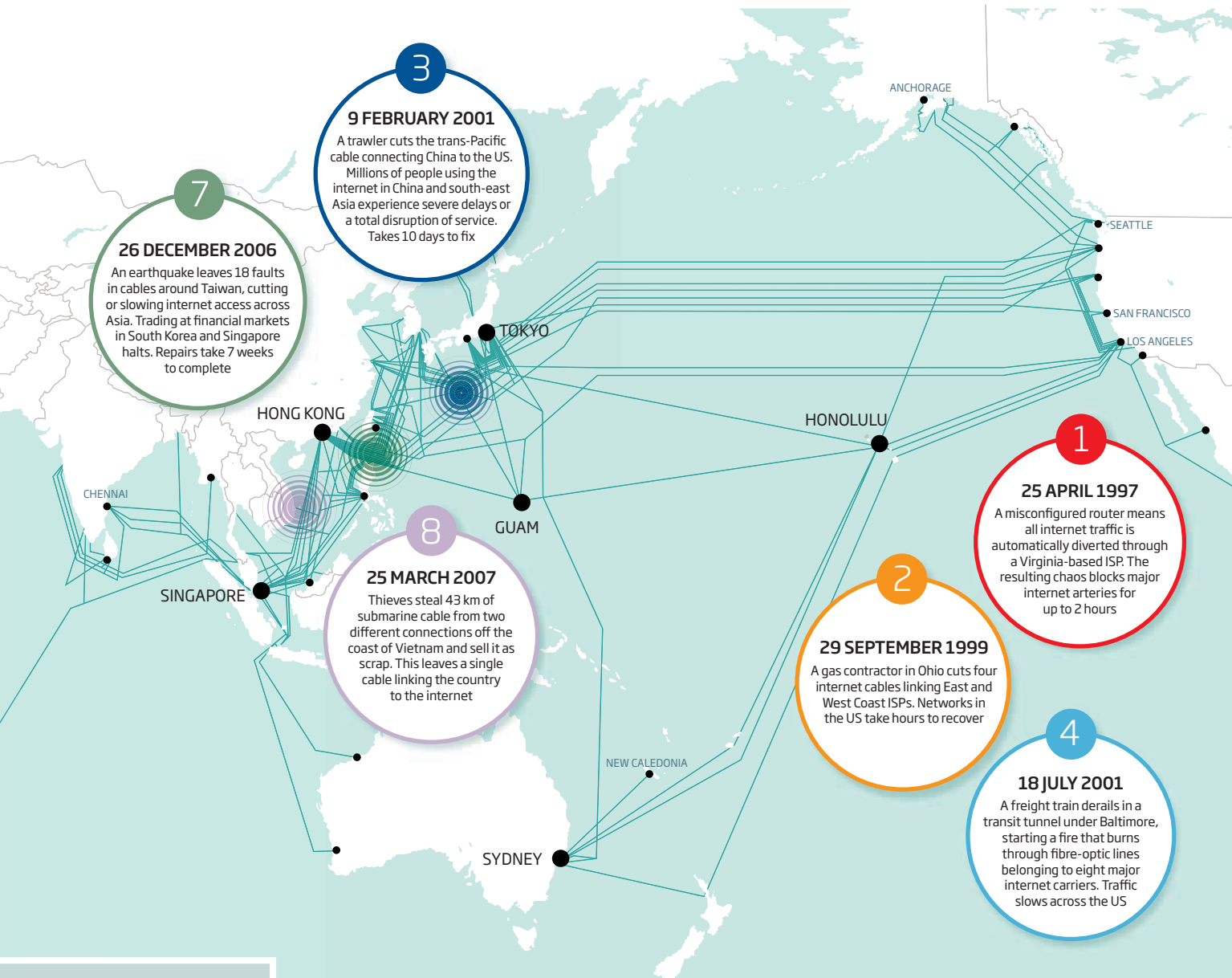
"They say it's a fine line between genius and madness," says Liley. "Maybe we're finally beginning to understand the wisdom of this statement." ■

David Robson is a junior editor at *New Scientist*

Network on a knife edge

The internet is groaning under the weight of its own success. Yet no one has found a way to bring the 40-year-old system up to date – until now. **Bennett Daviss** reports

ON 18 July 2001, a freight train derailed in the Howard Street tunnel running beneath downtown Baltimore, spilling 20,000 litres of hydrochloric acid. The resulting chemical fire destroyed fibre-optic cables owned by eight major US internet carriers. Moments later, Verizon Communications, which operates key portions of the internet's physical infrastructure in the US, lost links to two operations buildings and several other carriers' networks. For many hours, internet traffic slowed to a crawl across the entire country. "That tunnel is basically the I-95 [the main US East Coast highway] for fibre," one repair contractor told reporters. "It was a once-in-a-lifetime place for vulnerability."



Eight years on, and events have proved otherwise. A series of catastrophic failures seems to suggest that the internet is rather more vulnerable to accidents, earthquakes or misplaced ships' anchors than people thought. At tens, perhaps hundreds, of places around the world, the net seems to be hanging by a thread.

These days a major failure has the potential to cause far greater disruption than in 2001. Yet much of the internet's physical infrastructure is decades old. It badly needs upgrading, but clearly we can't just tear up sections of the network and rebuild them from scratch. Nor is it likely that governments and telecoms companies will bear the enormous costs of laying extra connections simply to insure against temporary problems. So how can we make the net more resilient?

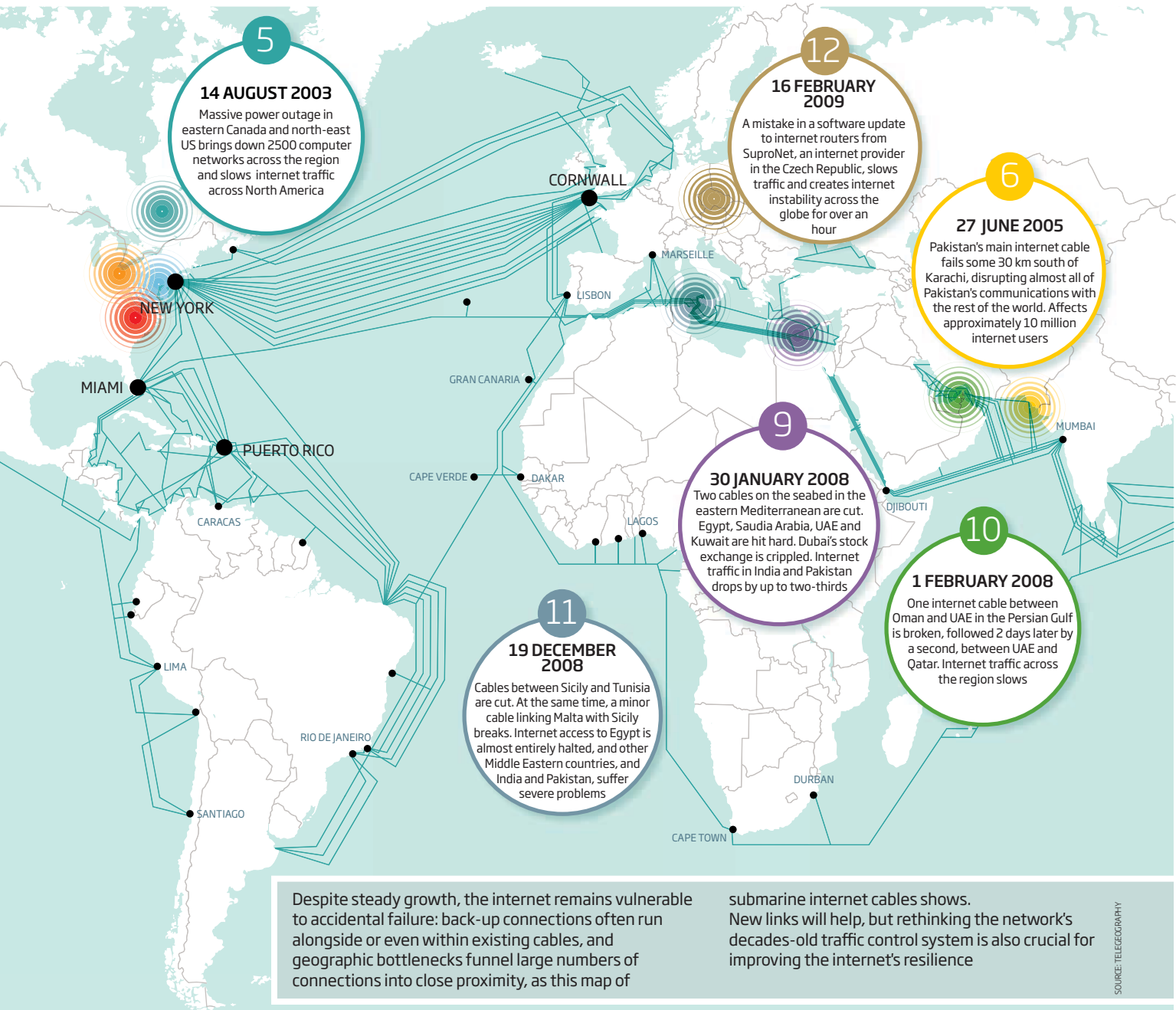
Nick McKeown, a computer scientist at Stanford University in California, thinks he has the answer. He believes the key to a better net lies with a prosaic black box called a router.

Routers are the internet's traffic controllers. There are millions in service, linking up the thousands of networks that make up the internet. They can direct huge flows of traffic for internet service providers, or just provide connectivity between a handful of computers. They check the addresses on data packets, direct them to the right destination and dictate which physical path they take to get there. When a connection breaks, they play a crucial role in helping divert data around it.

At the moment, though, routers are part of the problem, not the solution. For one thing, they can be very slow to find a way around a blockage, and in the many minutes it often takes, traffic backs up into jams so huge that much of the data is simply discarded.

Though numerous potential solutions to these problems exist, the other big sticking point is that there is nowhere to test them. Any update of router software ought first to be thoroughly tested on a large network – one that has all the complexity of the internet but which is physically isolated from it. Yet nothing like that exists.

Even if you could test it, says McKeown, it is very difficult to actually install new router software. Each router is pre-programmed ›



Despite steady growth, the internet remains vulnerable to accidental failure: back-up connections often run alongside or even within existing cables, and geographic bottlenecks funnel large numbers of connections into close proximity, as this map of submarine internet cables shows.
New links will help, but rethinking the network's decades-old traffic control system is also crucial for improving the internet's resilience

SOURCE: TELEGEOGRAPHY

according to international standards set 10 or 15 years ago largely by the manufacturers themselves. They contain proprietary circuits, and the software controlling the way data packets are routed operates in set ways, allowing little means for change.

Now McKeown, along with Stanford colleague Guru Parulkar, is developing the means to solve all these problems at a stroke: a system that can alter a router's control software on the fly as well as providing the perfect place to test it safely.

Smoother surfing

Named OpenFlow, their system is already running on Stanford University's network, and the first commercial products should reach the market this year. OpenFlow won't solve the problem of cable bottlenecks or prevent the odd accidental failure, but if the technology is adopted as McKeown hopes, it will enable the internet to adapt to changing loads, dynamically altering pathways to cope with spikes in traffic and giving every surfer a smoother ride, regardless of earthquakes, terrorists, ships' anchors and so on. "We are trying to enable a network that continually evolves and improves," says McKeown.

Anything that makes the internet more resilient should be good news, and not just for the millions of ordinary people who use it to book holidays or twitter to their friends. The financial impact of a net outage can be huge: online commerce is now worth over $7 trillion annually, representing about 12 per cent of global GDP. A 2005 study by researchers at the Swiss Federal Institute of Technology in Zurich calculated that cutting off all links to the internet would cost Switzerland over $3 billion per week – around 1 per cent of its GDP. And with e-commerce expected to account for 18 per cent of global GDP by 2010, the impact of failure is set to grow.

Aside from that, critical parts of our infrastructure, such as power and water utilities, now rely on the internet for information exchange and remote diagnostics. Banks and stock exchanges around the world swap financial data via the internet, as well as using their own networks. Transport systems, too, such as the German railway system, rely on it to link ticketing and information networks.

In fact, it might seem miraculous, given the internet's growing traffic density, that outages have not caused more problems. This is mainly down to the fact that the internet is a scale-free network, which is another way of saying that while it depends on a few highly connected nodes, most have just a few connections. That means an outage in one area has a limited impact elsewhere and it doesn't take much to adjust traffic flow to keep things moving.

Routers play a key role in making this happen. Normally a router checks the address on any data packet it receives and sends it on according to predefined rules held in a set of tables. Two sets of data going to the same address, say, are usually sent along the same path. If this path becomes impassable for whatever reason, the router checks in with its neighbours, finds out which still work, and calculates the best way to redirect data.

To do this, routers run a complex algorithm, but it can take many minutes to complete. Because of the problems with testing and updating new software, technical improvements have come at a glacially slow rate. Any change must be made very carefully, says Tom Anderson at the University of Washington in Seattle. "You have to make sure that you're not doing something that will create problems of its own."

That was highlighted in February, when a small error in a software update for a router in the Czech Republic spread across the web, causing traffic to slow to a crawl across the entire internet for over an hour. This is by no means the first time such a mistake has caused chaos (see map, page 38). Yet there is no large-scale testbed or "virtual internet" on which to experiment.

> **"With a multiverse of virtual networks, it should be possible to kick-start the evolution of the internet"**

In 2005, the US National Science Foundation (NSF) asked a team of researchers to find a way around this problem. Their solution was bold: construct a huge new national network, with much the same complexity as the internet, on which to test and refine novel concepts until they are ready to be transferred to the real thing. As if that wasn't ambitious enough, they also wanted to slice up the traffic on this network. The idea was that each slice could run on the same infrastructure of routers, switches and cables, but remain isolated from every other slice. That way thousands of researchers could experiment with different approaches all at the same time.

The NSF liked the idea enough to stump up over $10 million in start-up funds for what is now called the Global Environment for Network Innovations (GENI) project. The new nationwide grid will take many years, and over $100 million, to complete. Now, though, McKeown and his colleagues have come up with a plan that will not only allow GENI to be deployed much more quickly and cheaply, but the project will largely be able to use existing routers, switches and cables.

The key is OpenFlow. With the cooperation of the manufacturer, a small OpenFlow program can be added to almost any router, where it acts like a remote control for the proprietary algorithms and hardware inside. By creating an interface to the router's flow table – the thing that specifies the rules for handling traffic – it allows someone to take control of the way the router directs traffic, to make new routeing decisions and implement them.

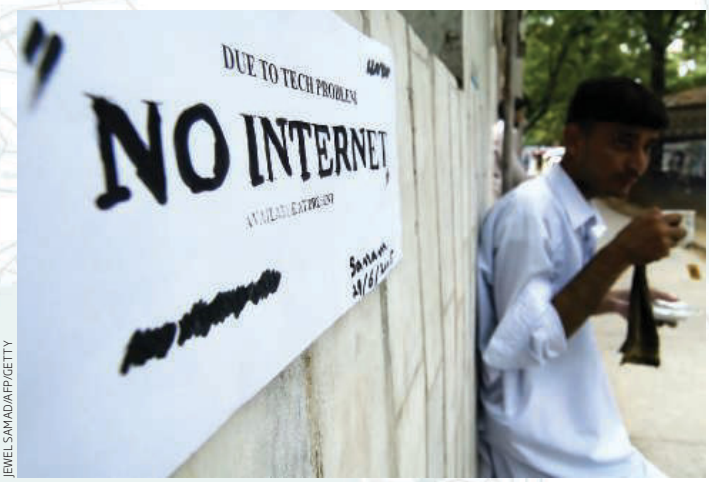
The upshot is that OpenFlow gives software engineers and developers the ability to create their own routes for data packets, by writing the algorithms on a regular computer and sending them via a secure connection to the router. By controlling the flow table, it becomes straightforward to partition a network into any number of slices, each isolated from the rest, on which researchers can test or refine their ideas. With a "multiverse" of virtual networks available for experiment, it should at last be possible to kick-start the evolution of the internet.

To speed up the process, McKeown and his team decided to make their system open source, meaning that the software is free for redistribution. This should help stimulate new ideas and help get them deployed more quickly, he says. "You get the benefit of sharing and building on top, creating a rapid rate of innovation," McKeown says. "That has never happened in networking."

OpenFlow is already providing internet testbeds on the Stanford University network, and the team plans to install it on half a dozen other university networks in the US in the near future. Their aim is to allow students to experiment and try out new ideas on virtual networks. With a number of manufacturers on board already, the team hopes to see OpenFlow-compatible commercial routers, internet switches or Wi-Fi access points reach the market this year.

The idea so impressed Chip Elliott, GENI's project director, that GENI is now one of OpenFlow's chief funders. It is a really good way to open up the network for experimentation and innovation, he says. The alternatives would be a lot more expensive and take longer to implement.

JOHN MAKELY/BALTIMORE SUN STAFF PHOTO



JEWEL SAMAD/AFP/GETTY

A derailed train slowed internet traffic in the US in 2001 (top), while Pakistan lost connection in 2005 after a fault in the Arabian Sea (left)

"What I really like is that they based it all on fast, cheap, commercial hardware."

Success, however, will depend on convincing the major manufacturers that the long-term advantages of OpenFlow are worth the short-term investment. To help persuade them, last year the team at Stanford put OpenFlow through its paces by installing a "virtual server" running a shoot-'em-up game on a computer on Stanford's network. Thanks to router software written using OpenFlow, players equipped with laptops found that even though they moved between wireless access points all round the campus, the game play was seamless. "No one lost connections," McKeown says. Then, while the game was still going on, the researchers moved the virtual server from Stanford to a machine in Japan. The game continued without any interruption. "You couldn't even tell that it had moved. That's the kind of thing you can't do in the current network."

Beyond this kind of smooth rerouting, OpenFlow should offer some important benefits for network operators. It could let them alter their router's rules so that particular kinds of data are sent along particular routes – to give emails priority over music downloads, say, or spread traffic over a large number of alternative connections when one path is broken. "It allows you to add new capabilities, new features to the network, without having to program inside that proprietary box," says McKeown. "In essence it is software-defined networking."

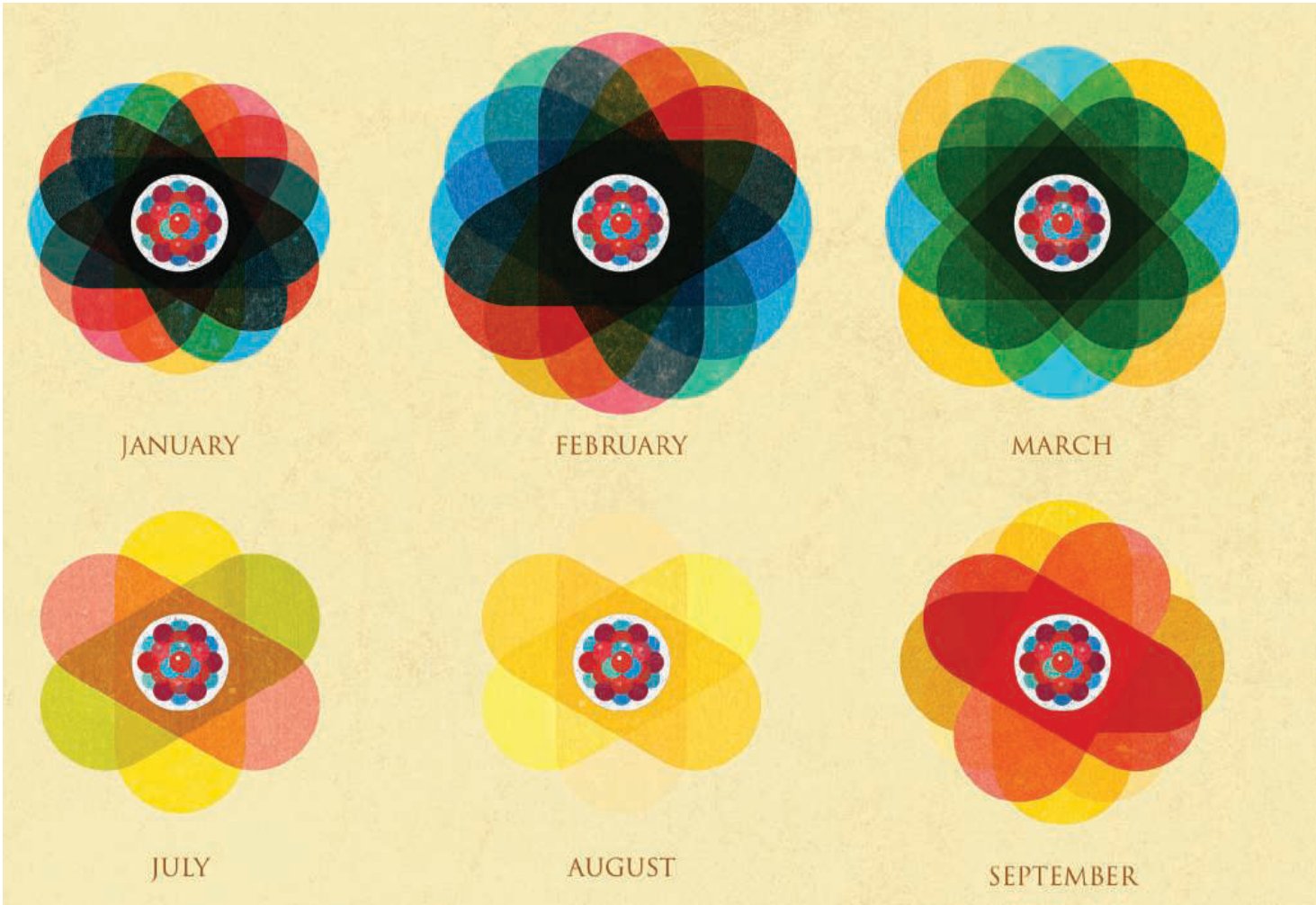
Another key problem that OpenFlow should help address is network security. After the recent router error in the Czech Republic, a group of experts took a close look at the software running on routers and switches. They found that there are vulnerabilities in every version of every router manufacturer's software, allowing hackers to hijack a router, say. In other words, the very fabric of the internet itself is at risk.

Initially, OpenFlow could actually make networks less secure since it offers a route for attack, admits McKeown. But that should change rapidly as engineers develop new, more secure versions of router code that can be tested on existing systems without slowing or interrupting traffic. Then, when an update is ready to be installed, the fix can be accomplished simply by programming in the new instructions, rather than taking the router off-line and reprogramming by hand.

One of the most important benefits of OpenFlow could arise from the ability to alter the way that data packets travel across the network. At the moment, emails between two particular computers always take the same path. Problems arise when any one connection on that path fails. So a number of research groups are exploring "multipath" routing, including Gyu Myoung Lee at the Korean Advanced Institute of Science and Technology in Daejeon. This involves splitting a message into several packets and sending each one via a different route to its destination, where they can be recombined. Lee and others are convinced that by spreading traffic more evenly, this approach will increase the internet's reliability and reduce congestion. There are several competing multipath schemes, and with OpenFlow they could all be tested on the same network to quantify the advantages they offer.

Such a test may not be too far off. This spring, two more universities, Columbia University in New York city and Georgia Institute of Technology in Atlanta, have started teaching students OpenFlow. Meanwhile, electronics manufacturer NEC has announced it will begin making OpenFlow-enabled routers. Within five years, McKeown predicts, we could see a thriving community of developers creating open-source software to redefine how the internet works. He expects internet data centres to be the movement's advance guard because they have vast arrays of routers and are used to creating their own software. "If in those same five years the net itself becomes software-defined," McKeown says, "well, that would be nice, too." ■

Bennett Daviss is a science writer based in New Hampshire



Decay for all seasons

A decades-old nuclear mystery hints that the sun has a ghostly influence on Earth's radioactive atoms, says **Justin Mullins**

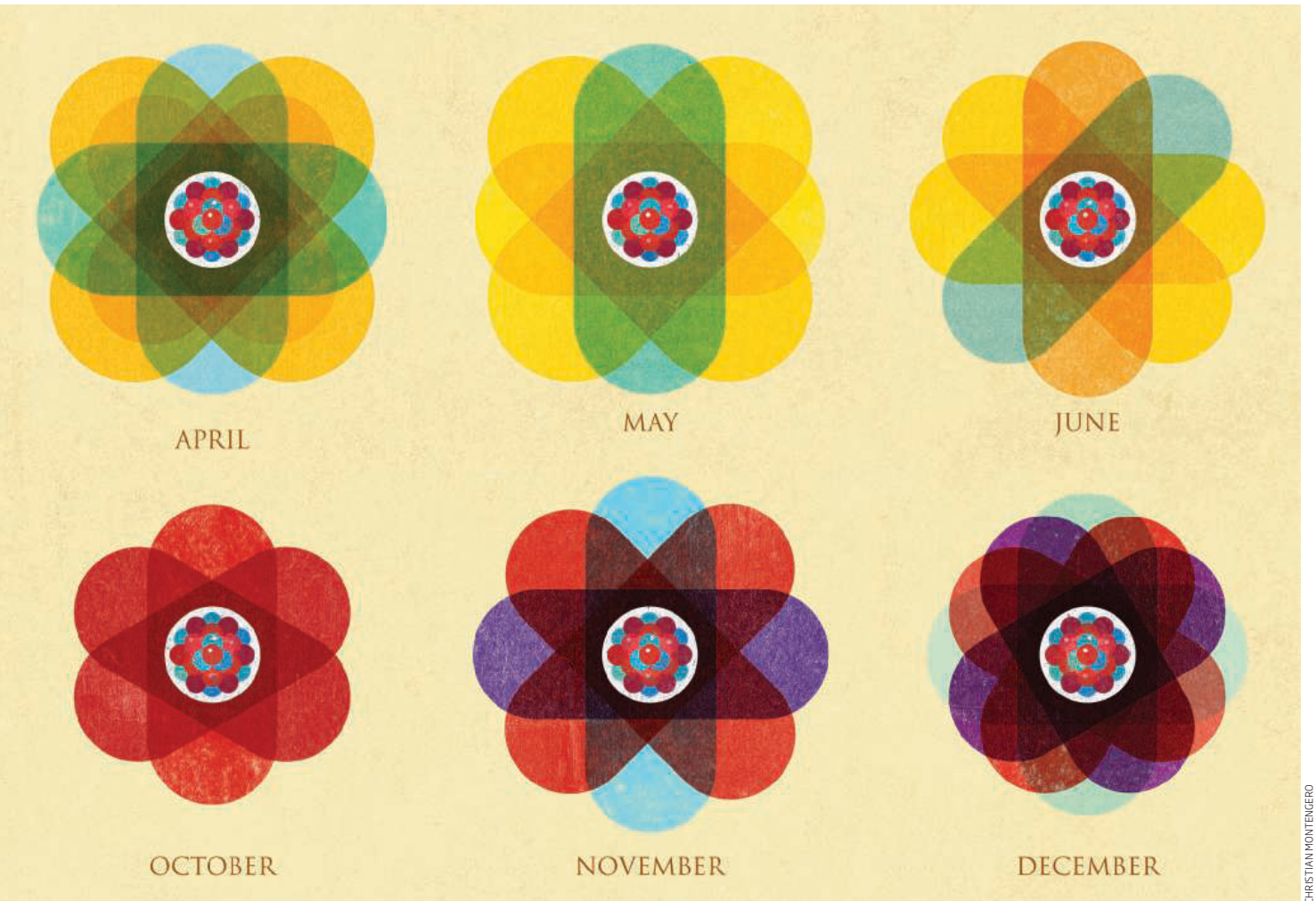
It's 1986, and there's a puzzle on Dave Alburger's desk. Not Ernö Rubik's latest toy, but the data from a four-year experiment to measure the half-life of the rare radioactive isotope silicon-32. On one level, the numbers fit together just fine, adding up to a half-life of 172 years, in keeping with previous estimates.

There's a devil in the detail, however. The sample's radioactivity has not been dropping steadily over time, as the textbooks demand. It has fallen, to be sure, but superimposed on that decline is an odd, periodic wobble that seems to follow the seasons. Each year, the decay rate is at its greatest around February and reaches a minimum in August.

If we know anything about radioactivity, it's that this kind of thing just doesn't happen. Radioactivity decreases predictably over time. That's why we can tell the age of rocks, fossils and prehistoric artefacts by the activity of radioactive atoms within them, and why nuclear waste becomes less toxic over time.

The fault was surely in some detail of the experimental set-up. Yet try as they might, Alburger and his colleagues at the Brookhaven National Laboratory on Long Island, New York – all nuclear physicists highly versed in this kind of painstaking measurement – couldn't find it. Eventually they published the result anyway, noting that although the variations were a puzzle, they had no bearing on their value for silicon-32's half-life (*Earth and Planetary Science Letters*, vol 78, p 168).

And there the result languished, a scientific skeleton in the closet. Until last year, that is, when it was rediscovered and dusted down by Ephraim Fischbach and Jere Jenkins of Purdue University in West Lafayette, Indiana. They



CHRISTIAN MONTENEGRO

think the data fits into an emerging pattern indicating that radioactivity is not quite the immutable process we assume it to be. Instead, it is susceptible to unseen interference from an unexpected quarter – the sun.

This controversial view goes against the grain established by Ernest Rutherford, the New Zealand-born physicist who discovered the structure of the atom. In 1930, he and colleagues measured the decay rates of various isotopes, concluding that "the rate of transformation of an element has been found to be a constant under all conditions".

We have since learned that certain decays can be influenced by electromagnetic fields, but Rutherford's core conclusion stands firm. Atoms in a chunk of radioactive material decay with an equal probability within a given time. It's a random process at the atomic level: you can't tell when any one atom will pop, but the fewer there are left, the less frequently it occurs. The result is a characteristic curve of activity that falls exponentially over time.

When Fischbach and a student, Shu-Ju Tu, stumbled upon Alburger's old results, they were not looking to overturn that picture. Rather the reverse: they had developed a new test of randomness and were using nuclear decay data to see if it worked. The Brookhaven results stopped them in their tracks. "We could see just by looking at it that the data was not random," says Fischbach. Intrigued, he and Jenkins began combing the results from other groups to see if anyone else had reported a similar seasonal effect.

Sure enough, someone had. It was not as clear-cut as the Brookhaven case, but in 1998 a team at Germany's national metrology lab, the Federal Physical and Technical Institute in Braunschweig, had seen an annual variation in the decay rate of radium-226, an isotope with a half-life of about 1600 years. The experiment had run for 15 years in the 1980s and 90s (*Applied Radiation and Isotopes*, vol 49, p 1397).

Do two swallows a summer make? Countless measurements of the radioactivity of many different elements have been made over the years. If just two had thrown up an anomaly – even the same anomaly – surely the error must lie in the experiments?

Yes and no. Tests of relatively few isotopes would throw up a subtle annual oscillation, even if it were a general feature. For a start, catching such variations requires decay rates to be counted over several years, impossible for the great majority of radioactive isotopes which have half-lives shorter than a few dozen years. Equally, counting experiments are not performed on stabler isotopes that decay over hundreds or thousands or millions of years at all: the change in count rates over the course of an experiment lasting even years would be too small to be measurable. That leaves relatively few elements, like silicon-32 or radium-226, with half lives of a few dozen to 1000 or so years, that would show the effect.

For Fischbach, the significant thing was that the results were both from world-class laboratories. It would not be surprising for odd variations to occur in a long-term experiment. Buildings and the equipment they contain heat up and cool down over the course of a year. Environmental parameters such as atmospheric pressure and humidity also change over time. ›

Alburger and his colleagues, though, had meticulously designed their experiment to avoid such problems. They measured the decay rate not only of silicon-32, but also of chlorine-36, a much longer-lived isotope, under the same conditions. By measuring the ratio of the decay rates, any systematic errors resulting from the way the experiment was set up or changes in its environment should have cancelled out. But they didn't.

Fischbach and Jenkins considered various possible explanations. Eventually, they hit on something promising. The seasonal variation seemed to track precisely the 3 per cent change in the distance between the Earth and the sun as the planet completes its slightly elliptical orbit. The closer Earth was to the sun, the higher the decay rate was. It was a convincing fit, but only half an answer. What on Earth – or off it – could be behind such a correlation?

Nuclei such as silicon-32 undergo beta decay, during which a neutron in the atomic nucleus decays into the slightly less massive proton. As it does so, it emits an electron and a near-massless particle, an antineutrino. As antineutrinos are notoriously difficult to detect, beta decay is signalled simply by a nucleus spontaneously emitting an electron.

Fischbach and Jenkins suggest that another reaction would, in theory, have the same signature. If a neutrino – a sister particle to the antineutrino – knocked into a neutron in an atomic nucleus, it would produce a proton and an electron. The nuclear fusion reactions that power the sun's core are spewing neutrinos equally in all directions. The further away from that source you go, the more spread out those neutrinos are. The higher flux of neutrinos through the Earth when it is close to the sun would therefore bump up nuclear decay rates (see diagram, below).

New interaction

It's a neat idea, with just one catch. For it to work, neutrinos must interact with neutrons much more readily than has ever been measured. "There would have to be some kind of additional interaction that for some reason had never been observed before," says Eric Norman, a nuclear physicist at the University of California, Berkeley. "That seems unlikely."

Peter Cooper agrees. A physicist at the Fermilab particle accelerator facility in Batavia, Illinois, his work had already questioned a claim that the energy of particles varied with the seasons when hitting an underground detector at the DAMA experiment at Gran Sasso National Laboratory in central Italy. This variation, with a maximum in June and a minimum in December, had been proposed as the signature of the solar system's passage through a sea of dark matter thought to perfuse our galaxy (*New Scientist*, 26 April 2008, p 14). But Cooper's analysis suggested that subtle seasonal effects affecting DAMA's detectors could not be discounted as the cause.

Following a suggestion made by Fischbach and Jenkins, Cooper tested the new claim by looking at the trajectories of space missions powered by radioisotope thermoelectric generators. These RTGs harness the heat created by plutonium as it undergoes beta decay to produce electricity. If the new idea were correct, the further out in the solar system the spacecraft travels, the smaller the flux of solar neutrinos would be and therefore the slower the rate of plutonium decay.

One spacecraft seemed an ideal candidate for investigation. NASA's Cassini mission to Saturn, launched in 1997, followed a trajectory first towards the sun, gaining energy in a gravitational slingshot around Venus, and then outwards past Earth and Jupiter. What Cooper found was: nothing. The power from Cassini's generators fell exponentially as it flew both towards and away from the sun in exactly the way it would have done on Earth.

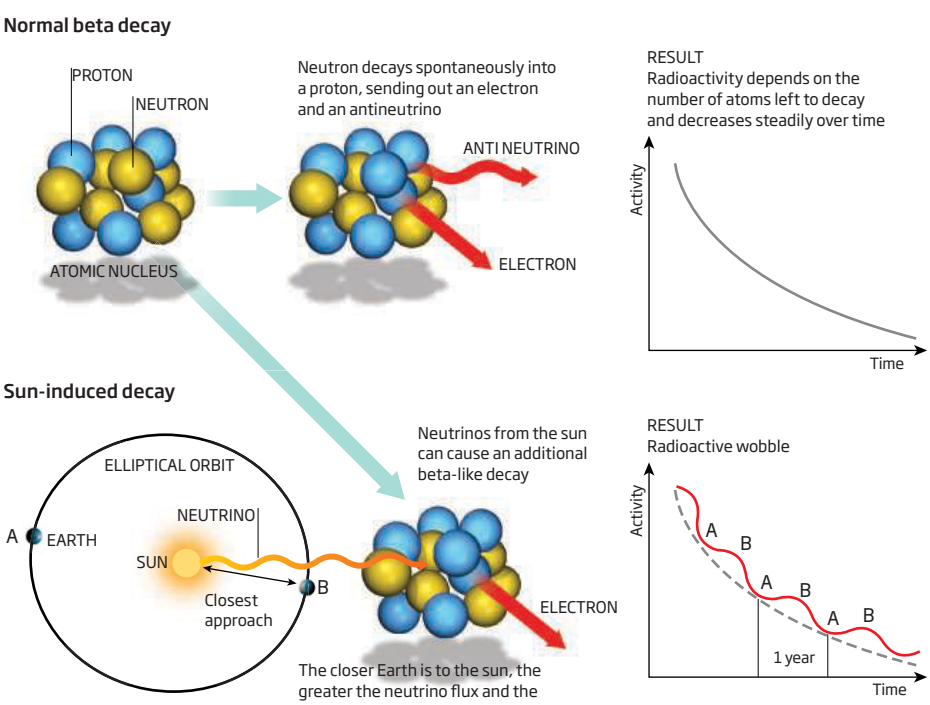
A quiet end to a heretical theory? Fischbach and Jenkins don't think so. They counter that the power developed by Cassini's generators is proportional to the difference in temperature between the plutonium it contains and the outside of the spacecraft. This temperature difference changes in accordance with the square of the probe's distance from the sun in exactly the opposite way to the neutrino flux. It would therefore almost perfectly cancel out any variations in the decay rate as measured by the RTG's power output.

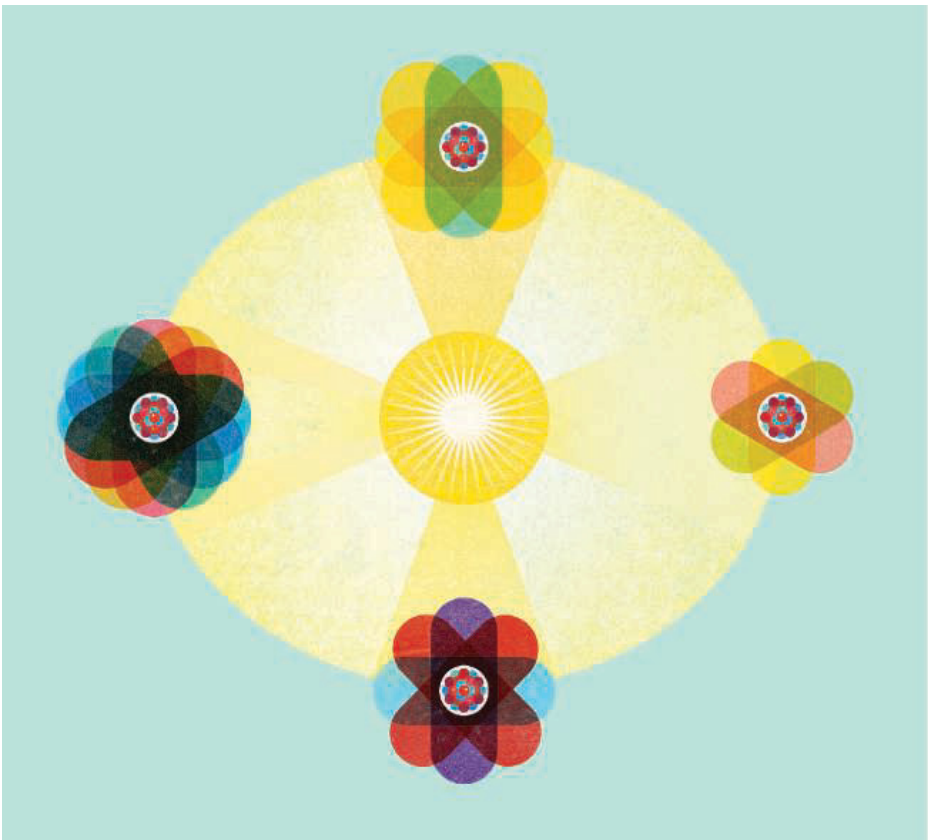
The duo is now busy combing the scientific literature for other evidence which might bear out their solar neutrino theory. They have had some success. There is the case, for example, of Ken Ellis, a medical physicist at Baylor College of Medicine in Houston, Texas, who over nine years found seasonal variations of about 0.5 per cent in the decay rate of plutonium-238 used for radiation studies of the chemical composition of the human body (*Physics in Medicine and Biology*, vol 35, p 1079).

The evidence is bitty, however, and the consensus is that much more is needed before the theory can be properly assessed. Alvin Sanders, a physicist at the University of

Can't count on it

If neutrinos from the sun do influence nuclear decays, radioactivity might not be the simple, random process we assume





CHRISTIAN MONTENGERO

Wibbly-wobbly neutrinos

If neutrinos cause wobbles in nuclear decay, it seems nuclear decay may return the favour by producing wobbles in neutrinos.

The background is research from the GSI nuclear physics laboratory in Darmstadt, Germany, which found a strange periodicity in the decay of two heavy radioactive ions, praesodymium-140 and promethium-142.

These ions undergo a process similar to beta decay known as electron capture, in which a proton in the nucleus absorbs an electron and changes into a neutron, emitting a neutrino. This decay changes the mass of the ions, and can be identified as a change in the speed at which they race around a magnetic storage ring.

Yuri Litvinov and colleagues, who carried out the experiments, found a standard exponential decay with half-lives of 3 minutes, 23 seconds for praesodymium-140 and 40.5 seconds for promethium-142. But superimposed on each was an oscillation, with the measured decay rate increasing and decreasing every 7 seconds – just like in the Brookhaven case, but on a much shorter timescale (*Physics Letters B*, vol 664, p 162).

Unlike in the Brookhaven case, there is a growing consensus as to the cause. Neutrinos come in three different "flavours" with different tiny masses, and they can oscillate between these forms. The suggestion is that this quantum-mechanical oscillation changes the momentum associated with an ion's decay, and so affects the time it takes the isotope to move around the ring. The regular oscillation between two states of the neutrinos emitted by the isotopes produces the observed 7-second cycle.

If so, that is an exciting development, because it raises the possibility of studying the behaviour of neutrinos in an entirely new way – and in a much smaller-scale experiment than has ever been possible before.

Tennessee in Knoxville, thinks there could be something in it. He reckons it might also hold the key to another curiosity – the fact that when the age of trees judged using carbon-14 dating is compared with their age gauged by counting their rings, the discrepancy between the two gets larger and smaller over a cycle of about 200 years.

"Wiggles in carbon-14 dates are well known as a nuisance," says Sanders. Fluctuations in incoming cosmic rays and in Earth's magnetic field have been proposed as explanations, but Sanders thinks that the solar neutrino theory is a plausible alternative. The well-documented 200-year period of sunspot activity, known as the de Vries/Suess cycle, would cause variations in the number of neutrinos being emitted by the sun, which would in turn influence carbon-14 decay rates.

"What we are seeing may be the heartbeat of the sun," says Sanders. It means that carbon-14 data from Earth, as a proxy for the sun's neutrino activity, could allow us to determine the history of the sun's internal reactor stretching back thousands of years. Quite generally, if Fischbach and Jenkins should ultimately be proved right, nuclear decay would represent a powerful way to detect neutrinos – something that currently requires experiments on a huge scale – and a new type of telescope with which to peer inside the sun.

At the moment that is speculation. Twenty years on, the mystery of Alburger's result remains, and until it is explained nothing should be dismissed out of hand. Researchers are still searching for a mundane explanation. Last month, Tom Semkow, a physicist with the New York State Department of Health in Albany, and his colleagues proposed that despite all the precautions taken, some of the variation in the Brookhaven data might be explained by seasonal temperature changes. Their idea is that hot air is less dense and absorbs fewer beta particles, increasing the count rate registered at a detector (*Physics Letters B*, vol 675, p 415). Even if that is right, though, it doesn't look to be enough to explain the whole effect.

Alburger himself, long since retired, is almost apologetic that the issue remains unresolved. "I am sorry that I am unable to throw any further light on these curious and as-yet-unexplained results," he told *New Scientist*. Fischbach and Jenkins might have made a worthy stab at explaining them, but it looks likely that this skeleton will be hanging in the closet for a while yet. ■

Justin Mullins is a consultant for *New Scientist*

IMPERIAL WAR MUSEUM, LONDON

Walter Munk was never much of a surfer, but that hasn't kept him from becoming a legend in the sport. An oceanographer by training, Munk has spent 67 years studying how waves form, how they travel and how they break when they hit the beach. In the second world war, he saved countless lives by helping the Allied military determine when troops could make amphibious landings without being swamped by big surf hundreds of metres from a hostile shore. After the war, Munk's methods helped surfers find the biggest waves. Today, anyone who checks out a surf forecast on the internet is drawing on his pioneering research.

The calm before the storming of the beach

IN THE summer of 1942, Walter Munk went to the beach. It wasn't a holiday; Munk worked for the Pentagon and he was there to watch American troops practise for an amphibious landing in north-west Africa. The Allies were losing the war, and the invasion would be their attempt to retake the initiative.

The troops were using boats called LCVPs (Landing Craft, Vehicle, Personnel) – smaller versions of the drop-bow boats that would later storm beaches from Normandy to Iwo Jima. They were not the most seaworthy of vessels. "When the waves exceeded five feet, the LCVPs would swamp," recalls Munk, now emeritus professor at the Scripps Institution of Oceanography in La Jolla, California. "They would call it a day, and wait for another that was a little calmer."

Munk was concerned. "I went back and learned about waves at the landing beaches in north-west Africa. In the winter they exceeded six feet most of the time. I thought a terrible catastrophe was about to happen."

His commanding officer dismissed his objections. "They", the officer said, must have figured this out. Today, the 91-year-old Munk is convinced there never was a "they".

Everyone knew that waves were generated by distant storms, but no one knew where they came from or why, and no one had tried to make surf forecasts. Munk decided to tackle the problem on his own, puzzling out the physics of how storms generate swells and what happens as they hit a beach after crossing thousands of kilometres of open water. A month later, he took his findings back to his superiors. Again they brushed him off.

Luckily, he was stubborn. Before the war, Munk had been studying oceanography, so he took his concerns to his mentor, Harald Sverdrup, then director of Scripps and widely regarded as the top oceanographer in the US.

> **"This time the army listened, and 35,000 US troops went ashore in calm surf"**

Previously, the two had worked on anti-submarine warfare, looking for ways to help defend North Atlantic convoys from German U-boats. Munk, however, had been born in Austria and Sverdrup had relatives in German-occupied Norway. Partly because of rumours spread by rival scientists, both had trouble maintaining security clearances in the super-clandestine field of anti-submarine warfare.

"Ironically, the US may have inadvertently won the war by denying [them] clearances and getting them out of anti-submarine warfare and into surf forecasting," says Peter Neushel, a historian at the University of California, Santa Barbara, and an avid surfer.

Despite his security problems, Sverdrup had the clout to get military chiefs to recognise the need for forecasts. He and Munk developed a model but they still needed to test it. "We were desperate to see whether the method was working," Munk says.

Then they learned that before the war Pan Am had been flying seaplanes on an Atlantic test route between Bermuda and the Portuguese archipelago of the Azores. On each trip, the pilots had recorded the height of the surf. It was a treasure-trove of data.

Sverdrup and Munk hunted down old weather maps, then plugged the weather data into their model to "hindcast" wave heights for each Pan Am landing. To their joy, they found a close correlation with what the pilots had recorded – with one puzzling exception. "Once in a while, the observations showed a big spike which we missed," says Munk.

Then they noticed that these spikes occurred at evenly spaced intervals – always on Saturday nights, Munk remembers. "We decided they were related more to Portuguese wine than meteorological conditions."

Reassured, the oceanographers were able to give the thumbs-up for a landing in north

RICK DOYLE/CORBIS

Surf's up at La Jolla, California, and (left) US troops land safely in north Africa in 1942

Africa on 8 November 1942. This time the army listened, and 35,000 US troops went ashore in calm surf. "I'd say we were tremendously lucky with not-so-good weather maps and not-so-good beach charts," says Munk.

Meanwhile, Munk and Sverdrup set up shop at Scripps and began turning out entire classes of surf forecasters. Soon, their disciples were spreading out into the Pacific or teaming up with counterparts in the UK to try to figure out how to predict surf conditions in Normandy, for the long-anticipated D-Day invasion.

The British group, based at the Admiralty's lab on the river Thames, combined Scripps graduates with a team led by George Deacon, the UK's top oceanographer. Dubbing themselves "The Swell Committee", they recruited coastguards to collect as much data as they could about surf in the English Channel. They appear to have met some resistance from the coastguards, who saw their mission as repelling German spies.

Eventually, the Channel model was accurate enough to persuade Allied commander Dwight Eisenhower to postpone the D-Day invasion by a day when faced with weather conditions linked to dangerously high surf.

Sverdrup and Munk's method of surf forecasting was then used in every major Allied landing in the war. "As we learned more, our predictions became pretty good," Munk says.

Only once did things go badly wrong. In November 1943 at Tarawa in the Pacific, landing craft got stuck on a reef 500 metres offshore. When soldiers jumped out with their guns and packs, they found themselves in deep water. Many drowned.

According to most histories, someone misread a tide table and scheduled the invasion for a day when the tide was too low to clear the reef. But Munk thinks no one knew the reef was there. "The major failing was not waves, but beach intelligence. The landing craft ran into an uncharted shoal."

After the war, Munk's interest shifted to surfing, which he could watch from his cliff-top home in Southern California. Historically, surfers drove up and down the coast, looking for big waves. Sometimes they found them. Often they heard the frustrating refrain: "Gee, you should have been here yesterday!"

Munk began to ponder where the good waves came from. By studying the way waves spread out as they travel, he was able to calculate that some came from as far as 15,000 kilometres away – farther than the entire width of the Pacific. "There was only one possible answer, which is that they came from the Indian Ocean," he says.

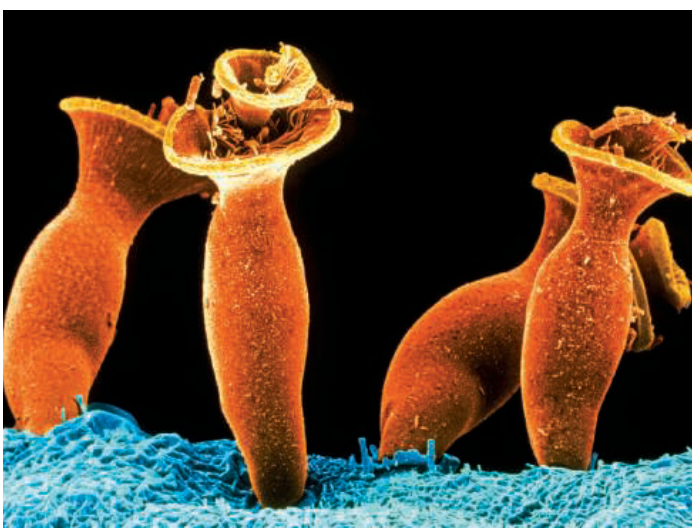
To confirm this, he borrowed a technique from radio astronomy and set up an array of wave detectors near San Clemente Island, about 100 kilometres off the California coast. The array allowed him to pin down the direction of the incoming swells, confirming that they had indeed originated in tropical storms half a globe away, then spent weeks travelling around the southern tip of New Zealand before reaching California. "Today, every surfer in California is familiar with the fact that the waves come from far away," Munk says. "At that time, nobody knew it."

Munk's one regret is that he missed the potential fortune to be made from forecasts. In the 1950s and 60s, surfing was a small sport, pursued by a few dedicated enthusiasts. Now, surf forecasting is big business. "The question 'Is there surf?' is one a dedicated surfer will check every day via the web or real-time animated film," says Neushel.

But there remain mysteries in the waves. Surfers know that waves come in clusters, with groups of big ones interspersed with smaller ones – but no one knows why. Nor is it fully understood how waves lose energy over long distances, says Munk. "It's kind of a puzzle." **Rick Lovett** ■

Living programs

Simple life forms boast sophisticated powers, and all thanks to computation



VOLKER STEGER/CHRISTIAN BARPELLE/SPL

Wetware by Dennis Bray, Yale University Press, £18.99/$28

Reviewed by Graham Lawton

A BAG of biochemistry less than a millimetre across that spends most of its life attached to pond scum, the single-celled organism *Stentor roeselii* doesn't sound impressive. Yet its behaviour is remarkably sophisticated. Squirt a jet of water at a *Stentor* and it will dive into its mucus holdfast, emerging cautiously soon after. But squirt another identical jet at the same *Stentor* and it ignores it.

Now squirt a jet of an irritant chemical and the *Stentor* will arch its stalk-like body out of the way, moving from side to side to avoid the stream. If this fails, it retreats. If the chemical is still there when it re-emerges, it retreats again. Eventually, it retreats with such force that it tears itself free and floats off in search of a new home.

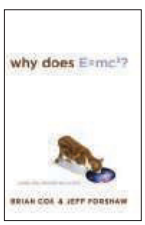
How can such complex behaviour arise in such a simple life form? This is the question that Dennis Bray tackles with remarkable clarity and style in this excellent book. In a nutshell, his answer is that living cells, like the single-celled protozoa pictured, are chemical computers. They take information from the environment and process it to produce behavioural "outputs". The processing units are proteins, which perform all the same operations as the logic gates of a computer. Inputs from the environment cause the proteins to flip shape, to aggregate, and to chemically modify other proteins in a cascade of information processing that sweeps through the cell until it reaches effector proteins that make the cell move or change shape.

This computation is the essence of "wetware", and of life. And when billions of chemical computers congregate into multicellular bodies, amazing things happen. Highly recommended. ■

Ambitious workings

Why Does E=mc²? (and why should we care?) by Brian Cox and Jeff Forshaw, Da Capo Press, £12.99/$24

Reviewed by Stephen Battersby



THE breezy title of this book conceals the authors' ambition. To get at the origins of $E=mc^2$, the poster-child for Einstein's special theory of relativity, they must delve into deep principles of science and wield a good deal of mathematics. They do it well, aside from a few too many digressions and an over-optimistic attitude that "you will have a go with the maths even if you have no prior experience at all". It means some of the crucial exploration of relativity is tangled up with a simultaneous attempt to explain the basics of algebra.

Nevertheless, they have blazed a clear trail into forbidding territory, from the mathematical structure of space-time all the way to atom bombs, astrophysics and the origin of mass. And if special relativity isn't enough for you, there's a final-chapter taster of Einstein's more difficult theory, general relativity, and its weird world of warped space-time.

Science on the map

The Geek Atlas by John Graham-Cumming, O'Reilly, £22.99/$29.99

Reviewed by Celeste Biever

HEADING abroad? Don't forget *The Geek Atlas*. It will tell you if you'll be staying near a slice of Charles Babbage's brain (London), a visible 660-tonne stabilising pendulum suspended from the upper floors of a skyscraper (Taipei, Taiwan), the best place to buy a robotic toilet seat (Tokyo, Japan), or any of the 125 other places of scientific or technological wonder it features.

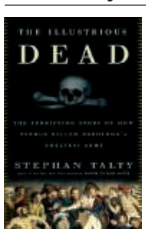
Nothing is too small (Alexander Fleming's penicillin mould) or big (the Galapagos islands). Each entry has a short description, practical visiting information and an explanation of a scientific concept associated with the place. A delightful example is Infinite Loop, the road in California where Apple has its headquarters, accompanied by a description of a software bug that is created when two programs get stuck in infinite loops.

My only quibble is that the book is quite UK and US-centric: aren't there places where science comes alive in, say, Africa?

Killer microbe

The Illustrious Dead by Stephan Talty, Crown, $25.95

Reviewed by Saswato R. Das



ON 24 June 1812, against the warnings of his closest advisors, Napoleon invaded Russia with a huge army of almost 600,000 soldiers and 50,000 horses. Napoleon had boasted he would defeat Russia in 20 days. Yet he failed miserably. The Russians retreated, following a scorched-earth policy, burning the countryside along the way. Napoleon's soldiers found it harder and harder to forage for food, and they started to die from hunger, exhaustion and sickness: more than 5000 died each day. Within a few weeks, before any major battle, Napoleon had lost 100,000 men. What went wrong?

Napoleon's disastrous Russian campaign is the subject of Stephan Talty's new book. He focuses on typhus, a virulent disease that wreaked havoc on the Grand Army and foiled Napoleon's ambitions for Russia. He tells a gripping tale of man against microbe, set against the stark backdrop of one of history's most notorious military campaigns.

Photography: Oscar Rejlander/Oxford University Press 2009

Art meets evolution

Darwin's Camera: Art and photography in the theory of evolution by Phillip Prodger, Oxford University Press, $39.95

Reviewed by Ewen Callaway

FEW scientific fields have escaped the influence of Charles Darwin, from anthropology and geology to zoology and, of course, evolutionary biology. Now we ought to add photography to the list, argues Phillip Prodger, a curator at the Peabody Essex Museum in Salem, Massachusetts, in his revealing new book.

Darwin's influence on art is surprising; most of his published works included few images, and he showed little aptitude for art. *On the Origin of Species* contains just one illustration, a "tree of life" with all the composition of a stick figure. Indeed, the naturalist often relied on abler hands to illustrate his works.

Yet when his scientific interests turned to the evolution of behaviour and facial expression, Darwin and his collaborators pushed the boundaries of photography, an art form still in its infancy at the time. The result, *The Expression of Emotions in Man and Animals*, wasn't the first scientific book to include photographs, but when it was published in 1872 it was the most important.

For *Expression*, Darwin needed images depicting spontaneous expressions such as happiness or surprise, but quick exposures were not yet technically feasible. He had little use for commercially available photographs, and instead turned to artists and other scientists, who sometimes went to great lengths to capture the right image.

French neurologist Guillaume-Benjamin Duchenne, for instance, plied a patient's muscles with electrical stimulation to induce a horror-stricken face that Darwin redrew for his book. He also collaborated extensively with Oscar Rejlander (pictured above), a prominent photographer known for overlaying multiple images to produce composite prints. Rejlander tinkered less with the photographs he produced for Darwin, but many of them, including several self-portraits, were exquisitely contrived.

Such manipulations may seem at odds with Darwin's commitment to objective evidence, but expressions are as much in the beholder as the performer. For Darwin, photographs were useful support for his ideas, not stand-alone evidence. ■

For more images from *Darwin's Camera*, visit **www.newscientist.com/topic/books-art**

Let's get it together

On its 20th anniversary of reunification, German science is thriving and offering a warm welcome to British scientists. **James Shelton** finds out how to get a piece of the action

DAGMAR SCHWELLE/LAIF/CAMERAPRESS

World class science and a view to match over the river Elbe, Hamburg

OVER 130 people died trying to crawl under it, smash through it or fly over it. Today, 20 years after the Berlin wall crumbled, a few isolated remains stand as a reminder of how far German integration has come. The decades following the second world war left German science in a sorry state. "We had lost our international standing," says Manfred Pinkal, professor of computational linguistics at the University of Saarland in Saarbrücken. "German scientists would first need to travel to America or the UK to cut their teeth."

Now, in a reunified Germany, a range of initiatives, investments and incentives has breathed new life into science. The European Innovation Scoreboard shows Germany to be an "innovation leader", and the fastest improving country. "Now we are a world player once more," says Pinkal.

What's more, Germany and its scientific institutions are welcoming foreign researchers. So what's the best way in?

The adventure starts here

Perhaps the most straightforward way to get a taste of German science is via the European Commission's Erasmus scheme. This exchange programme offers students and faculty a glimpse into German life without having to commit to a full three years' study. With 9 out of 10 higher-education institutions signed up, there's plenty of choice. What's more, it's simple to hop aboard. "I found the process very easy. All the application forms I needed were available to download," says Amy Johnson, an Erasmus student at the University of Freiburg in Baden-Württemberg.

Students from the UK who want to participate are likely to find themselves in a favourable position, according to Stefan Lauterbach, director of international affairs at the University of Saarland. "Erasmus works on the basis of reciprocity," he explains. "More German students want to study in the UK than vice versa, so when a UK student wants to come here, it is no problem."

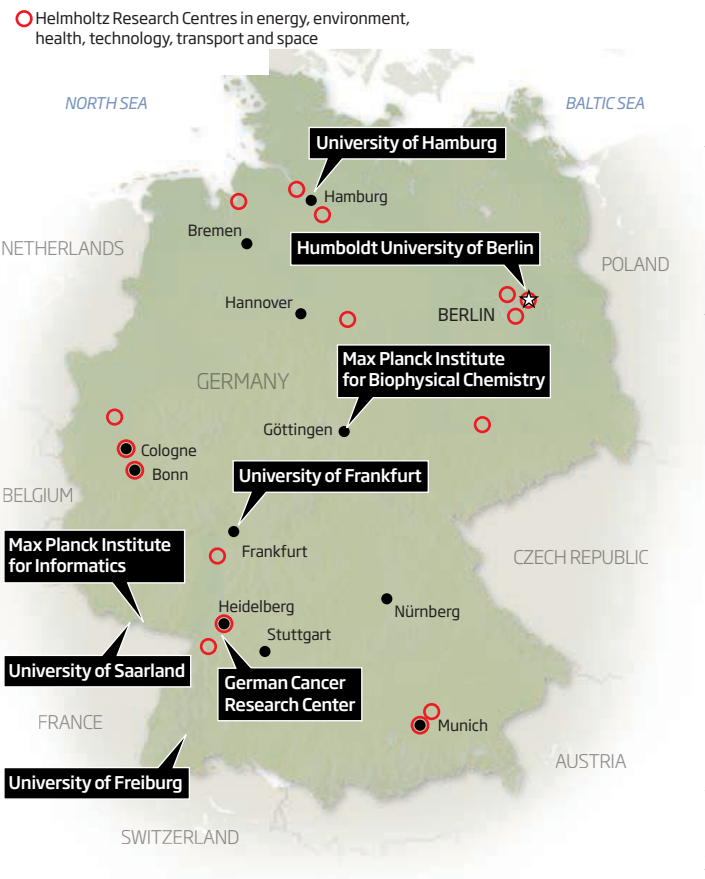
Those wishing to take the next step and do all their studying in Germany should apply directly through the international office of their chosen university. For regular bachelor-level courses, fluency in German is an absolute must and prospective students have to provide proof of their language skills by passing one of the official exams – either the TestDaF or the DSH. This is not, however, needed if you choose to study on one of the increasingly popular international degree programmes. "The majority are in science and engineering and taught completely in English," says Andreas Hoeschen, director of the German Academic Exchange Service (DAAD) UK office, which looks after incoming UK scientists from BSc to postdoc level. "The international programmes are designed to attract highly qualified young researchers from around the world, thereby internationalising the German university system," he says.

One of the driving forces behind the desire to internationalise is the global dominance of English. "English is the language of science," says Beverley Tkalcec, a geosciences student from the UK now studying for a master's at the University of Frankfurt. "I'm fluent in German, but if I intend to publish then I must write in English."

For some visiting students, the kudos attached to English can have its downside, however. "I chose Germany not only for the research excellence but to learn another language," says Ed Crossland, a postdoc physicist at the University of Freiburg. Yet at work he found precious little opportunity to develop his language skills. "The totality of English speaking, and the enthusiasm of my colleagues to practise it on me, meant I ended up taking a German evening course," he says.

For potential PhD students there are two routes to choose from when applying for a place:

Where it's happening



the "apprentice model", where you find a supervisor to agree to take you under their wing, or one of the structured PhDs available at some universities. As befits a country that has produced a plethora of Nobel laureates and is home to several world-class universities, German PhDs are

"I chose Germany not only for research excellence but to learn another language"

rigorous and internationally respected. The clincher for many students is that you get top-class teaching without the tuition fees.

For more established academics and researchers seeking a way into Germany, the first port of call is the Alexander von Humboldt Foundation (AVHF). Here you can find guidance on funding and fellowships – and more besides. "Not only is the AVHF funding a project, but more importantly investing in the person," says Georg Scholl, head of communications. "Once a Humboldtian, always a Humboldtian."

Those already established in Germany can seek funding through a range of German-centric bodies, by far the largest and most influential of which is the German Research Foundation (DFG). With an annual budget of approximately €2 billion, it runs a range of funding programmes. Its most important scheme is without doubt the Excellence Initiative, designed to reward institutions for supporting young scientists and conducting high-level innovative research, to which it has committed €1.9 billion over five years. "There's a lot of money for science in Germany right now," says Priya Bondre-Beil, DFG's programme director of international affairs.

Much of that money goes to Germany's most prolific institutions, including the Max Planck institutes, the Helmholtz Association and the Fraunhofer institutes. There are also a growing number of partnerships between research institutes. One of these is the Helmholtz Alliance: it brings together DESY – the German Electron Synchrotron in Hamburg, which is Germany's biggest particle physics research centre – the Max Planck Institute of Particle Physics, and 18 German universities. The alliance "promotes communication and sharing of resources be it experience, intellectual or computation", notes Tim Namsoo, a British physicist at DESY.

This symbiosis hasn't gone unnoticed by big industrial players such as Intel, which recently instigated a partnership with the Max Planck Institute for Informatics and the University of Saarland to create the Intel Visual Computing Institute. "We could have put our research and development site anywhere in the world," says Justin Rattner, Intel's chief technical officer. "We chose Germany." Intel is not alone in seeing the country as a prime location for companies looking to collaborate with academic researchers. "We've had about 60 industrial collaborations with major firms in Germany such as BASF, Carl Zeiss and Bayer," says Christina Beck, head of communications at the Max Planck Society.

After hours

No matter where in Germany you find yourself, there is plenty to do apart from studying. Cities like Munich and Berlin have all the benefits of metropolitan life. If rural pursuits such as hiking and skiing are your thing, a university or institute in one of the smaller towns such as Göttingen or Freiburg may suit you better. Germany borders no fewer than nine countries, and the UK is around an hour's flying time away.

When it comes to living costs, in Germany as elsewhere it's cheaper to live away from the city centre. "In Freiburg, I currently pay €300 a month for a double room and that includes all of my bills," says Erasmus student Amy Johnson.

Affordable rent isn't the only perk for Johnson. She also enjoys the busy social scene, pubs, clubs, cafes and ice cream parlours. And if the UK beckons, "Freiburg is close to two airports, which makes it easy to fly home." ■

James Shelton is a science writer based in London

WHAT kind of broken clock, we wondered innocently on 6 June, could ever be "right" more than twice a day? Readers have written in their droves to disabuse us of our innocence.

Let Barry Morse take the floor first: if there is a change to daylight saving time so that clocks go back, then on that day a broken 12-hour clock "may actually be right three times in one day. Assume the clock is stopped at, say, 3:00 and the clocks go back at this point. It has been right once already. In an hour's time it's right again and in 12 hours' time it's right again." Dozens more made the same point. Artificial intelligence guru Marvin Minsky of MIT was probably the most famous reader to point out that if we moved our stopped clock westwards through all the time zones it "would be right 24 or 25 times a day".

Dozens more pointed out that a "broken" clock isn't necessarily a stopped clock. Several spoke from experience of clocks that suddenly started to race forward so that they showed the right time three, four, five and more times a day. Others noted that a 12-hour analogue clock that runs backwards – whether spontaneously or as part of a prank as, for example, when Bob Crofoot arranged to enliven his household's morning rush for work – is right four times a day. We had to scratch our heads over this. Sadly, the spreadsheet to prove it is correct will not fit within this page's margins.

Then there are broken digital clocks. Hugh Datson, remembering the youthful fun he had making numerical digits form rude words by turning those new-fangled electronic calculators upside down, claims that by occasionally inverting a digital clock stopped at 12:01 you can make it right four times a day – "and four more if you use a mirror". Confirming this is left as an exercise for the reader.

Taking speculation a step further, if not too far, Andrew Fogg wonders how often a clock would give the right time if it divided the day into a number of shorter periods, such as an 8-hour clock, a boon to those working three-shift patterns. "The idea of a fractional number of periods was amusing," he writes, but when he got to irrational divisions such as dividing the day into pi chunks, "my head started to hurt". We can only concur.

"Security authentication – avoid phishing attacks" was the subject line of an email to *New Scientist* which turned out to be – you guessed? – a phishing attack

IN WHAT he describes as "an early introduction to relativity", David Stott overheard this exchange outside his local primary school.

Mother, to her young daughter who had run on ahead: "Donna, come here!"

Small indignant voice: "Mummy, I *am* here!"

IF IT ain't broke… Here's a nice example of an improvement that wasn't needed and that simply makes things worse. Reader "Richey" received a newsletter from DynDNS.com telling him: "Account Upgrade service underwent a makeover recently, re-emerging as the Dynamic DNS Pro service. Why the facelift? For starters, 'Account Upgrade' is a rather bland and nondescript title, and we hope the new name helps to make its purpose clearer."

Richey says he's puzzled as to how the words "Dynamic DNS Pro" can describe "account upgrade" more clearly than the words "Account Upgrade".

FINALLY, now is your last chance to win a piece of the moon.

Depending on which time zone you are in, 20 or 21 July 2009 sees the 40th anniversary of the first moon landing. Our competition to celebrate that event offers a fabulous winning prize: some rock from the moon.

The competition is simple to enter. You will doubtless know the words spoken by Neil Armstrong when he stepped off Apollo 11's lunar module and onto the moon itself: "One small step for [a] man – one giant leap for mankind." Can you think of something else he might have said instead – something equally memorable, or perhaps something funny?

Your entry should be no more than 75 characters long (including spaces). You can send your entries by email (address below; please put "Competition" in the subject line), by fax or by post, or online at www.newscientist.com/article/dn17213, where you can also read the specifications of the rock from the moon that you could win, along with an analysis of it performed for *New Scientist* by a team at the Open University in the UK. See also last week's feature "When the moon lands" (20 June, p 40) on how the analysis was performed.

The competition closes on Monday 29 June and no entries will be accepted after that date. The results will be published in the 18 July issue of *New Scientist*, in anticipation of the anniversary of the landing.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Pretty in pink

Why are girls, and particularly young girls, drawn to the colour pink? Is it something society has instilled in them? Or is something attractive about the colour itself? Shops seem to be full of pink clothes for young girls – are they reacting to demand or just forcing their designs upon children who would not otherwise choose this colour? (Continued)

■ Previous answers drew attention to a study in 2007 by Anya Hurlbert and Yazhu Ling to support the idea that girls have an innate preference for pink (*Current Biology*, vol 17, p R623). In fact, the study came up with less definite results than the ensuing press coverage would have us believe.

The pair's suggestion that a preference for red (note red, not pink) relates to recognising ripe fruit is, they would agree, speculation. The experiment was not designed to test such a hypothesis. Post-hoc rationalisation of results is best kept out of the argument: not all ripe fruits are red, and in any case one could equally suggest a preference for red being associated with the hunter's kill – supposedly a male trait.

I understand that the researchers plan to study young babies to see if colour preference is present before socialisation.
Pauline Grant
Business psychologist
Beaconsfield, Buckinghamshire, UK

Wotsisface?

Why, after I've spent hours attempting to remember somebody's name or something similar, does the answer eventually arrive in the middle of the night when I'm not even trying?

■ It has been suggested that when someone has this kind of sudden insight (an "aha!" moment), one's mind has taken unconscious "pathways" that have led to the solution of the problem – whether it's your cousin's boyfriend's name or 5-down in the crossword you attempted yesterday.

It seems that the first time you were trying to remember that name, however, your mind activated the wrong pathway. That misdirected activation might have been stronger than the answer-related activation, masking the latter, even though you knew the answer. Only when the former subsides can the solution-related activation surpass the threshold of consciousness and be perceived. It might happen when you're not expecting it, like just before sleeping. More information on these processes can be found in a *Psyconomic Bulletin and Review* article published in 2003 (vol 10, p 730).
Dilza Campos
Rio de Janeiro, Brazil

■ Just because the conscious mind is not focused on recalling a name, does not mean the brain is not churning away at the problem, even during sleep. Indeed, as a designer I have learned to trust this non-conscious, problem-solving process. Upon retiring, I will often select some difficult unsolved design dilemma from a current project and "assign" it to myself. When I awake in the morning, almost invariably, I will discover that I have worked out a solution.

Many older people – myself among them – whose memories may be increasingly cluttered and whose recall mechanisms may be slower, discover that, precisely by not trying to recall a name or term but merely waiting or continuing with another thought or activity, the sought-after memory comes to them of its own accord.

"The conscious mind may not be focused on the problem, but the brain is still churning away"

Larry Constantine
Department of Mathematics and Engineering
University of Madeira
Funchal, Portugal

Wakey wakey

Why, when we are tired do the blood vessels in our eyes become more visible?

■ Apart from causing droopy eyelids, sleepiness slows down blinking, a process which normally keeps the conjunctiva – the outer layer of the eye – moist and well lubricated with fluid from the tear ducts. Its drying out triggers mild inflammation. The more obvious effect is red eyes, a consequence of the dilation of the conjunctiva's capillary blood vessels, which are usually invisible.

All this causes the eyes to become itchy, and rubbing them only makes things worse, as does a dry indoor atmosphere or smoke. Contact lenses become unbearable by this stage, and if they dry out, too, can cause painful scratching of the conjunctiva.

Other than trying to remember to blink more frequently or going to bed and having a good night's sleep, going outdoors into cooler and moister air helps, as does the humid air from a warm shower (though remove contact lenses first).

The quick fix of resorting to eye drops to reduce the inflammation and then going straight back into a dry, smoky atmosphere would be a short-sighted approach (pun, of course, intended).
Jim Horne
Sleep Research Centre
Loughborough University
Leicestershire, UK

THIS WEEK'S QUESTION

BLOOD BROTHERS

At the risk of flogging a dead, er, penguin. Why don't polar bears' feet freeze?
Paul Newcombe
Zurich, Switzerland

Questions and answers should be concise. We reserve the right to edit items for clarity and style. Include a daytime telephone number and email address if you have one. Restrict questions to scientific enquiries about everyday phenomena. The writers of published answers will receive a cheque for £25 (or US$ equivalent). Reed Business Information Ltd reserves all rights to reuse question and answer material submitted by readers in any medium or format.

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For a list of all unanswered questions send an SAE to LWQlist at the above address.