

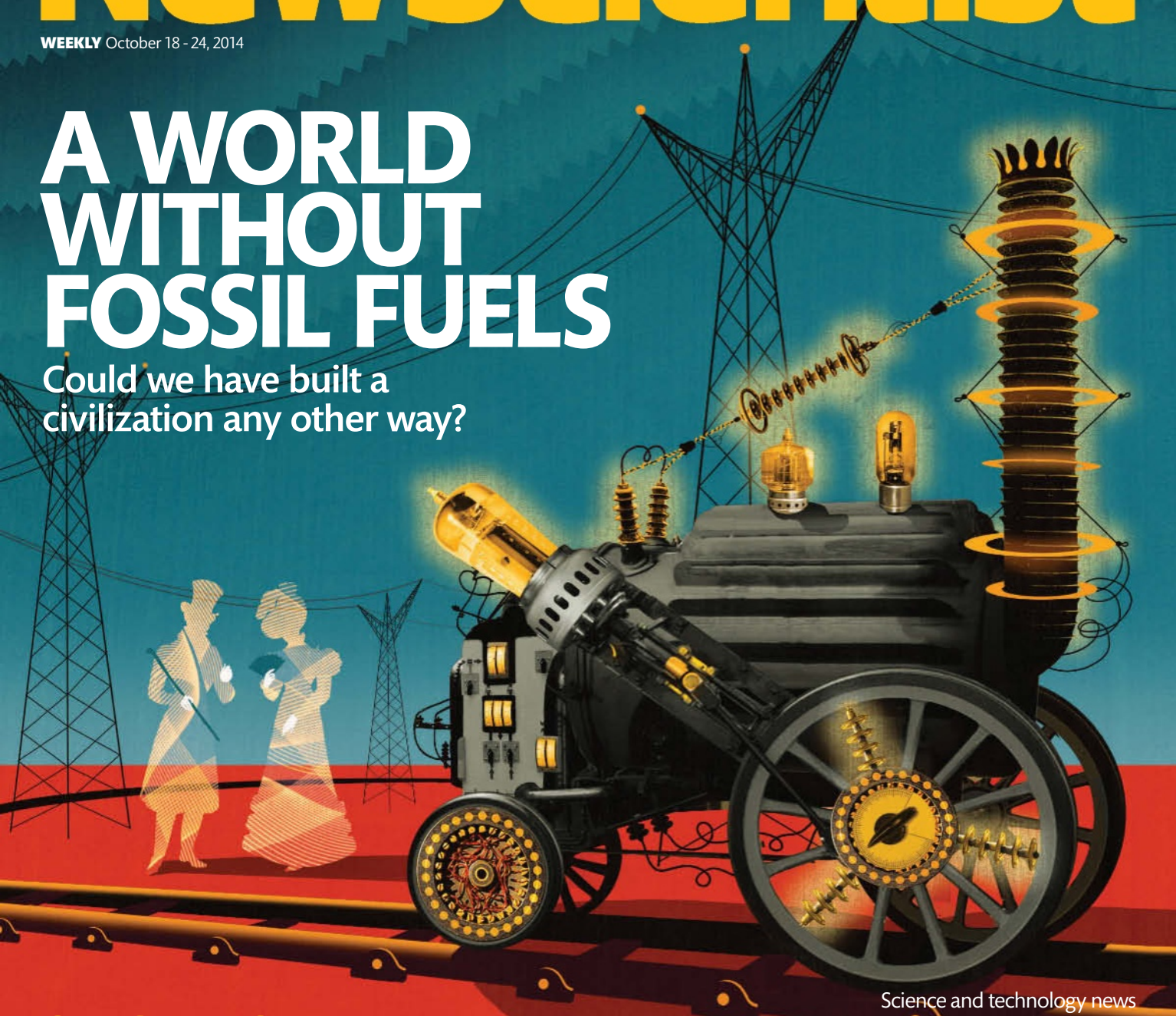
LET'S MOVE TO E-STONIA
Baltic state offers digital citizenship to all

NewScientist

WEEKLY October 18 - 24, 2014

A WORLD WITHOUT FOSSIL FUELS

Could we have built a civilization any other way?



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Restoring touch with mind-controlled prostheses

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Microelectronics: the next 20 years

This elastic market is illustrated by the case for computers in the home. On the one hand are the disbelievers who state that there is only a small range of operations for which the householder will ever need a computer — estimating his taxes once a year, paying bills and balancing budgets once a month and very little else. On the other hand are the optimists who argue that if **microelectronics can make small computers as inexpensive as telephones then people will buy them, even though they are in use for a small fraction of the time. Once in the house, or small office, new uses will be found for them and eventually they will affect life to an even greater extent than the TV set has.** If the optimists are right then the market is huge. Other markets which are waiting to be opened up are ground and air traffic control, process control of all sorts, medical as well as industrial, and on-line reservation systems. Whether or not microelectronics has this particular future depends on improvements in what we already have today — not all new materials, new

New Scientist, 16 March 1972



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CLAUSMEYER/MINDEN PICTURES

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BARBARA SANTORO/SINEACORNERS

The e-citizen test

Digital residency may point the way to a post-nation-state world

FANCY becoming an Estonian? There are plenty of reasons why you would. The tiny Baltic country is a technology powerhouse, with digital infrastructure as good as anywhere, online elections and compulsory coding classes. Now some of the benefits its 1.3 million citizens enjoy are open to all: Estonia will let anyone become an e-resident (see page 24).

E-residency isn't citizenship – you won't be able to vote, or move there unless you are already entitled to. But it will allow you to access Estonia's excellent online services, such as banking and the incorporation of companies. These currently require a physical address, but will soon be as easy as opening an email account.

Estonia's move offers a tantalising hint of a new world order that transcends the nation state. At present many of the services we are entitled to are an accident of where we were born. But when the functions of the state shift online, there's no longer a reason to restrict them to physical residents. Soon, digital residency could become as important, if not more so.

And digital residency can be a matter of choice. In the market that will emerge, even cities will compete. Paris has already shown an interest in allowing outsiders to become e-Parisians.

How this will all play out is unclear. Once more people are e-residents than actually live

within a country's borders, who gets to vote? Who pays taxes? Does a country even need a physical location any more?

It is hard to come up with answers to these questions, in part because concepts of nationality and nationhood are so deeply ingrained in how we see ourselves and the world. But these concepts are a relatively recent invention in response to the upheavals of the industrial revolution (*New Scientist*, 6 September, p 30).

Though it is widely agreed that the nation state model has begun to outlive its usefulness, what will follow is not at all obvious. The experiments in Estonia and Paris may point the way. ■

Look, it's working!

BOSSES have always wanted to know how to get the most out of their workers. Back in 1924, the big cheeses at the Western Electric Company wanted to find out how the level of lighting, among other things, affected productivity at their Hawthorne Works factory near Chicago.

So they gradually reduced the illumination in one part of the factory. Rather to their surprise,

productivity rose as lighting levels fell, even when the workers could hardly see. But even more unexpectedly, it also rose where the lighting was unchanged.

The company's analyst eventually concluded that the gains were actually caused by the added attention the workers had received from bosses. This "Hawthorne effect" is often invoked when a workplace

intervention appears to achieve its goals: was it the action or the scrutiny that made the difference?

That question is taking on a whole new dimension with the advent of wearable technology designed to monitor and motivate workers – combining both action and scrutiny (see page 22).

The ethics of this are complex; so are the practicalities. Firms will have to be very careful about how they use it. Otherwise, they may end up doing little more than turning the lights up and down. ■



Looking out for extremist weather

Army gets climate-ready

CLIMATE change does not respect borders and we must work together to fight its threats. These are not the words of a tree-hugger, but the US Department of Defense.

A report published on Monday says that extreme weather, rising temperatures, unpredictable rainfall and rising oceans could fuel armed insurgency and heighten the impact of a pandemic, through their effects on political instability, poverty, migration and resource disputes.

It warns that developments like these could undermine fragile governments and challenge stable ones, creating "an avenue for extremist ideologies and conditions that foster terrorism".

The roadmap, intended to prepare the US military for climate change,

reveals that more than 7000 US military installations have already been surveyed for vulnerability. Some sites have even begun to prepare for sea-level rises.

The report also notes that rising seas may affect amphibious landings, while extreme weather could interfere with reconnaissance flights over foreign territory.

It points out that the military may increasingly be called upon to help civil authorities when natural disasters occur.

"We must be clear-eyed about the security threats presented by climate change, and we must be proactive in addressing them," said US Secretary of Defense Chuck Hagel as he launched the report in Arequipa, Peru.

Eyes revitalised

SEEING is definitely believing, when it comes to stem cell therapy. A trial in 18 people with damaged retinal cells is being hailed as the most promising yet for a treatment based on human

"One stem cell recipient has recovered enough sight to ride a horse again. Others regained colour vision"

embryonic stem cells (hESCs).

Ten years ago, a team at Advanced Cell Technology in Marlborough, Massachusetts, announced they had successfully converted hESCs into retinal pigment epithelial cells.

These cells help keep the eye's light-detecting rods and cones healthy. But when retinal pigment epithelial cells deteriorate, blindness can occur. This happens in age-related macular degeneration (AMD) and Stargardt macular dystrophy (SMD).

In a bid to reverse this, hESC-derived retinal cells were injected into one of the eyes of each participant, half of whom had

AMD and half had SMD. A year later, 10 people's eyes had improved, and the rest had stabilised. The untreated eyes had continued to deteriorate.

The treatment enabled the participants to see three extra lines on a standard eye chart, on average. There were no serious side effects – and no sign of tumours, which can be a risk in stem cell-based therapies.

One person recovered enough sight to ride his horse again. Others regained colour vision. A larger trial is planned (*The Lancet*, DOI: 10.1016/S0140-6736(14)61376-3).

Science agenda

A YEAR after his government was criticised for failing to appoint a science minister for the first time in decades, Australian prime minister Tony Abbott has announced he will be chairing a Commonwealth Science Council. Its aim is to "improve the focus on science" and be "the pre-eminent body for advice on science and technology in Australia".

The panel includes astrophysicist and Nobel laureate Brian Schmidt, the co-developer of the cervical cancer vaccine, Ian

Frazer, Australia's ministers for health, education and industry, and its chief scientist.

The council has a budget of A\$12 million (\$10.5m), mostly earmarked for improving science education in primary and secondary schools.

An article in *Business Insider Australia* questions how far that cash will go: "\$12 million seems like a paltry investment in the education of future scientists". It notes that in May, A\$111 million was slashed from the budget of CSIRO – Australia's national research agency – over four years.



Guess my mission

Shhhh, it's a secret

WHAT is it doing up there? A top secret US spaceplane is due to land this week, after a record-breaking 22 months in orbit.

The X-37B, a miniature, uncrewed version of the space shuttle, built by Boeing for the US air force, has flown three times but its purpose is a mystery. Surveillance? Carrying out classified space experiments? We don't know.

The X-37B first flew in 2010

and again in 2011 and 2012. It launches aboard a conventional rocket, using solar panels for power while in orbit and gliding to Earth on its return.

The air force has said it will take over former shuttle hangars at the Kennedy Space Center in Florida, suggesting it plans to expand X-37B operations.

As *New Scientist* went to press, officials at Vandenberg Air Force Base in California would say only that they were preparing for the X-37B to land and disclosed no further details. Amateurs tracking the craft suggested it would land on Tuesday morning, local time.

Cancer nudge

AS IF we need reminding. Booze, cigarettes, sunbeds, obesity and lack of exercise all increase the risk of cancer. But if you follow a new 12-point code from the world's foremost cancer body, you could halve your risk of getting it.

"It includes more than 10 years' worth of scientific evidence," says Joachim Schüz, who helped put together the code for the International Agency for Research on Cancer in Lyon, France. "Smoking remains the major cause, but we've added risks not apparent last time the code was updated in 2003," he says.

The updated guidelines include recommendations for girls to get the vaccine for human papillomavirus, which causes cervical cancer. A vaccine against hepatitis B is recommended for newborns to protect against liver cancer. Another addition is advice for mothers to breastfeed, because this reduces their risk of developing breast cancer.

Aimed mainly at Europeans, the code has been carefully worded to be a reminder to avoid unnecessary risks, rather than a hectoring, "nanny state" style decree. "It's meant to be an authoritative reference people can consult, and something they can rely on," says Schüz.

Sea and sickness

WILL we be swimming in the sea in 2100? We know that warming oceans are bad news for fish and corals, but the jury is still out on the effect of pollutants and toxins already in the sea.

"It seems that a lot of the toxins can be altered by temperature, such that they then potentially interact differently with humans and marine organisms," says Niall McDonough of the European Marine Board in Ostend, Belgium. A report on the impact of oceans on human health that he helped create was discussed at the

EuroOcean 2014 meeting in Rome last week.

The report includes evidence that higher sea temperatures may actually reduce the toxicity of some organic pollutants such as pesticides, pharmaceuticals and aromatic hydrocarbons, mainly by breaking them down faster.

But it also warns of increasing health threats from blooms of toxic algae, which are projected to become more frequent and intense in warmer seas.

Exposure to contaminated seafood, water and sea spray will lead to acute and chronic illness in humans, the report warns.

Quagga mussel invasion hits UK

IT'S here. The quagga mussel, native to Eastern Europe, has been found in the UK, in the Wraybury river near London's Heathrow Airport.

"It's only in one place so far, but we have yet to check the river Thames and all its associated reservoirs," says David Aldridge of the University of Cambridge.

Over the past 20 to 30 years, the mussel has invaded rivers and lakes across Europe and has reached the US. The quagga is a direct threat to native species, such as the UK's depressed river mussel (*Pseudanodonta complanata*), because it kills other mussels by sitting on their shells and pushing them into the underlying sediment. It also changes the native ecosystem

by cleaning the water it lives in, allowing more light to reach the riverbed and helping nuisance freshwater weeds to flourish.

Although only 5 centimetres long, quaggas breed very quickly, and can rapidly block pipes and other water inlets and outlets. This costs the water industry millions to manage, usually through physically dislodging them.

Quagga mussels cannot be eradicated once they have settled into a river or a reservoir, but Aldridge and his colleagues have developed a "poison pill" that could keep numbers in check. "It contains a salt, and because quaggas have dilute body fluids, it comes as an osmotic shock that kills them," he says.



Here to stay

60 SECONDS

Gas trouble

A move to natural gas may not help the climate after all. It's a blow to those who have suggested that the gas, which is now cheaper to extract thanks to fracking, might replace more damaging fossil fuels. But energy models predict that natural gas will push down the use of renewable energy, resulting in little or no benefit to the climate (*Nature*, DOI: 10.1038/nature13837).

Out of the bubble

Gene therapy for "bubble boy disease" is proving its mettle. Nine children were given a healthy version of the faulty gene that had left them without a fully functioning immune system. Eight of the children are living outside their sterile bubbles up to 43 months after treatment (*New England Journal of Medicine*, doi.org/wbr). The other child died from a pre-existing infection.

Swap shop

Gene-swapping helped the archaea, some of Earth's most primitive microbes, to evolve new functions and form new groups. These single-celled organisms are different from bacteria, but thousands of genes have moved between them, mostly from bacteria to archaea (*Nature*, DOI: 10.1038/nature13805).

Fast food light

Junk food in the US is healthier than it was two years ago. Retailers are cutting calories in advance of new nationwide laws that will force them to include calorie counts on menus. While existing meals have not changed, new additions to menus had on average 12 per cent fewer calories than existing foods.

Carrot and stick

While Amazon deforestation dropped by 77 per cent between 2004 and 2011, it has now levelled off. A study suggests that incentives should be devised to reward hard-up smallholders who stick to the rules (*PNAS*, doi.org/wbn).

Once more with feeling

Sensitive prostheses are helping people regain a realistic sense of touch

Helen Thomson

THE race is on to return a natural sense of touch to people who have lost all feeling through paralysis or amputation. One group of researchers has pulled ahead of the competition with the completion of a successful trial, and several other teams are recruiting people to test their technologies.

Recent breakthroughs have allowed people who have lost the use of a limb to move a prosthesis and handle objects. But movement alone isn't enough. The ability to perceive what you touch is fundamental to precisely controlling and accepting a prosthesis as a part of the body.

That was cracked for the first time last week by Dustin Tyler

at the Louis Stokes Veterans Affairs Medical Center in Cleveland, Ohio, and his colleagues. The team has found a way of transmitting long-term, realistic tactile sensations, such as the feel of a cotton wool ball, to two people who lost hands in industrial accidents.

So good is the sensation that one man, on leaving the lab where he tried the prosthetic, said it was like leaving his hand at the door.

In recent years, there have been attempts to recreate a sense of touch by delivering vibrations to a person's residual limb that equate to pressure on the prosthesis. But this has proved more distracting than helpful and hasn't been widely adopted. People have also tried attaching electrodes to the inside of residual

nerves, but the tingling sensations they produce can diminish over time.

Tyler's team attempted something more complex. Two years ago, they implanted a cuff of electrodes around the three main nerves in the residual part of the two people's limbs. These are the nerves that would usually transmit sensory information from the hand to the brain.

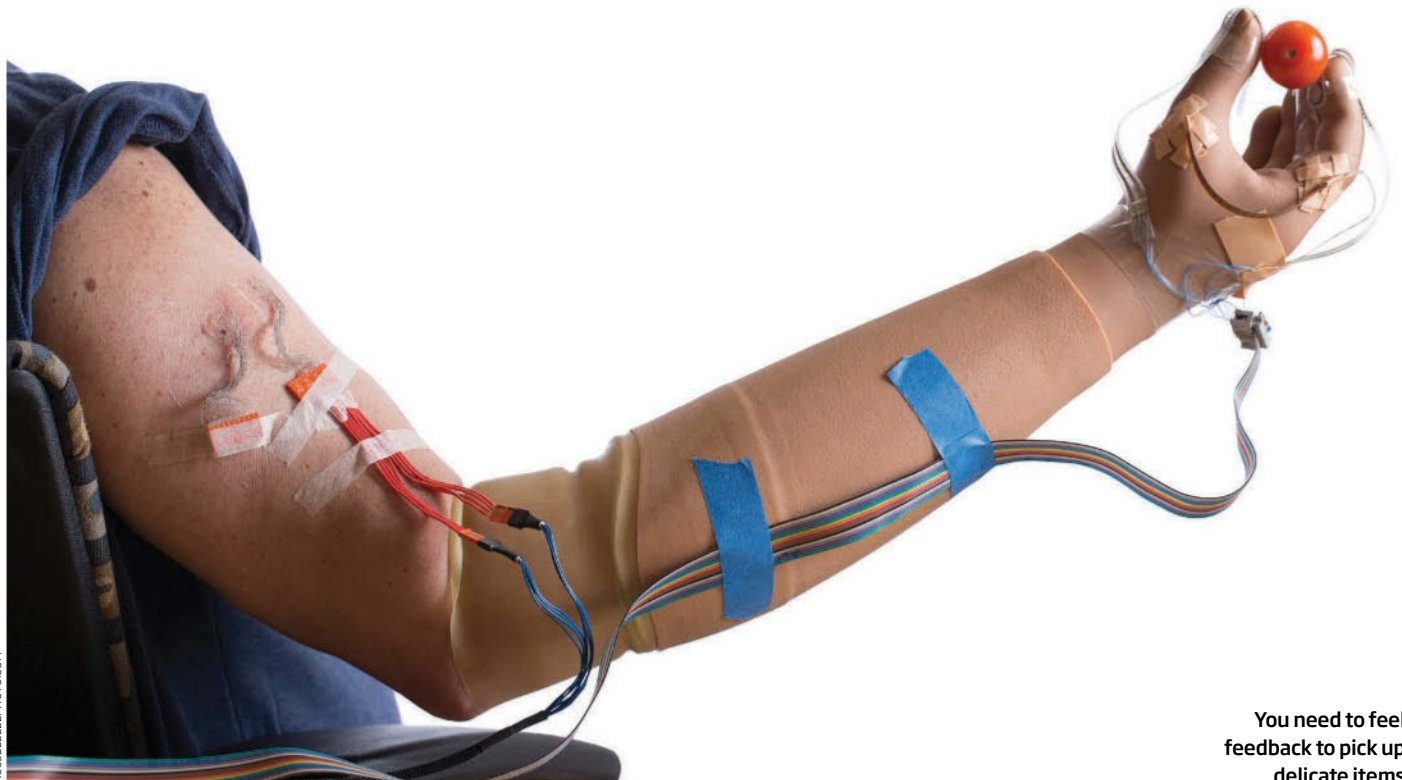
Each cuff contained electrodes that could stimulate different parts of the nerves. Wires linked the electrodes to a machine providing a stream of electrical pulses. This was connected to the

"When we stimulated his nerves, he said 'that's the first time I've felt my hand since it was removed'"

prostheses the men were already using (see diagram, right). Eventually, the idea is that the system will operate wirelessly.

"As soon as we stimulated the nerves in the first subject, he immediately said 'that's the first time I've felt my hand since it was removed,'" says Tyler. As the team switched on each electrode in turn, the men felt a tingling sensation as if it were coming from the tip of their prosthetic thumb, then the tip of the index finger and so on until touch sensations were created across the whole of their prosthetic hands.

With a real hand, touching distinct objects results in different patterns of nerve activity. To mimic this, the team altered the frequencies and intensities of electric pulses. After a healthy



You need to feel feedback to pick up delicate items

In this section

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- Two new particles discovered by the LHC, page 14
- Wearable tech lets bosses track staff, page 22

dose of trial and error, the first subject said “that’s not tingling any more, it feels real”.

Eventually, the team was able to deduce the pattern of stimulation required to recreate many realistic tactile sensations, such as a pulse, the feeling of pressing a finger very lightly on the tip of a ball-point pen, of someone stroking a finger, and even the sense that a cotton wool ball was being lightly rubbed on the skin.

No more juice

This is only half the battle though. For a prosthesis to be useful outside the lab, it needs to provide a wearer with sensations appropriate for different scenarios. Sensors on the prosthetic limb attempt this by measuring various aspects of touch and pressure. This information is sent to the machine controlling the electrodes, enabling them to fire in the correct stimulation pattern.

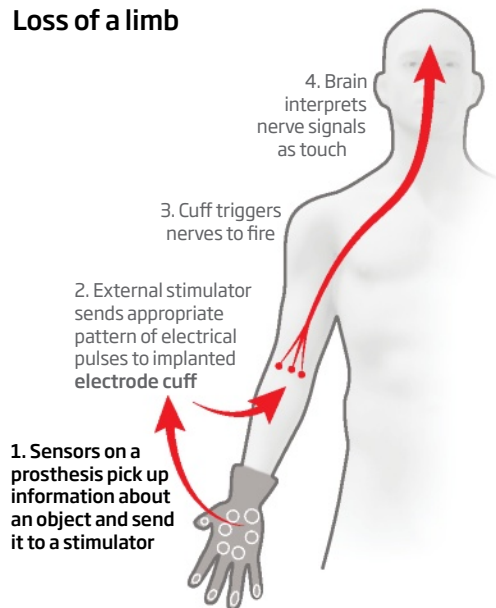
The acid test for a prosthesis is how well it handles delicate objects like soft fruit. For example, with tactile feedback, the men could successfully pull the stem from a cherry using their prosthesis without crushing the fruit or letting it drop. “When the tactile feedback was off you make a lot of juice,” said one volunteer.

There was an unexpected health benefit, too. Before trialling the prostheses, both men had phantom limb pain – one described it as like “a nail being driven through my thumb”, the other said it often felt like his fist was being squeezed in a vice. Over the two-year testing period, the pain diminished and eventually disappeared. In addition, although the men had to leave their sense of touch in the lab, their electrode cuffs stayed in place. Each time they went back to the lab, the reconnected cuff produced consistent sensations, even though they had led active lives doing things like chopping wood and doing DIY in between

Back in touch

A prosthetic hand that communicates with a nerve cuff or a brain implant could help people who have lost physical sensation to feel objects they touch

Loss of a limb



sessions (*Science Translational Medicine*, doi.org/v8j).

Providing a realistic sense of touch to a person who has lost a limb is a remarkable achievement. Doing the same for someone who has been paralysed by spinal cord injury is more difficult. A spinal injury prevents nerves from talking to the brain, so communications between the brain and prosthetic limbs must bypass these nerves. In 2012, a team at the University of Pittsburgh, Pennsylvania, implanted a device in the brain of a woman paralysed from the neck down, to allow her to control the world’s most sophisticated prosthetic arm, using just her mind.

The arm has 26 joints, controlled by 17 motors, and numerous sensors that can produce a high level of tactile information as the arm interacts with objects. The problem so far, says Michael McLoughlin of the Johns Hopkins University Applied Physics Laboratory, who helped develop the arm, is that only between 10 and 20 per cent of its capabilities

Spinal cord injury

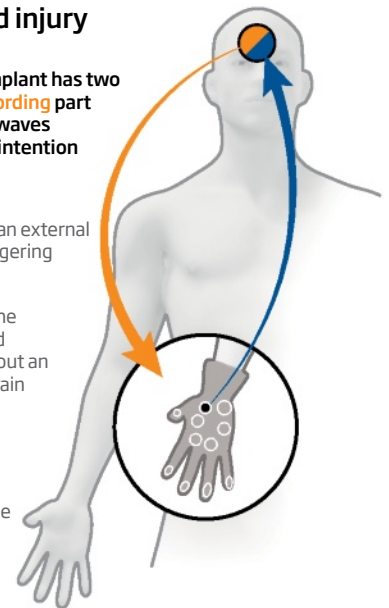
Proposed scheme

1. The brain implant has two parts. The **recording** part picks up brainwaves that signal an intention to move

2. This sends information to an external prosthesis, triggering movement

3. Sensors on the prosthesis send information about an object to the brain implant which **stimulates** the sensory cortex

4. Person is able to feel object



can be exploited, because of limitations in the devices that transmit information to and from the brain. “It’s like having a smart phone and only being able to send email,” says McLoughlin. He hopes to collaborate with people like Tyler, to eventually utilise the arm’s full range of motor and sensory capabilities.

One problem in providing sensory feedback is how to read the brainwaves from one area of

“It’s a bit like using the internet in the 80’s – we’re beginning to get all this connectivity”

the brain that signal the wearer’s intention to move – in order to trigger movement in the prosthesis – and simultaneously stimulate another brain area to reproduce the sensation of touch (see diagram, above). That’s because electrical activity from the stimulating electrodes can interfere with the ones doing the recording.

This month, Christian Klaes at the California Institute of

Technology in Pasadena and his colleagues provided a solution. By filtering out the interference from electrodes, they have developed a brain implant that could conceivably allow a paralysed person to move a robotic limb and perceive touch at the same time. Monkeys with the implant were able to control a digital version of a prosthetic arm and distinguish between two hidden objects by their textures (*Journal of Neural Engineering*, doi.org/v2n).

The only way to find out exactly what sensations the monkeys are getting is to see what happens in people – and Klaes aims to do this next year. He has already identified a suitable candidate and hopes to be able to do a trial in the next six months or so.

McLoughlin says that two other teams are also recruiting for candidates. “It’s a bit like using the internet in the 80s – we’re just beginning to get all this connectivity to see what will happen. When it all comes together we will achieve some tremendous advancements. It’s a very exciting time.” ■

Need for speed with Ebola vaccine

Debora Mackenzie

EBOLA rages on in West Africa. More cases outside the hardest hit countries are inevitable, and they could seed further outbreaks. It may be too late for some regions, but could an effective vaccine halt Ebola's global march?

What has been done so far?

The tried-and-tested approach is to isolate infected people and quarantine those they had been in contact with. But unlike previous outbreaks, this one spread in cities, and cases multiplied too fast for overburdened medical teams to keep up.

Where are we with a vaccine?

Thanks to post-9/11 fears of Ebola being used as a bioweapon, some promising vaccines were developed. Funding dried up as those fears faded, though. Two vaccines – each made of a harmless live virus with an added Ebola protein – fully protected monkeys in experiments. One was developed by the Public Health Agency of Canada (PHAC), the other is owned by British pharma giant GSK. But they have to be tested in people before they can be widely deployed.

Tests? In a situation this desperate, can't we just give them to people in the epidemic zone?

To some extent, yes. GSK is now testing its vaccine in a few dozen people to determine dosage and side effects. It then plans to have 10,000 to 20,000 doses ready to deploy in Africa by December. This week PHAC is sending 800 vials of its vaccine to the World Health Organization in Geneva. These hold up to 8000 doses depending on how big a dose is needed in humans. Tests to find that out have just started.

Experts who met in Geneva in late September agreed that the vaccines should undergo a randomised, controlled trial in the epidemic zone.

Vasee Moorthy of the WHO says vaccine could be given to around 5000 healthcare workers, while another group of perhaps 1000 could get another anti-viral vaccine that has no effect on Ebola, as a control.

Hold on. These people are risking their lives caring for Ebola patients and we're giving some of them a placebo?

Moorthy and Peter Smith of the London School of Hygiene and Tropical Medicine argue that we truly don't know if the vaccines work: comparison with a control group is the fastest way to find out. It's controversial. Last week, a group of top Ebola experts including Peter Piot, its co-discoverer, argued in *The Lancet* that death rates are so high that withholding any treatment is immoral. If the vaccine looks good early on, says Moorthy, everyone in the trial will get it.

The Geneva meeting also agreed that while the vaccine is being tested for efficacy in the outbreak countries, another 5000 people should get it in Ghana, Senegal and Mali to test safety.

Wouldn't that waste precious vaccine on people who aren't at risk?

To test safety you need to follow lots



Crying out for a vaccine

of people for months to make sure there are no rare but nasty surprises. This will be hard in the epidemic zone.

What harm could this vaccine do that's worse than getting Ebola?

That is exactly why the Geneva meeting recommended giving the vaccine to high-risk people in the epidemic zone before large safety studies are done. To make a real difference to this epidemic, companies will have to make millions of doses, and for that the vaccine needs to be licensed, fast. That requires large safety trials.

Ebola cases could reach a million by January. When will a vaccine be ready? Large amounts of either vaccine will not be ready until April next year.

The chilling truth, according to calculations presented at the Geneva meeting, is that if we don't slow this epidemic with quarantine, we're already too late for many. By April, if current rates of spread continue (see graph), the epidemic will have peaked in Liberia. That means so many people will have had Ebola – and either died, or survived and become immune – that cases will start falling as fewer people are susceptible. Sierra Leone will peak in August next year. Infections among health workers may peak as early as January.

We can still vaccinate in those places to protect anyone still susceptible, but by then we will also need the vaccine to help stop new epidemics igniting elsewhere. That will require vaccinating healthy people not yet at risk – and for that we need a vaccine we know is safe.

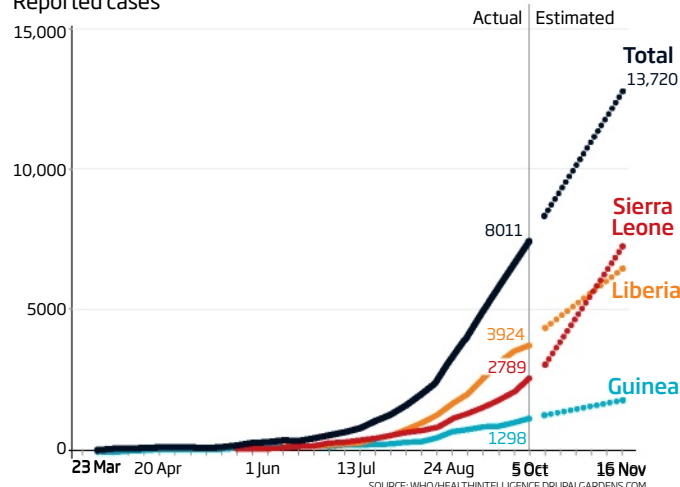
In the meantime people are dying. What can be done?

Old-fashioned isolation and quarantine might yet work – if we can just do enough of it. Treatment centres where patients can be isolated are still in short supply, and aid groups are using stopgap measures to slow the spread of disease.

For example, the WHO and Save the Children are setting up care facilities in which one family member can look after the patient, removing the threat from homes. Médecins Sans Frontières is also trying to protect homes with sick residents by distributing masks, gloves and disinfectant. ■

Ebola set to soar

Reported cases



Extinct giant kangaroos didn't hop - they walked

THEY had faces like rabbits and some were 2 metres tall. But now it seems that an extinct giant kangaroo didn't hop – it walked.

Known as “short-faced giant kangaroos”, sthenurines roamed Australia for 12.5 million years before being wiped out 30,000 years ago. No one knows what killed off these relatives of modern kangaroos, although they may have struggled as Australia's climate grew more arid.

Unlike kangaroos today, these ancient giants walked just like us. “All our evidence fits with these animals leaning on one leg at a time, like humans,” says Christine Janis of Brown University in Providence, Rhode Island.

She and her team took

hundreds of measurements of the bones of 66 living species of the kangaroo family and 78 extinct species, including 71 from sthenurines, to calculate the likely size and function of each animal's bones and muscles.

They found that the ill-fated sthenurines had bone structures resembling those of animals that move by shifting weight from one foot to the other, like humans and apes (*PLOS One*, DOI: 10.1371/journal.pone.0109888). A flange at the base of their shin bones, similar to those found in horses and humans, would have prevented their feet from collapsing sideways under the weight of their body.

Like walking primates, their



NGS/ALAMY

No hopping here

pelvises fanned out at the rear. “They had big bums, and much more room for these large gluteal muscles than today's kangaroos,” says Janis. These muscles would have supported each leg during walking.

Sthenurines had stiffer spines and shorter tails than modern kangaroos, which use their tails like a fifth leg. “It's reasonable that the ancestors of modern-day kangaroos moved differently,” says Max Donelan of Simon Fraser

“They had big bums, and much more room for large gluteal muscles than today's kangaroos”

University in Burnaby, Canada. “If pentapedal walking did not make biomechanical sense to these large, extinct kangaroos, they would have likely found a different solution.”

Janis suggests they were browsers, taking advantage of their height and bipedalism to browse trees and shrubs for berries or other food, without having to waste energy hopping between them. **Andy Coghlan** ■

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Lung cancer sleeps before it strikes

Michael Slezak

CANCEROUS cells can sit dormant in a person's lungs for decades, waiting to diversify and spread. The discovery sounds scary but it raises the possibility of early detection, screening and maybe even turning the tide against the world's deadliest cancer.

Most people with lung cancer find out they have the disease only after it has started to spread. Because of this, less than a third of people survive for more than a year after diagnosis.

New work on how the cancer evolves could change that picture. The research suggests that the genetic seeds of cancer can sit dormant in a person's lungs for decades, providing hope that the disease could be detected early. But it also shows that when the cancer does develop, it has a spectacular amount of genetic diversity – essentially evolving into several diseases at once.

Charles Swanton and his colleagues at Cancer Research UK examined the tumours of seven people with the most common form of the disease, non-small-cell lung cancer. It affects both smokers and non-smokers. They sequenced the complete genomes of multiple regions in each tumour and looked at which mutations were present in all cells and all regions of each tumour, and which were present in just some. By comparing these, they were able to construct an “evolutionary tree” of mutations that showed how the tumours had changed as they developed.

Of particular interest were two participants who were ex-smokers. Cigarette smoke causes telltale mutations in a tumour. Since the researchers knew when these two people had quit, they were able to

match parts of the evolutionary tree – those when smoking-related mutations were emerging – to rough time periods in their lives. This revealed that many of the key mutations that allow the cancer to spread had developed more than 20 years before, when the people still smoked.

It's impossible to know whether these mutations immediately made the cells cancerous, or whether that happened only later. Either way, the findings imply that many of the genetic characteristics associated with cancer can be present well before they cause any symptoms.

Next, the team examined the

later stages of each tumour's evolutionary tree. They found that some important cancer-associated mutations were present in all cells from one region of a tumour, but undetectable in another. This makes deciding on a course of treatment difficult. For example, in one person, they found that taking a biopsy from one region of a tumour would suggest treatment with one type of chemotherapy but a biopsy from another pointed to a completely different type of drug. Treatment with either one alone would have allowed the other region to spread (*Science*, doi.org/v8x).

This makes it imperative to catch cancers early, before they have developed their genetic diversity, says Swanton.

One option would be to screen those at high risk of lung cancer because they are current or past smokers of a certain age.

Annual lung cancer screening using CT scans to identify tumours has already been trialled in 55,000 people in the US, with good results, and there are ongoing studies in Europe.

Early detection via a blood test might also work. Such a test would search for mutated DNA released into the blood by affected cells.

What triggers the cancer to emerge from its dormant state

“The work raises the possibility of early detection of cancer, before it becomes malignant”

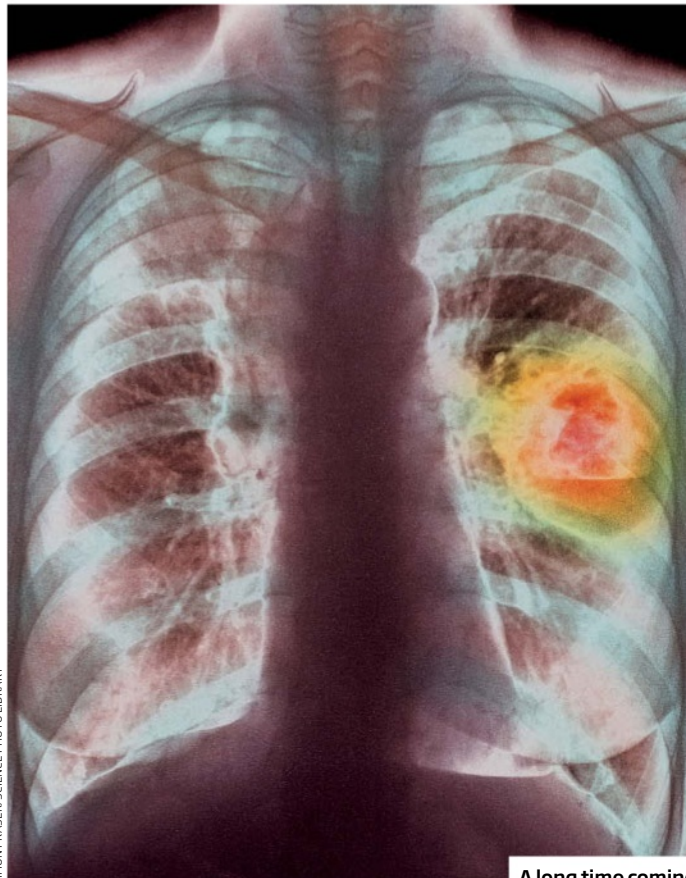
into a full-blown deadly disease remains a mystery. But there are two main possibilities.

The first is that it could just be one last random mutation that finally provides the cells with the genetic wherewithal to become malignant, says David Thomas, a cancer researcher at the Garvan Institute of Medical Research in Sydney, Australia.

The other is changes in the immune system, Swanton says. When it is operating normally, the immune system is able to clean up some mutations. But as we age it weakens, and that could allow the cancer the freedom to get going.

If that's the case, boosting the immune system before symptoms appear could stop a tumour from becoming malignant. “You could give heavy smokers or ex-smokers maybe six months of an immunomodulatory compound that would release T-cells,” says Swanton, to see if that reduces the development of new lung cancers.

“In principle, there may be an opportunity for chemoprevention,” Thomas agrees. “If the root events were treatable then one might contemplate potentially intervening in high-risk individuals.” Tinkering with the immune systems of people yet to be diagnosed with cancer would be a risky strategy, but given lung cancer's prognosis, it may prove worth it. ■



A long time coming

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New strange and charming particles

Nicola Jenner

TWO new particles have been discovered by the LHCb experiment at CERN's Large Hadron Collider near Geneva, Switzerland. One of them has a combination of properties that has never been observed before.

The particles, named $DS_3^*(2860)^-$ and $DS_1^*(2860)^-$, are about three times as massive as protons (arxiv.org/abs/1407.7574 and arxiv.org/abs/1407.7712).

"The unique properties of one of these particles could help us explore the strong force"

The distinctive characteristics of these particles should help us find out more about a fundamental force of nature known as the strong force.

Back in 2006, physicists at the BaBar experiment in Stanford University in California spotted an energy peak given off when smashing electrons and positrons together, which might indicate the presence of a particle. A team at the LHC found a similar peak in

CERN's data, and have been trying to pinpoint the cause.

"Our result shows that the BaBar peak is caused by two new particles," says Tim Gershon of Warwick University, UK, lead author of the LHC work.

The pair are both mesons, and so contain two quarks – subatomic particles that make up matter and are thought to be indivisible. These quarks are bound together by the strong force.

Quarks come in six different flavours known as up, down, strange, charm, bottom and top, in order from lightest to heaviest. The new particles each contain one charm antiquark and one strange quark.

Quarks also have a property called spin, which can be $+1/2$ or $-1/2$. When they come together to form mesons, there is an extra spinning effect due to the exact arrangement of the quarks. This adds to the individual spins to give a "total angular momentum".

Different quark arrangements can give the same total angular momentum, so a particle's exact configuration is often ambiguous. However, $DS_3^*(2860)^-$ is a special



MAXIMILIAN BRICE/CERN

Had it with hadrons? Move to mesons

case: its total angular momentum is three, a value for which there is no ambiguity and so it's clear how the quarks are arranged. This is the first particle containing a charm quark seen to have such properties.

The unique characteristics of this particle could help us explore the strong force, one of the four fundamental forces along with gravity, electromagnetism and the weak force. This is partly because the calculations involved are more straightforward for heavy quarks than lighter ones.

The LHCb team used a method known as Dalitz plot analysis, which had never before been used

on LHC data, to untangle the peak into its two components. This helps separate and visualise the different paths a particle can take as it decays. Now that it has been used successfully on the LHCb dataset, says Gershon, it may be applied to more LHC data.

"This is a lovely piece of experimental physics," says Robert Jaffe of the Massachusetts Institute of Technology. "The fact that LHCb was able to use Dalitz plot methods is a testimony to the quantity and high quality of the data they have accumulated. We can look forward to other similar discoveries in the future." ■

Flames that never die traced to their source

IN SOUTHERN Turkey, there are fires that never go out. The flames have been alight for millennia, but the source of the methane that fuels them was a mystery – until now.

The seeping gas feeds dozens of half-metre-high flames at the site, called Yanartas, Turkish for "flaming stone". The flames are believed to have inspired Homer to create the fire-breathing Chimera in his *Illiad*.



Burning question

But the gas fuelling the flames was not derived from biological processes – such as abiogenic methane is only supposed to form at temperatures much higher than conditions at Yanartas.

Now Giuseppe Etiope of the National Institute of Geophysics and Volcanology in Rome, Italy, may have found the answer. Working with Artur Ionescu of the Babes-Bolyai University in Cluj-Napoca, Romania, he has shown that ruthenium, a rare metal found in the igneous rocks beneath the site, can act as a catalyst, allowing methane to form in the lab at temperatures below 100°C – similar

to the temperatures at Yanartas (*Geofluids*, DOI: 10.1111/gfl.121106).

"These results demonstrate that abiogenic methane production is possible at much lower temperatures than is typically suspected," says Michael Whittaker of the University of Victoria in Canada.

The experiment is the first to show that the untreated form in which ruthenium occurs at Yanartas can act in this way.

"There could be considerable quantities of abiogenic methane elsewhere in the world," says Etiope. "We could be looking at a new source of hydrocarbons." Robin Wylie ■

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Lab black hole has Hawking radiation

Lisa Grossman

A BLACK hole model that traps sound instead of light has been caught emitting quantum particles. The effect is analogous to Hawking radiation, the stuff Stephen Hawking predicts should be emitted from black holes. It is the first time that a lab-based black hole has created Hawking particles in the same way as expected from real black holes.

Black holes are ultra-dense concentrations of matter left behind when a star or other massive body collapses. Their gravity is so strong that nothing, not even light, can escape from them once it has crossed a threshold called the event horizon.

Given that, physicists expected that black holes would be, well, black. But in 1974, Stephen Hawking of the University of Cambridge predicted they should emit a faint glow of particles now known as Hawking radiation.

The existence of this radiation is based on an oddity of quantum theory, which says that the vacuum of space is not truly

empty, but fizzes with pairs of particles and their antimatter counterparts. Normally, these pairs appear, annihilate each other and disappear in an instant. But if one of the pair gets caught inside an event horizon, the other is free to escape and becomes observable as Hawking radiation.

The glow from an actual black hole is too faint to see, so to look for evidence, physicists have built artificial black holes using quantum mechanical fluids. In 2009, Jeff Steinhauer at the Technion-Israel Institute of Technology, in Haifa and his colleagues made one using a Bose-Einstein condensate (BEC), a quantum state of matter in which a clump of supercold atoms behaves like a single atom.

Now the team claims that their model has produced just the kind of Hawking radiation expected of a real black hole. "This tells us that Hawking's idea actually works," Steinhauer says.

The team used one laser to confine the BEC to a narrow tube and another to accelerate some of

it faster than the speed of sound. This fast flow created two horizons: an "outer" one at the point where the flow became supersonic, and an "inner" one where the flow slowed down again (*Nature Physics*, doi.org/v9r).

The horizons create pairs of particles of sound, or phonons. One phonon escapes the horizon, and the other is trapped inside it.

A single phonon is too weak to observe, but the phonons inside the analogue black hole bounced back and forth between the inner and outer horizons, triggering the creation of more Hawking phonons each time, much like a laser amplifies light.

"The Hawking radiation exponentially grows, it self-

"This is the first clear-cut evidence of Hawking effects seeded from the quantum vacuum"

amplifies," Steinhauer says. "That allows me to observe it."

The phonons were pulled from the quantum vacuum, says William Unruh at the University of British Columbia in Canada.

"This is the first clear-cut evidence of Hawking-related effects seeded from the quantum vacuum," says Daniele Faccio at Heriot-Watt University in Edinburgh, UK. ■

First Mars settlers may be doomed

THE first human colonists of Mars may be poisoned by their own lettuce.

The Mars One project plans to send volunteers on one-way trips to live out the rest of their lives on the Red Planet. But a new analysis suggests the would-be Martians may begin dying after just 68 days.

If Mars One can raise enough funds through selling reality TV rights, the first four colonists are scheduled to arrive at a pre-assembled Martian base in 2024. Four more colonists will follow every two years after that.

But a team led by Sydney Do at the Massachusetts Institute of Technology told the International Astronautical Congress in Toronto, Canada, last week that Mars One is making assumptions about life-support and habitat technology that don't stand up to scrutiny.

The MIT team ran computer simulations that suggest Mars One's proposed crop growth system will produce too much oxygen - poisoning colonists after 68 days as levels build up inexorably. "If crop growth provides 100 per cent of the settlement's food, the system will produce unsafe oxygen levels in the habitat," says Do.

The team also criticises Mars One's assumption that mission support technologies that work on Earth will operate reliably on Mars. There is no oxygen removal technique that has been shown to work in space, Do says. The same is true of water scavenging: a method invented to take water from urine on the International Space Station worked on Earth, Do says, but bone density loss in microgravity increased the amount of calcium in urine, causing precipitation that stopped the machine working.

But Bas Lansdorp, founder of Mars One, believes there is more than enough time to fix these issues before 2024. "There are many problems between today and landing humans on Mars, but oxygen removal is certainly not one of them," he says.

Paul Marks ■



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Poisonous frogs safe to sing longer and louder

HE'S sexy and he knows it. The little devil frog is noisy in pursuit of a partner, and doesn't care who hears him.

Female frogs prefer males that produce long, loud, fast and continuous calls, as these describe a mate who is healthy, large and probably has good genes. But they also make the male more noticeable to predators.

The little devil frog's fearlessness in the face of hungry predators could be down to his toxicity. The little devil, *Oophaga sylvatica*, is a member of the dendrobatid group of poisonous frogs. His bright colours warn predators that he is unsafe to eat, which Juan Santos of the University of

British Columbia in Vancouver, Canada, believes has allowed the evolution of more flamboyant mating calls.

Santos and his colleagues examined the calls, colourings and toxicity of 170 species of frog, including the little devil. They found a strong relationship between the volume of a frog's call and its aposematism - markings that warn of its toxicity. In general, the more toxic a frog, the brighter and more noticeable it is - and the louder and more rapidly it sings (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2014.1761). Non-toxic frogs are camouflaged and call from less exposed perches, says Santos.

"Females can have a significant effect on the selection of the most noisy males, given that predators will avoid these aposematic individuals," says Santos.

Why toddlers make good canaries

SMALL children have a reputation as disease magnets. That's partly a result of their lax personal hygiene, but also because their immune systems are still developing. Could we turn that vulnerability into an early warning system for disease?

"They are like the canary in the coal mine," says Andrew Hashikawa of the University of Michigan. But most public health

departments do not routinely monitor nurseries and daycare centres for outbreaks of illness.

So Hashikawa's team asked four centres in Michigan looking after about 600 under-fives to test a web-based system for four months last winter. The staff reported daily absences due to illnesses such as colds, flu, stomach bugs and conjunctivitis.

Crucially, the team saw a two-

day spike in stomach bugs that seemed to foreshadow a gastroenteritis outbreak among school-age children in the county three weeks later. Such an early warning would give schools and nursing homes time to step up hygiene measures, says Hashikawa, who presented the study last week at the American Academy of Pediatrics conference.

For flu, such surveillance could remind adults to get vaccinated as outbreaks are starting, he says.

Spacecraft will seek geysers solo

WHEN the Rosetta spacecraft sends its lander to the surface of a comet next month, the lander will follow prearranged orders from Earth. But future spacecraft may be able to do it all on their own.

Kiri Wagstaff and her colleagues at the Jet Propulsion Laboratory in California have written software that can identify a plume of water vapour on a celestial body's surface, with the goal of directing another instrument to make follow-up observations. They tested it on images of Comet Hartley 2 and Saturn's moon Enceladus (*Astrophysical Journal*, doi.org/v82).

Comets, asteroids and icy moons have all shown signs of venting plumes into space. But because these bodies are far from Earth and the jets are not always active, exploring them remotely is challenging. "The more spacecraft can do without us, the better they can explore," Wagstaff says.

Toads hop straight to invade Oz faster

DAMN straight. Invasive cane toads are taking straighter paths to conquer Australia faster.

Rick Shine from the University of Sydney and his colleagues analysed 10 years of tracking data collected as toads invaded an area in the Northern Territory. The first toads to arrive there travelled in relatively straight lines, the slower toads that hopped all over the place got there years later.

Breeding speedy toads together showed the team that the progeny of fast toads followed more direct paths than the offspring of slower parents (*Proceedings of the Royal Society B*, doi.org/v9k).

Shine suggests that this heritable trait may be new and explain the acceleration of the invasion.

Stradivari drove violin evolution

STRADIVARIUS violins enjoy a near mythical status today – and perhaps they did from the moment they left Antonio Stradivari's workshop. An analysis of violin body shape confirms that many renowned 17th and 18th-century violin-makers, or luthiers, built instruments inspired by his design.

Keen viola player Daniel Chitwood, a biologist at the Donald Danforth Plant Science Center in St Louis, Missouri, turned software designed to study evolution on the shape of violins. He analysed photos of 7000 of them, built by luthiers of the past 400 years.

Given that many of the fine details of violin shape probably have little impact on the instrument's tone, says Chitwood, the analysis could have shown much subtle variation.

In reality, the violins clustered into four groups, each containing one of the great luthiers of the 17th century: Jacob Stainer, Giovanni Paolo Maggini, Nicola Amati and Stradivari. Of these, Stradivari inspired the most subsequent luthiers (*PLoS One*, doi.org/v8bm).

We can think of the Stradivarius shape as a neutral evolutionary trait that spread, says Chitwood. "It didn't necessarily make violins any better, but because everyone perceived Stradivari's violins as superior and worth copying, traits like the shape went along with that."



Mini MRI to check bone health on space station

ASTRONAUTS may soon have a portable MRI machine to keep an eye on their muscles and bones during a spell on the International Space Station. The custom-built, lightweight MRI should be ready to fly by 2016.

Bone and muscle loss in microgravity is a major health issue in orbit – astronauts are usually checked before and after missions. "But we don't know how bone and muscle density change with time during a mission," says Gordon Sarty at the University of Saskatchewan in Canada. "You can

only guess with the before and after data we have today."

Hospital MRIs can weigh more than a tonne thanks to their strong superconducting magnet, making them impractical for the ISS. So Sarty and his colleagues have developed a technique called Transmit Array Spatial Encoding or TRASE, which uses fluid as a proxy for bone and muscle mass. Its novel radio wave timing technique means the device has much smaller magnets. At just 50 centimetres wide and with a mass of 50 kilograms, it is small

enough to fit on an ISS experiment rack. Astronauts need only place their wrists inside to have their bones checked.

The technology can also be used in far-flung places on Earth. "Five years down the road I expect really portable MRIs based on TRASE to be everywhere," Sarty told the International Astronautical Congress in Toronto, Canada, on 3 October. "You'll see new applications in the ER, in surgery, with telehealth in remote communities and even in ambulances."

Moon's volcanoes may still be alive

THE man in the moon may still have some fire in his belly. Magma erupted on to the lunar surface less than 100 million years ago – a geological blink of an eye – new research argues.

The moon is thought to have formed from the debris of a collision between Earth and a Mars-sized body about 4.5 billion years ago. It has been cooling since its fiery birth, and volcanic eruptions were thought to have stopped about a billion years ago.

Now Sarah Braden at Arizona State University in Tempe and her colleagues say that dozens of small rocky formations spotted by NASA's eagle-eyed Lunar Reconnaissance Orbiter were laid down by lava surprisingly recently (*Nature Geoscience*, doi.org/v9h).

The features, dubbed irregular mare patches (IMPs), suggest that "the moon was more active in recent history than previously thought possible", says Braden.

Peter Schultz at Brown University in Providence, Rhode Island, thinks the IMPs formed as a result of the explosive release of underground gas instead, some as recently as just 10 million years ago. Either way, IMPs suggest "the moon is not dead", says Schultz.



Oil rigs are fertile homes for fish

THINK twice before condemning all oil rigs as threats to nature. A submarine study has found that fish are 27 times more productive under rigs than on reefs off the coast of California.

Jeremy Claisse at Occidental College in Los Angeles and his team surveyed 16 oil or gas platforms and seven rocky reefs each year for five to 15 years, from 1995 to 2011. From this they calculated the weight of fish supported per square metre of sea floor in each habitat.

Fish were much more abundant around the rigs: with a productivity 27 times the output of the reefs

surveyed (*PNAS*, DOI: 10.1073/pnas.1411477111). When compared with previous studies, the rigs were 10 times more productive than natural habitats elsewhere on Earth.

Claisse suggests rigs are havens for fish because of their huge surface area which, unlike in reefs, spans the whole water column. This supports a bounteous food base for fish to feed on. "These results show the potential importance of man-made structures in enhancing natural habitats," says Daniel Jones at the UK's National Oceanography Centre in Southampton.



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Get in the race

Stomach-dropping speed and stunts are the norm in first-person drone racing, finds **Hal Hodson**

NOW you can satisfy the need for speed while staying stock-still: by racing super-fast drones through fields and forests. For the pilots streaming the view from an on-board camera through headsets, it's just like flying.

The first large-scale first-person video (FPV) drone race in the US kicked off in Los Angeles on 11 October. Organised by LA resident Ryo Rex through his start-up, Aerial Grand Prix, it's the latest event for a sport that has spread around the world in the past year. It attracts speed freaks who crave the thrill of zipping between trees, fences and other

of it. Toy drones like the popular Parrot AR can be had for far less money – but would be outclassed in a community that revels in tinkering to eke out maximum velocity and manoeuvrability.

Puertolas hasn't raced yet – instead he focuses on stunt flights that he posts to YouTube – but he wants to. Races have been cropping up everywhere from Australia to the mountain town of Argonay, France, where last month 25 racers zipped through the woods (pictured, above).

In the US, though, events so far have been difficult to organise because federal regulations prohibit drones from leaving a person's line of sight. To solve this problem, Rex's race in LA had one spotter for every pilot, watching the drone as it raced the course, making sure it stayed on track. They also avoided cash prizes, because that might fall foul of regulations banning "commercial" drone activities. Instead, winners got free equipment from the small group of companies that have sprung up to meet the burgeoning demand for FPV drones and accessories.

"Sometimes when you are flying for a while you might pass yourself and think, 'Hey! Who is that?'"

obstacles at up to 160 kilometres an hour – but without risking life and limb in the process.

"Your body is on the ground, but your mind is up there," says Edward Lyons, who is getting his own racing group, FPV America, off the ground in Maine. "It's liberating."

Getting airborne requires some special equipment. For a start, the drone needs a light, tough, high-resolution camera so it can be piloted around obstacles at speed. It also needs a powerful wireless transmitter to stream the video back to the pilot, and the pilot needs a headset to watch the stream.

Still, a good rig isn't much more expensive than, say, a high-end laptop. Carlos Fernández Puertolas from San Francisco flies a set-up drone that cost around \$1200, although he has customised nearly every piece



Thrill of the chase

"We're trying to make it as safe as possible," Rex says. "We're trying to organise it in a way which shows everyone else in the world that we can do this safely. There's tension with the Federal Aviation Administration and we want to show them we can be responsible."

Rex says his plan for Aerial Grand Prix is to stream future races over the internet. Fans could jump between live feeds of their favourite racers, experiencing the same thrills as the pilots. The insane stunts are possible because no humans are at risk, but for the pilot and

viewers, it feels as though you are flying yourself.

"Imagine somebody gives you the keys of an F-16 and tells you 'Don't worry dude, it's OK if you crash it,'" says Puertolas. "Most importantly, you won't die in the process."

Rex points out that hobbyists have raced remote-control planes and cars for decades. Only now is first-person video bringing a dose of immersion to the sport. This makes it engaging for spectators – and is a big reason why more than 100,000 videos of FPV racing have been uploaded to YouTube in the past year or so.

For pilots, it can lead to a kind of out-of-body experience. As the drones zip through race courses or stunt runs, they sometimes come upon their pilots, watching themselves drive the instrument of observation. Many pilots report being startled by their physical selves as they fly around immersed in the drone's eye view.

"It was so weird," says Puertolas of the first time he flew past himself. "Sometimes when you are flying for a while you might pass yourself and think, 'Hey! Who is that?' Your brain plays tricks on you." ■



The safest way to fly

GEORGE GOODERHAM/AIR-VID.COM

Off the clock, on the record

More and more firms are digitally tracking their employees – at work, rest and play

Aviva Rutkin

SOME jobs come with a uniform. For an increasing number of employees, that uniform will soon include a badge that tracks everything they do.

Many companies – including BP, eBay and Buffer – already encourage employees to wear activity trackers like the Fitbit, often in exchange for discounts on health insurance. Last month,

“Everyone’s ‘digital exhaust’ is going to be available – it’s just a matter of who can take advantage of it”

California-based Misfit, which makes a sleep and fitness monitor called Shine, announced that it is teaming up with Coca-Cola as part of the drink-maker’s employee well-being programme. Several professional sports teams even monitor their athletes’ sleep habits (see “Sleep hard, play hard”).

In cases like these, wearables are designed to boost the health and general productivity of the employees, sometimes encouraging them to compete against one another online. That makes sense: a healthier workforce saves a company money in the long run. But elsewhere, such wearables are being used to monitor exactly how employees work.

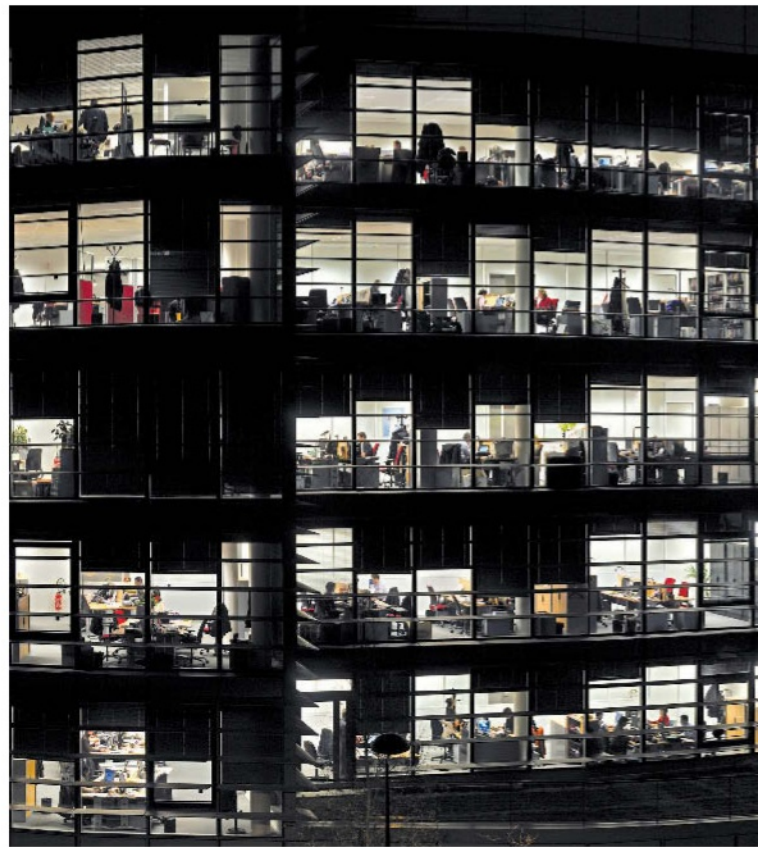
At the warehouses of UK-based supermarket chain Tesco, for example, workers wear armbands that track where they go, ostensibly so they can be sent location-specific tasks. At Capriotti’s Sandwich Shop in

Las Vegas, new recruits record their work with Google Glass for managers to assess later. Virgin Atlantic has plans to do the same.

“It is amplified intelligence,” says Bill Briggs, chief technology officer at Deloitte consultants in Kansas City, Missouri. “Sooner or later, the ‘digital exhaust’ of everything is going to be available. It’s just a matter of who can take advantage of it within the right ethical bounds,” he says.

But does monitoring your employees with wearable tech actually boost their productivity? There’s little research to show that it does, although Autodesk, a software firm in California, says it saw a “distinct change” in employees’ behaviour after more than 1000 signed up to receive Fitbits. The firm found that more people walked to work or held meetings while walking.

At a Bank of America call centre in Rhode Island in 2009, employees wore sensors made by Sociometric Solutions – a spin-off company of the MIT Media Lab – to figure out how co-workers interact. Over six weeks, sensors in the badges recorded where employees



went and who they talked to, how the tone of their voice and the movements of their body changed throughout the day. Drawn together, the data provided a unique insight into how the call centre worked. It turned out that workers who were more social were also more productive. In response, Bank of America changed the office structure to encourage employees to chat more with one another. Several European banks now track their

employees with the badges.

This year Chris Brauer of Goldsmiths, University of London, asked employees at London media agency Mindshare to wear one of three different activity trackers as they worked: an accelerometer wristband, a portable brainwave monitor or a posture coach. After a month, productivity had risen by 8.5 per cent and job satisfaction by 3.5 per cent overall. Most improvement was seen in employees who wore passive devices that collected data quietly rather than interrupting with ongoing feedback. “People recognise that effectively they’re on the clock, that they’re being tracked, and as a result they raise their game,” says Brauer.

However, Ethan Bernstein at Harvard Business School cautions that such devices could also have the opposite impact, due to what he calls the “transparency paradox”. Instead of trying to do the best job, some workers might

SLEEP HARD, PLAY HARD

If you sleep better, you play better. That’s why some pro basketball teams in the US are now monitoring their players in bed.

The first team to implement sleep-tracking was the Dallas Mavericks, who last year made their players wear a wristband-like smart patch called Readiband that monitors body temperature, movement and heart

rate. It also gives players a sleep score at the push of a button.

The idea is that the data lets team coaches see how sleep affects performance. They can then adjust training regimes or travel arrangements to maximise their players’ sleep quality. Some American football, soccer and ice hockey teams in the US are also using the system.



JEAN-PIERRE ATTAL/PLANIPICTURE
Alive with data

obsess over hitting their sensor-related targets, making them more likely to cheat and less likely to take potentially useful risks.

Wearables also open up new privacy dilemmas for companies – particularly if they remain on employees after they leave the workplace. US courts have grappled a little with these questions, at least when it comes to more common tracking tools like computer spyware and GPS trackers on company equipment.

“There must be rules in place to prevent employers from using this to the detriment of workers”

Several states, including California and Texas, have laws preventing equipment tracking without express consent. But in most places, it’s legal for firms to outfit their employees with wearables, as long as they are clear about what is being tracked and why.

“While the monitoring itself may be permissible, the information that you gather could create unforeseen, unintended consequences,” warns Joseph Lazzarotti, a lawyer at the firm Jackson Lewis in New Jersey.

No escape

For example, a GPS tracker or wearable that travels with an employee outside of work could help paint a detailed picture of that person’s private life, such as whether they spend lots of time in bars. This was also shown in Brauer’s study, which found that the devices recorded enough data to make detailed profiles of individual employees: their lifestyle, exercise and sleep habits.

In the future, bosses could rely on such profiles of their employees to make daily decisions depending on who’s had a good night’s sleep or a sudden burst of productivity, says Brauer. Conversely, people could use their tracker data to put together “biometric CVs” that prove they’re particularly well suited to jobs that take place at odd hours or under stressful conditions.

“People are going to have to decide how much of their lives are accessible and available to their work,” says Brauer. “What we always thought of as a dichotomy between work and ‘life’ instead becomes something like a lifestyle.”

There need to be rules in place to prevent employers from using this technology to the detriment of employees, says bioethicist Arthur Caplan at New York University. One could imagine a future in which bosses choose who to promote and who to fire based on tracking data, or encourage employees to take mild drugs like melatonin or caffeine to boost their workplace performance.

“I think when you have monitoring capability, the obvious question is: where does your job end and your home life begin?” Caplan says. ■

ONE PER CENT



Skin buttons expand smartwatches

Real estate on a smartwatch is scarce, but LED-based projectors could use your skin to expand the touchscreen by up to 3 centimetres on each side. Gierad Laput at Carnegie Mellon University in Pittsburgh has built a watch that uses four red laser diodes to project buttons onto the wearer’s skin. Touching a button causes light to be reflected back to the watch, which recognises which one has been pressed. Laput presented the work at the User Interface Software and Technology conference in Hawaii on 6 October.

“This car is nuts. It’s like taking off from a carrier deck. It’s just bananas”

Tesla Motors CEO **Elon Musk** on the P85D, which will sport a limited “autopilot” function as well as the ability to go from 0 to 60 miles per hour in 3.2 seconds

Sidewinding snake-bot slithers up sand

Watch out, desert-dwellers: a snake-like robot can slither its way sideways up a sand dune, just like real snakes. Daniel Goldman at the Georgia Institute of Technology in Atlanta and colleagues observed six sidewinder rattlesnakes at Zoo Atlanta as they made their way up sandy slopes at different inclines. The team used the observations to program the snake-bot, allowing it to sidewind up dunes with a 20-degree slope (*Science*, [doi.org/v83](https://doi.org/10.1126/science.1238833)).

Snapchat images stolen

Snapchats were supposed to be safe, with the sent images – sometimes explicit photos – automatically deleted seconds after being viewed. But on 9 October, anonymous users on internet bulletin board 4chan released 13 gigabytes of Snapchats they had stolen before the images expired. The thieves used third party applications that let people connect to the Snapchat network without using the official app. Much of Snapchat’s user base is under 18, so the photos likely include images that legally qualify as child pornography.

INSIGHT Politics



BARBARA SANTORO/SIME/4CORNERS

Tallinn calling

E-citizens unite

You can now apply to be an e-resident of Estonia, says **Hal Hodson**

ESTONIA flung open its digital borders last week. The eastern European country invited anyone, anywhere, to open a bank account or start a business. By the end of the year, anyone with an internet connection will be able to live their financial life in Estonia, all without being physically present.

Such e-residency, as it is known, is a step towards a world where a person's online identity matters just as much as their offline identity; where the location of data, rather than documents, is more important.

"This is the beginning of the erosion of the classic nation state hegemony," says John Clippinger, a digital identity researcher at the Massachusetts Institute of Technology. "It's going to get whittled away from the margins."

Max Ischenko – a Ukrainian entrepreneur who runs a job site called Djinni – is signing up. "It's very complicated to do business from Ukraine," he says. "For instance, I can't sign up for Paypal Business payments, because it's not available."

Crucially, Estonia offers firms a foothold in the European Union single market. Taavi Kotka, the Estonian government's chief information

officer, says they are aiming to have 10 million non-Estonian e-residents signed up by 2025. More than 4000 are already lining up.

Getting e-residency in Estonia will require going there to have your identity verified – and fingerprints and face biometrics taken by border police. But Kotka says they are working on letting people sign up at Estonian

"This is the beginning of the erosion of the classic nation state hegemony – it's getting whittled away"

embassies. For Estonia, embassies will no longer just be about extending the country's physical presence into other countries – but about extending their digital reach too.

E-residents don't get citizenship in the traditional sense – they can't apply for passports and visas, or vote in elections. But Kotka acknowledges that if all goes as planned, the new cohort of e-Estonians will have to have a say in any future changes to the country's corporate tax structures, for instance, and perhaps more.

"Imagine that thanks to e-residency we have 100,000 new companies.

That means we have more companies run by e-residents than by people physically in Estonia," says Kotka. It makes sense that e-citizens should have a say if the government wants to change tax laws, for example.

Estonia already has the world's most advanced internet voting system – votes were cast online by Estonians living in 98 different countries in elections earlier this spring. Kotka says they could easily extend the system to let e-residents vote from anywhere in the world.

Clippinger thinks Estonia's move will create a market in which countries compete for digital citizenry. More flexible rules on starting businesses around the world may open the door to more fluid livelihoods – our homes may be in one country while our job and bank accounts are in another. This is already happening to an extent, but programmes like Estonia's promise to accelerate the trend.

Nor is it all business. "Given where things are going with the US National Security Agency, backdoors and control over personal data, I think this could be a starting point for people who don't trust their own governments," Clippinger says. ■

Light beacons help blind people find their way

WHEN regular vision doesn't work, try infrared. A science museum in Delhi, India, has installed an infrared navigation system to help visually impaired people find their way.

The system, nicknamed Roshni or "light" in Hindi, was developed by Dhruv Jain at the Massachusetts Institute of Technology. People download a mobile app with a map of a building, then type or speak their desired location. Small infrared units mounted on walls around the building detect the user and send their whereabouts to the app. From this, the app can then give audio directions like how many steps to take, where to turn and the location of potential hazards such as pillars and fire extinguishers.

Roshni will be presented later this month at a conference on computers and accessibility in Rochester, New York, and has been installed at the National Science Centre in Delhi.

Roshni was trialled across four floors of a university building at the Indian Institute of Technology in Delhi, where 10 visually impaired people had the chance to test it for the first time. They negotiated their way through the building more quickly and with less outside assistance than usual. "I feel aware of the surroundings just like someone is speaking to me," said one. Aviva Rutkin ■



RAPHAEL GALLARDE/GAMMA/GETTY

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Just chilling

THE Puszcza Piska forest of northern Poland is huge, covering some 1000 square kilometres. Hidden amid the wilderness is a network of wartime German bunkers, and in one room, this Daubenton's bat was found hanging from the ceiling, asleep.

Lukasz Bozycki and his biologist friend Piotr Tomasik were exploring the forest in winter, looking for hibernating bats. It was intensely cold, down to -25 °C. For a week the pair slept in sleeping bags in an unheated wooden house. Then they found the bunkers. Bozycki said it was slightly warmer there, and he found some water he could wash with.

To illuminate the scene, he had Tomasik set a flashlight in the doorway, and trained another on the bat. "By this time, I was shivering so much that it was hard to set up the shot," Bozycki says.

It's a wonderful image, one that has made him a finalist in the mammals category of this year's Wildlife Photographer of the Year competition.

But severe hardship - and then worse - was to follow. Their car was a few kilometres away, and Bozycki says it was a huge challenge to trek back to it in the freezing conditions. He contracted pneumonia. Then Tomasik died. "I then abandoned the project," Bozycki says. "I'd like to dedicate this picture to him." Rowan Hooper

Photographer

Lukasz Bozycki bozycki.pl

Wildlife Photographer of the Year 2014

Scientific revolutionaries

This weekend European scientists will take to the streets to protest against research austerity. About time too, says **Sabine Louët**

SCIENTISTS complaining about budget cuts and job insecurity is nothing new. But in Europe, they have had enough. This week, thousands will take to the streets as part of an orchestrated, continent-wide protest.

The action will culminate on 17 and 18 October in Paris, Madrid and Rome. The scientists taking part hope to highlight how Europe's knowledge economy is being undermined by austerity, short-termism and a lack of adequate career structures.

In France, the protests are being organised by the Sciences en Marche movement. To minimise the risk of eliciting a Gallic shrug in a country famous for street protests, they are cycling to Paris from labs across the country, staying along the way with host families who have expressed their willingness to "adopt a scientist".

To coincide with the arrival in



Paris, researchers in Spain will take to the streets of Madrid. Activist groups there are organising under the Red Tide for Science umbrella. It will be the second such street protest in a month. The following day, Italian scientists from the For The Sake Of Science And Culture movement will meet Italian MPs and MEPs in Rome.

The protests are part of a bigger movement. Last week, activists from the UK, Greece, Portugal and Germany joined forces with their French, Spanish and Italian counterparts to publish an open letter to their governments and the European Union. It calls for an end to austerity and criticises their ignorance of "the crucial contribution of a strong research sector to the economy".

In Spain, for example, research spending has been cut by 40 per cent since the start of the financial

Panic isn't the problem

Ebola has reached Europe and the US, but how well prepared are we, asks **Debora MacKenzie**

THE Liberian who carried Ebola to the US has died. In Spain, a nurse has caught the virus while treating a returned missionary. More people will carry Ebola from the epidemic in West Africa into rich nations.

What will happen? Health officials insist there is little risk. But the world could still face a

rough ride. Epidemic models say that France, the US, the UK and Belgium are the rich countries most likely to be affected. Officials say sporadic cases are possible but that they are well prepared.

Yet "controlling Ebola won't be easy and it won't be cheap", says Peter Smith of the London School of Hygiene and Tropical Medicine.

It will also involve a steep learning curve. Despite warnings, Spanish and US hospitals let people stay in the community while infectious.

Between ageing populations, austerity measures and other spending cuts, many health services are under pressure. Spain's health budget shrank nearly 14 per cent in 2010, and further last year. Medics there complain of poor protective equipment. The doctor treating the Spanish nurse says his gown

was too small, exposing his skin, which could have left him vulnerable to the virus.

The UK is said to have a 50 per cent chance of admitting an Ebola case this month. Four hospitals have been designated for isolating cases, but only one is equipped so far. State-funded health staff will have to spot and isolate suspected cases despite pressure to cut spending and a flood of patients with similar symptoms of fever, diarrhoea and vomiting caused by less serious viruses.

The UK, the US and Canada are screening arrivals for fever at key airports. This might identify some cases, but, according to the World

"Canada, the US and UK are screening for fever at key airports. That could give a false sense of security"

crisis. In Greece, university research budgets have halved. And half of Portugal's state-funded research units are under threat of closure. The signatories hope to gain the support of many more scientists through a petition at openletter.euroscience.org.

It is ironic that it has taken so long for European scientists to take joint action on issues of mutual concern. After all, they have been collaborating scientifically for decades.

But now they have started, and the momentum is building. The activists have also launched a blog, *Homo scientificus europaeus*, hosted on the EuroScientist website. Named after what they fear is becoming an endangered species – the European scientist – the blog is an open forum for participants to debate issues and discuss action.

Europe's scientists have been quiet for too long in the face of deteriorating conditions. It is encouraging to see them collaborating across borders not just to do science, but also to make their voices heard. ■

Sabine Louët is editor of *EuroScientist*, an independent, participatory online magazine about issues in European research. It recently published a special issue on research activism

Health Organization, it could give a false sense of security. People can travel while infected but symptom-free or arrive overland.

Official reassurances that we are safe are understandable. Governments say this when they think they need to prevent panic. But panic isn't the real problem. Our main need now is to mount a massive effort to stop Ebola in Africa, and prepare for its arrival in other nations – both rich and poor. Telling the rich they are safe won't drum up support for that. It also isn't entirely true. ■

Debora MacKenzie is a consultant for *New Scientist*

ONE MINUTE INTERVIEW

Spine-tingling innovation

A decade after Christopher Reeve died, his son **Matthew Reeve** is carrying on his efforts with a large trial to treat spinal injury



PROFILE

Matthew Reeve is on the board of the Christopher & Dana Reeve Foundation, which seeks new treatments for spinal injury. The late Christopher Reeve, who played Superman, became paralysed in 1995 after a horse-riding accident

You're planning a large study of a paralysis treatment that has already helped four young men. What will it entail?

This study will include 36 people with spinal cord injuries who will be treated with epidural stimulation – a technique in which a device is used to apply electrical current to the spinal cord. If we see the same results as we did in the first four, this therapy could have a profound impact on thousands of people living with paralysis. It has the potential to become as commonplace as the pacemaker is for cardiac problems.

How well has the treatment worked for the four men who have already received it?

Prior to epidural stimulation, they had all suffered chronic conditions caused by completely severed spinal cords. All four have seen dramatic improvements, including the ability to voluntarily move their toes, feet, ankles and legs, and even stand at times, when the device is on.

One unexpected bonus has been the return of autonomic function, such as bladder and bowel

control and sexual function. From a quality-of-life point of view, this is the biggest improvement. Also unexpectedly, these autonomic functions continue in all four men even when the device is switched off, although they still need it to stand, move their legs and do exercises.

How does the device work?

It is a 16-electrode stimulator that is implanted in the same place on each patient's spine, irrespective of where their cord was severed. When the recipient operates the device, it applies a continuous electrical current – at varying frequencies and intensities – to specific regions in the lower spinal cord where there are dense bundles of nerves that control the hips, knees, ankles and toes. It mimics signals that would normally come from the brain to rekindle movement in those regions artificially.

Will anything be different in the larger trial?

The four people treated so far are all fit young men, so we want to try out the treatment in a wider range of individuals, including women and people of different ages, and with differing degrees and duration of injury. We're using the same device but are working to improve it, so it may be upgraded to allow for easier manipulation of the controls, for example.

When will the trial start?

We're aiming for next year, and it will run for five years. To fund it, we have to raise \$15 million, and we already have \$5 million of that. We're hoping people will each donate \$36 – that's \$1 for each patient. The faster we raise it, the sooner we start.

What would your father have made of the progress so far?

He would be proud of what we've achieved and learned, but would want to keep moving forward. His goal was a world of empty wheelchairs. And though it may end up requiring a combination of treatments, I can say that it's a question of when, not if, we will eventually succeed.

Interview by Andy Coghlan

We're looking at death the wrong way

When our days are limited, medical priorities may not align with what matters to us most, says surgeon **Atul Gawande**

Why are you interested in mortality?

Medicine is grappling with what is ultimately an unsolvable problem. I never felt I had good answers for people who were facing death; when do we push ahead with treatments and when do we not? It wasn't until I connected with experts working in palliative care that I began to gain a sense of how you can unravel these problems. At the centre of the issue is the difference between the medical priorities of health, safety and survival, and an individual's priorities for well-being.

Has medicine got its priorities wrong?

We make trade-offs every single day. For my patients in nursing homes, often their biggest struggle is with things being taken away from them, in the name of health, that they care deeply about. You'll see people with Alzheimer's who want nothing more than a cookie, but are given only pureed food because they might choke. We do these things in the name of health, but there's a larger idea about what makes life worth living that we're not serving. That comes to bear most obviously at the end of life.

Why have we come to see the end of life as primarily a medical problem?

I think the big change has been the family. My grandfather lived in a village in India and died at the age of 108. He spent the last decade of his life needing substantial help to live, but it didn't require him to be in an old age home. It worked because he was surrounded by family who would take care of him – but that only worked because young women were more or less enslaved to the task.

The success and growth of our economies have come from giving young people the

freedom to choose the work they want and where they want to live. Pensions have been important in giving older people the financial independence to live without family; the problem comes when you can no longer take care of yourself. We've decided that this is a medical problem, but the medical focus is on health and safety – not on what people might see as their most important priorities.

You have written that the medicalisation of death is "an experiment that is failing". Why?

We see failure on multiple levels. One is the sheer amount of suffering endured by people in institutions such as old age homes or intensive care units. On another level, you are admitted into these institutions and no one knows who you are; no one recognises the arc of your life and the things that have been important along the way. The most important thing about you is that you are diabetic, and you have some problems walking and swallowing – that's who you are.

But there are other approaches. For instance, one major study in cancer patients found that people who receive early palliative care choose less chemotherapy, spend less time in hospital, and start hospice care earlier. And the result? They have less suffering, lower cost, and they live 25 per cent longer on average. This suggests we've just been making bad decisions.

Is death a subject that doctors feel comfortable discussing with patients?

Generally, we're very confident about our ability to manage these situations. I'm very good at telling people: "You've got a bad situation. We could do an operation and there's a 50 per cent chance that you won't

PROFILE

Atul Gawande is a surgeon at Brigham and Women's Hospital in Boston and a professor of surgery and public health at Harvard University. He is a staff writer for *The New Yorker*. His latest book, *Being Mortal: Illness, medicine and what matters in the end* (Profile Books), is out this month

make it through, but if you don't have the operation there's a 100 per cent chance that you won't make it through."

But we're not good at helping people tell us what trade-offs they are and aren't willing to make. Choosing that 50 per cent chance is absolutely the right thing to do if you are pursuing goals that are in line with a person's priorities. But if survival means she'll be cognitively impaired, never return to her house, have to be fed through a feeding tube and endure pain and suffering – when the most important thing to her is being with her



family, being mentally aware, or completing some work she's focused on – suddenly a different choice might be better.

Have you ever offered treatment you knew probably wouldn't work and could make someone's life worse?

Absolutely. In my new book, *Being Mortal*, I describe a 34-year-old woman who was diagnosed with metastatic lung cancer during her first pregnancy, and then turned out to have thyroid cancer too. I found myself offering surgery for her thyroid cancer, when the

reality was the lung cancer would kill her long before the thyroid cancer caused problems. The difficulty and anxiety of trying to come to sensible decisions and acknowledge what's in the room – that here's a problem we aren't going to be able to control, just manage – can leave you offering fantasies of the future.

Has researching the book changed the way you interact with dying patients?

The core change has been to shift from saying: "Here are the pros and cons, what do you want to do", to asking: "What is your understanding

of your condition; what are your goals and fears; what trade-offs are you willing to make?"

Recently a friend came to me whose best friend has been diagnosed with advanced brain cancer and needs increasing amounts of help with each passing week. His doctors aren't acknowledging this person crumbling in front of them. They're rightly trying the first rounds of chemotherapy and radiotherapy, but in the meantime nobody knows what could happen next, and no one is asking: "How shall we help him cope, and what would he actually want if time becomes short?"

So what advice did you offer your friend?

That there's a powerful conversation to be had around what well-being means to that person. Ask those questions, hear his answers, use them to make plans, and then understand that

"The goal shouldn't be to have a good death, but a good life - right to the end"

they will change and you will have to ask the questions again in a few weeks. His friend may not yet be at a point where he can discuss any more than one of those questions, but it would be a lot more than they've got to go on now.

Do you support the idea of assisted dying?

I think there's often a misplaced goal. The goal shouldn't be to have a good death, but to have as good a life as possible, all the way to the end. I support having the capacity to do something for people with unbearable suffering, but it troubles me that we have focused on assisted dying without having figured out assisted living very well.

Have you thought much about how you'd like to spend your own twilight years?

Right now, I'd say that if my body went I would still want to be alive, but if my brain went, let me go. But I know that what I think is likely to change, and I want to be in circumstances where I can re-evaluate and have that conversation about my priorities.

We all live for something larger than ourselves – it might be family and community connections, or making our own contribution to the world. Those are the things I want to hang on to. I also want to be in a place where I have some freedom to choose how I cope with my limitations; where I can have a cookie, even if it isn't the healthiest thing to do. ■

Interview by Linda Geddes

CHRISTOPHER MORRIS/VII

Reserve judgement

From Abhimanu Kundasamy, Mauritius High Commissioner
Fred Pearce eloquently highlights that the UK's purported establishment of a "marine protected area" (MPA) around the Chagos Archipelago was a highly political decision, rushed through against the advice of senior officials (27 September, p 26).

However, Pearce has proceeded on the erroneous assumption that the UK has sovereignty over the Chagos Archipelago. It does not.

The government of Mauritius does not recognise the so-called British Indian Ocean Territory, which the UK created in violation of international law and UN resolutions by excising the Chagos Archipelago from the territory of Mauritius prior to its accession to independence.

The government of Mauritius reiterates that the Chagos Archipelago, including Diego Garcia, forms an integral part of the territory of Mauritius under both international law and Mauritian law.

The government of Mauritius is deeply concerned that the purported creation of the MPA not only infringes the sovereignty of Mauritius over the Chagos Archipelago and Mauritius's full range of rights over it – including fishing and mineral-resource rights – but also impedes the exercise of the right of return of the Mauritian citizens who were forcibly removed from the Chagos Archipelago by the UK.

Mauritius considers that the UK had no authority under international law, including the United Nations Convention on the Law of the Sea (UNCLOS) to establish an MPA around the Chagos Archipelago, and on 20 December 2010 instituted proceedings against the UK government under UNCLOS to challenge its legality.

The merits of the case and the objections of the UK were heard by the Permanent Court of

Arbitration (PCA) at a tribunal held this year in Istanbul, Turkey, and a decision is awaited.

The written pleadings of the parties involved are available on the PCA's website (bit.ly/ChagosMPA).

London, UK

From Charles Sheppard, Chair, Chagos Conservation Trust
Designating the Chagos

Archipelago a no-take marine protected area (MPA) was based on the best available science.

The precautionary principle was rightly applied to ensure that lengthy deliberation did not allow further destruction of the world's most pristine coral reefs.

Policies should, of course, be reviewed as further scientific evidence comes to light. In the case of Chagos, new research continues to corroborate the decision to protect this unique ecosystem.

It is misleading to claim that the no-take policy is another barrier preventing the displaced Chagossians from returning to the islands. The MPA declaration states that the level of protection would be reviewed – in full consultation with the Chagossians – in the case of resettlement.

A mere 2.8 per cent of the world's ocean has any protection, with only 0.6 per cent fully protected, well below international commitments.

With the cleanest sea water in the world and a staggering diversity of marine life, the Chagos Archipelago is a site of resilience within the heavily overexploited west Indian Ocean.

It is an underwater sanctuary that deserves to be afforded the ultimate protection.

Warwick, UK

Split decisions

From Andrew Clifton
How strange that supporters of the many-worlds interpretation

of quantum mechanics fail to grasp the bleak moral implications of this view (27 September, p 32).

If it's true, it is surely absurd to worry about the consequences of "decisions", since we all make every possible choice and enjoy or suffer every consequence. Since everything happens, nothing we decide makes any difference to reality as a whole.

Fortunately, the many worlds theory may not be true. It is favoured by some theorists because it avoids aspects of quantum mechanics which they find intuitively disturbing –



but does so at the cost of infinite existential extravagance, for which there is as yet no empirical support.

Without such evidence, I shall continue to assume that moral decisions matter.

Bradford on Avon, Wiltshire, UK

From Ed Subitzky

In your fascinating article on the multiverse, much is made of the way that my decisions (in this universe) affect what happens to the other versions of me in other universes.

However, isn't the situation symmetrical? Wouldn't the decisions of my clones in other universes have as much effect on me as I have on them? And what happens to our conceptions of morality and truth in this two-way – or should I say infinite-way – scenario?

New York City, US

From David Diamond

I was delighted with this article, but it left out a number of issues which make Hugh Everett's theory of the multiverse even more fascinating.

Suppose I make a choice, and meanwhile an inhabitant of a planet 1 light year away makes an unrelated choice. Are there four universes immediately, or in a year's time? I would prefer to think that the multiverse phenomenon is local.

Another question: if all universes continue until they reach maximum entropy – in which all energy is evenly distributed – could they then be considered to have merged back into a single universe, since they would all be indistinguishable?

North Potomac, Maryland, US

From Martyn Stevens

Surely if there are multiple universes, we are simply in one of them, with all those going before us and after us creating further universes of their own with every decision, giving more multiverses than I can shake a stick at.

At least I know now who to blame for bad things in my life – it's the idiot who went before me. But where does the energy come from to create all these extra universes?

Leighton Buzzard, Bedfordshire, UK

The editor replies:

■ It's a common criticism. One answer is that, since the parallel worlds are inaccessible, they cannot be sources or sinks of energy. Thus the energy "needed" to make splitting multiverses doesn't have to come from anywhere, because there is no extra energy.

From Bob Miles

In the multiverse interpretation of quantum computing, Rowan Hooper states that the necessary calculations are conducted in many universes at once.

Does this mean that there must be communication between

parallel universes in order to arrive at the final answer?
Sidmouth, Devon, UK

Noble pursuits



From Brian Josephson
Replying to my defence of televised investigations into the afterlife, Craig Gosling writes that “in the absence of evidence, David Silverman and the rest of us have every right to chuckle” (4 October, p 32).

He seems not to have read my letter closely enough. The BBC series that I referred to was very much concerned with evidence, not just blind faith.
Cambridge, UK

Free willy

From Anthony Castaldo
Dan Jones asks whether we would abandon our belief in free will if brain scans could predict our every action (27 September, p 11).

When did my brain stop being a part of me? My conscious self may be an executive in charge of hundreds of unconscious modules in my brain.

These days I type fast with very few errors, and I no longer need to make conscious decisions to press specific keys at specific moments. Similarly, when my work requires me to solve certain problems creatively, these modules are generating and filtering the possible solutions. It is still me that solves the problem when

inspiration strikes, even if my conscious executive did not laboriously reason step-by-step to that final insight.

When did the triumphant insight occur that beat the myriad other possibilities? Probably many milliseconds, even seconds, before I was consciously aware of it. But my brain is me, and my free will came in the form of accepting the solution.
San Antonio, Texas, US

From Carl Zetie

While it is true that losing belief in free will might affect how people feel about cheating or punishment, as Dan Jones asserts, the only scenario in which this matters in any way is if free will truly does exist, but people incorrectly believe that it doesn't.

In any scenario where there is no free will, all behaviour must be pre-ordained, including what people believe about free will, how they act on these beliefs, how moralists wring their hands about such actions and so on. And none of it will matter since in the absence of free will choice, ethics and morality are empty concepts.

Personally, I have decided that the only logical course is to believe in free will. If there is none, my belief is pre-determined and doesn't matter anyway. But if free will does exist and I mistakenly deny it, my loss is enormous.
Waterford, Virginia, US

Side-on to the sun

From Rick Gammache

The protection of critical circuits from cosmic radiation may also be increased by reducing the cross section that is exposed to these high-energy particles (27 September, p 42).

During a recent coronal mass ejection – a burst of solar wind – I held a strip sensor so that it faced the sun, then changed the orientation to line up with the path of incoming cosmic rays. The decrease in detection-event

counts was dramatic.

An additional precaution against cosmic rays may be to put circuit boards on gimbals so that they can align their components with the stream of radiation.
Springfield, Virginia, US

Ticked off

From Gerald Legg

As a keen microscopist I was delighted to see Arthur E. Smith's micrographs featured in your magazine (4 October, p 24).

However, I have to point out that the “sheep tick” is in fact a type of louse-fly, the sheep ked *Melophagus ovinus*.

Having curated old microscope slides I quite often found slides incorrectly labelled, the slides



often being created by a microscope-slide preparator rather than an entomologist or arachnologist.
Hurstpierpoint, Sussex, UK

Dream worlds

From Trevor Jones

I happened to be reading Catherine Brahic's article on the importance of imagination (20 September, p 32) in tandem with Donna Tartt's *The Goldfinch*, which contains a quotation from Friedrich Nietzsche: “We have art in order not to die from the truth.”

This seemed to resonate with Maurice Bloch's notion, as reported by Brahic, of civilisation

and culture being made up of “arbitrary products of our creative thought”.

This is a revelation, and one that makes sense of imagination not only in its exotic form of discovery, invention and creativity, but also in its mundane everyday usage.

It is reassuring and life-affirming to realise that anything which isn't memory is imagination. It means forming new ideas, images or concepts is open to anybody, anytime, anywhere. And it confirms John Lennon's observation that “reality leaves a lot to the imagination”.
Cheveley, Cambridgeshire, UK

Neutronyms

From Julia Derrick

Further to previous letters on naming neutrons separated from their spin, how about “nontron” or “nontronspun”?
Ballina, New South Wales, Australia

For the record

■ Our article on quantum encryption incorrectly identified Shuang Wang as the leader of the research group (20 September, p 12). The leader is Zheng-Fu Han.

■ Guilty as charged: our article on mitochondria contained two errors (20 September, p 42). Hemes are not proteins but cofactors, and not all free radicals carry a charge.

■ Contrary to the claim in our article on dolphin intelligence, cetaceans do not currently have personhood status in any country (27 September, p 46).

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Our advanced civilisation is built on easily exploited coal, oil and gas. Michael Le Page explores an alternative history

World without fossil fuels

YOU are probably reading this on a piece of ex-tree. Felled by a petrol-guzzling chainsaw, it was carted to a paper mill in a diesel-powered truck. Or perhaps these sentences are on a tablet, with plastic components that started life as crude oil, and metal smelted with coke produced from the tar sands of Canada. Either way, the words are probably lit with electricity from a coal-fired power station. Maybe you are even sipping wine, grown with fertiliser made using natural gas, in a glass created in an oil-fired furnace.

The list goes on and on. Our civilisation is built on fossil fuels. We depend on them not just for energy but for all kinds of raw materials and even the food we eat. Weaning ourselves off this stuff is not going to be easy.

But what if there were no fossil fuels on Earth, or at least none that were easy to exploit. Would history have taken a different course? What of the industrial revolution? Would modern civilisation even exist? To tackle such questions, we must go on a journey that will carry us from medieval times into a counterfactual yet strangely familiar world. It's a fascinating thought experiment with implications for the future of our own planet, as well as for alien civilisations.

A long time ago we weren't too bothered about fossil fuels. Early civilisations sometimes used them if they were there for the taking, but did not rely on them. Wood or charcoal were superior for just about all purposes. In medieval Europe, only Britain began to use coal on a large scale. Why? The answer has to do with geography,

argues historian Rolf Sieferle of the University of St Gallen in Switzerland.

In the 13th century, water transport was cheap. Floating wood down a river required almost no energy, and a single horse could pull a barge weighing 50 tonnes. Going overland was far more difficult: a horse could pull only 1 or 2 tonnes. If wood had to be hauled any distance, its price rose rapidly. This was bad news for Britain, which lacked the long navigable rivers of continental Europe. What it did have, though, were large outcrops of coal right next to the river Tyne in northern England, which could be loaded on to ships and taken by river and sea south to London.

Coal was regarded as a dirty, stinky fuel that wrecked people's health. But in Britain it became cheaper than wood, and caught on because it could replace wood for many purposes – making lime for mortar, firing bricks, heating homes and so on.

Yet raw coal is inferior to wood in one crucial way – it is no use for smelting copper or iron ores. The impurities in coal weaken the metal. Instead, smelters relied on charcoal, says Benjamin Roberts of Durham University in the UK, who studies early metallurgy.

Then, in the 17th century, English inventor Hugh Plat suggested that coal could be purified by “charring” it – a process called coking. In 1642, brewers began to use coke for malting, achieving a new lighter roast that led to the production of the first pale ale, and in 1709, Abraham Darby started using coke to smelt iron ore, ending the dependence on charcoal. This, some argue, was the pivotal ➤

“They [coal minerals] exude an evil and corrosive smoke that is most dangerous to chest and lungs and without doubt the cause that a certain Englishman proclaims that a third of the inhabitants of London die of the wasting disease and lung ailments.” J. Huber, 1717



The heyday of wind power in the US was from the 1870s to the 1930s, when millions of wind turbines were used on farms

ALTERNATIVE EARTH

What would a world without fossil fuels be like? An industrial civilisation could only develop if it could tap some energy source other than biomass, and hydroelectricity looks like the only possible alternative (see main story). This means electricity would be the main power source. Trains would be pulled by electric locomotives. In cities, electric trams and trolleybuses would probably dominate. Electric cars might cruise the asphalt-free roads too – there were, after all, already 30,000 electric cars in the US by 1912 – but with their limited range there would be no call for motorways.

In our world, cheap fossil fuels killed off early renewable energy technologies. In a hydroelectric world, they would probably continue to develop. Wind mills would be a common sight, providing valuable extra energy. Biofuels and hydrogen might be produced, too, as technology advanced – biogas from manure could power tractors on farms, for instance – but liquid fuels would be far more expensive than electricity. Which means there would be no passenger aeroplanes. Airship flight would be possible, but with hydrogen-filled craft only, as helium is derived from natural gas. International trade and travel would rely largely on sailing ships, perhaps fast, metal-hulled ones like the *Preussen*, built in 1902. On land, canal networks would be far more extensive and important.

This alternative world would have familiar challenges, too. Extensive damming would cause many environmental problems and conflicts. “Wars might be fought over sites with water power potential instead of over oil,” says Terry Reynolds of Michigan Technological University in Houghton. And without coal, the greater demand for land for producing materials and fuels might lead to even greater deforestation than in our world.

innovation that kick-started the industrial revolution in the 18th century, by providing a plentiful supply of cheap iron which led to many other innovations such as iron railways.

The question is, could wood alone have fired the industrial revolution?

Before the 18th century, the main source of energy was the solar power captured by plants – biomass. The energy needed to pull ploughs or haul loads came from the food consumed by animals or labourers. The heat for cooking, heating and industry came mainly from wood. Plants were also the ultimate source of many raw materials, from wool and cotton to timber for houses and ships. Other materials, from cement to iron, couldn’t be made without burning wood or charcoal. This meant that as populations grew and energy use rose, land area became a limiting factor. Negative feedbacks kicked in. If charcoal burners used more wood, there was less for building and ship making. If more trees were planted, there was less land for growing food.

Plenty of things could be done to relieve these constraints, from better growing practices such as coppicing to trading with neighbouring countries or taking land by force. But as growth continued, the limits were soon reached again. “Expansion in one area meant contraction elsewhere,” says historian Tony Wrigley of the University of Cambridge.

Exploiting coal, however, gave us access to a virtual forest bigger than all the continents put together – millions and millions of years of accumulated plant growth. It’s a finite resource, but one so vast we still haven’t exhausted it.

New iron age

Coal enabled Britain to produce iron cheaply, without large forests. Iron farm tools boosted productivity and iron railways made it cheaper to move that food and other goods. “There were positive feedbacks,” says Wrigley. “Each advance made the next more likely.”

Here’s how important coal was: by the 1820s, growing enough wood to replace all the coal used in Britain would have required a land area larger than the country. “It is inconceivable that there would have been a development worthy of the name industrial revolution based on charcoal,” Sieferle writes in his book *The Subterranean Forest: Energy systems and the industrial revolution*.

What if we had no coal or other fossil fuels? By the 19th century, says Sieferle, the growth constraints imposed by limited land area



Cooking is easy but even today it is difficult to harness the sun for industrial purposes

would have kicked in. In earlier civilisations, periods of rapid advance were often followed by collapse, he says. “There was no collapse in Europe because we had fossil fuels.”

Clearly, a world without fossil fuels could not develop far without an energy source that does not depend on biomass. There are many other potential energy sources – the key question is whether any can be exploited without advanced technology.

For a start, we can rule out nuclear power and solar photovoltaics. By contrast, solar thermal power is easily exploited to heat air or water using little more than black pipes. An array of mirrors can focus enough heat to melt metal. But even today exploiting this on an industrial scale is a huge challenge. In a world without fossil fuels, the sun might be used for cooking or heating homes and water, but as an energy source for industry it’s probably not viable.

That leaves wind and water. On the sea, wind powered most trade and exploration until well into the 19th century. On land, wind and water mills have been used for at least 2000 years. In medieval Europe the technology reached new heights. By around 1600, wind and water mills were grinding grain, sawing wood, boring pipes, polishing glass, drilling holes, pressing seeds for oil, grinding up stones, pumping out mines and more. It was in these mills, some argue, that the foundations



TINASTALLARD/GETTY

water power already. Most factories had to be located near ports and navigable rivers, where hydropower resources are limited. “In Britain in the late 18th century some streams were so dammed up that no further power could be squeezed out of them,” Reynolds says. There were vast untapped hydropower resources in distant hills and mountains, but there was no way to get the energy to where it was needed.

In our world, two technologies changed this. First, pioneers like Michael Faraday worked out how to transform motion into electrical power. Later in the 19th century, engineers worked out how to transmit electricity over long distances. “Electric power transmission transformed hydropower into a vital contributor to the modern world’s power mix,” says Reynolds.

It seems clear, then, that to develop on the basis of hydropower rather than fossil fuels, a civilisation would have to develop hydroelectricity. Is that feasible?

Without fossil fuels, western Europe could have developed technologically to around the 1800 level, Sieferles thinks. This was the time when innovators like Faraday and Humphrey Davy were developing the basic components of modern electrical technology.

So where would this alternative path take us? Forget steampunk: this would be a hydroelectropunk world (see “Alternative Earth”, left). For a start, industrialisation might have taken off in the mountains of Norway or Switzerland rather than Britain. Without easily exploitable fossil fuels, economic and technological development, and population growth, would certainly have been slower. ➤

“An intolerable smell diffuses itself throughout the neighbouring places, and the air is greatly infected, to the annoyance of the magnates, citizens, and others there dwelling and to the injury of their bodily health,” declared a 1307 royal proclamation banning coal burning in London. It was ignored

for the industrial revolution were laid.

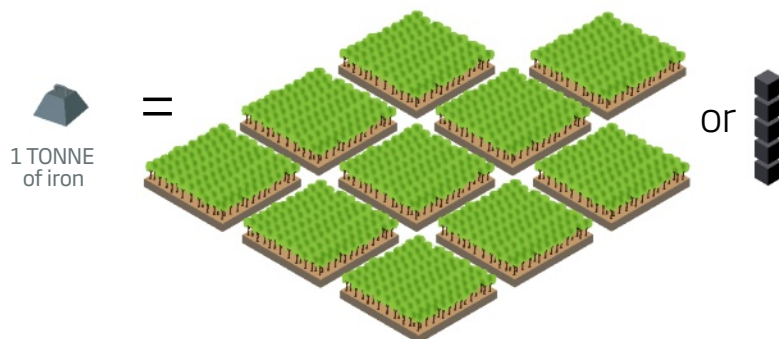
Water continued to power factories throughout the industrial revolution. It wasn’t until 1820 that coal-powered steam engines overtook water as the main source of mechanical power in British factories, says Terry Reynolds of Michigan Technological University in Houghton, and author of *Stronger Than a Hundred Men: A history of the vertical water wheel*. “In the US, the date was around 1870.”

Factories turned to coal in part because they were using pretty much all of the available

The rise of coal

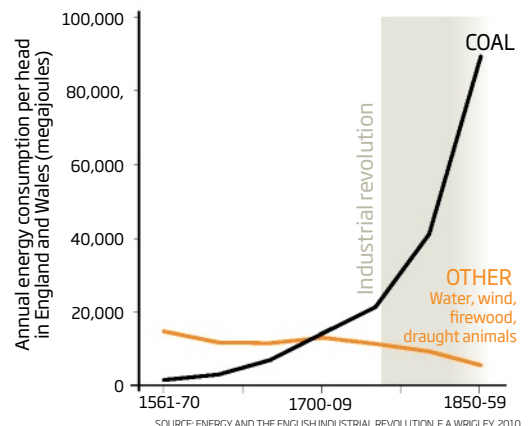
Before 1700, iron production required charcoal and thus large forests

Making 1 tonne of iron requires **10 hectares of forest** or **~5 tonnes of coal**



SOURCE: ROLF SIEFERLE

Once we learned how to use coal instead, energy use per person could grow exponentially



"The strong mineral coal vapour gives London this advantage over all other towns in the world, that one can smell it an hour's distance away." Alberti, 1790

DO ALIEN WORLDS HAVE FOSSIL FUELS?

Won't any planet on which intelligent life evolves possess a plentiful supply of fossil fuels? The only life we know is carbon-based, after all, and when its remains accumulate in places with little oxygen, such as the bottom of seas and swamps, fossil fuels form. So such an energy source will almost certainly form wherever carbon-based life thrives.

Yet fossil fuel formation is not essential for life, says James Kasting of Pennsylvania State University, who studies what makes planets habitable. Life does require a planet with a carbon cycle: if some of the carbon that gets locked away in rocks isn't eventually released in the form of carbon dioxide, life would run out of carbon. But fossil fuels are not an important part of this process. "Most of Earth's carbon is not in fossil fuels, it's in carbonate rocks," says Kasting.

In fact, Earth's plentiful supply of coal - the key fuel for the industrial revolution and still a major power source in most countries - may be the result of evolutionary accidents. Most of the coal we use today formed from around 360 to 290 million years ago, during the Carboniferous period. "The vast majority of coal was laid down during this brief interval," says David Hibbett, who studies fungal evolution at Clark University in Worcester, Massachusetts.

Why? The first large land plants evolved at the start of this period. These plants were very different to modern trees, and their chemical make-up may have made them particularly likely to form coal. The Carboniferous climate was also warm and wet, favouring plant growth, and the swampy conditions needed for coal formation.

More than that, the end of the Carboniferous era seems to have coincided with the evolution of white rot fungi, Hibbett and colleagues recently reported. "Lignin is the major precursor of coal," Hibbett says. "And white rot fungus is the major degrader of lignin."

If early trees had contained less lignin to start with, or white rot fungi had evolved much earlier, there might be much less coal. On the other hand, perhaps there are planets where coal is even more abundant than on Earth.

Regions with abundant hydropower resources, including Scandinavia, Canada and parts of South America and Africa, would have had a huge advantage (see map, right).

Without dirty coal fires, cities would not be grimy and smoke-stained. Driven by the need for better hydroelectric generators rather than more efficient steam engines, science would focus more on electrodynamics than thermodynamics, perhaps hastening the development of smaller, lighter electric motors and batteries.

The pace of life would also be slower - going from London to New York would involve weeks spent on an iron sailing ship rather than hours on an aeroplane. The world might even be more equitable: without steam power, some European nations may have struggled to establish vast empires. Most important of all, there would be no impending climate doom.

It is an appealing vision, but perhaps an unlikely one. We tend to assume that technological progress is inevitable, but it may not be. China started smelting iron with coke as early as the 9th century, for instance, but the industrial revolution did not happen there. It happened in Britain only because a very particular set of geographic, social, economic and cultural factors came together.

Hydroelectricity is a more complex technology than steam power, and even if

developed by a pre-industrial civilisation there are reasons to doubt that it could drive an industrial revolution. With relatively simple technology, electricity can be used for lighting, heating, cooking, powering engines, making fertiliser and even melting metals. However, while electric power can reduce the amount of charcoal needed for smelting iron by more than half, it cannot replace it entirely. So wood would still be a limiting factor, and without cheap iron to make tools, machines and railways, rapid industrialisation would be extremely difficult.

Dam them all

Scaling up hydroelectricity is also more challenging than scaling up coal mining. It was possible to build dams long before the industrial age. In 1177, for example, the 400-metre-long Bazacle dam in Toulouse, France, was built to power water mills. In 1888, it was converted to a 4-megawatt hydroelectric power station.

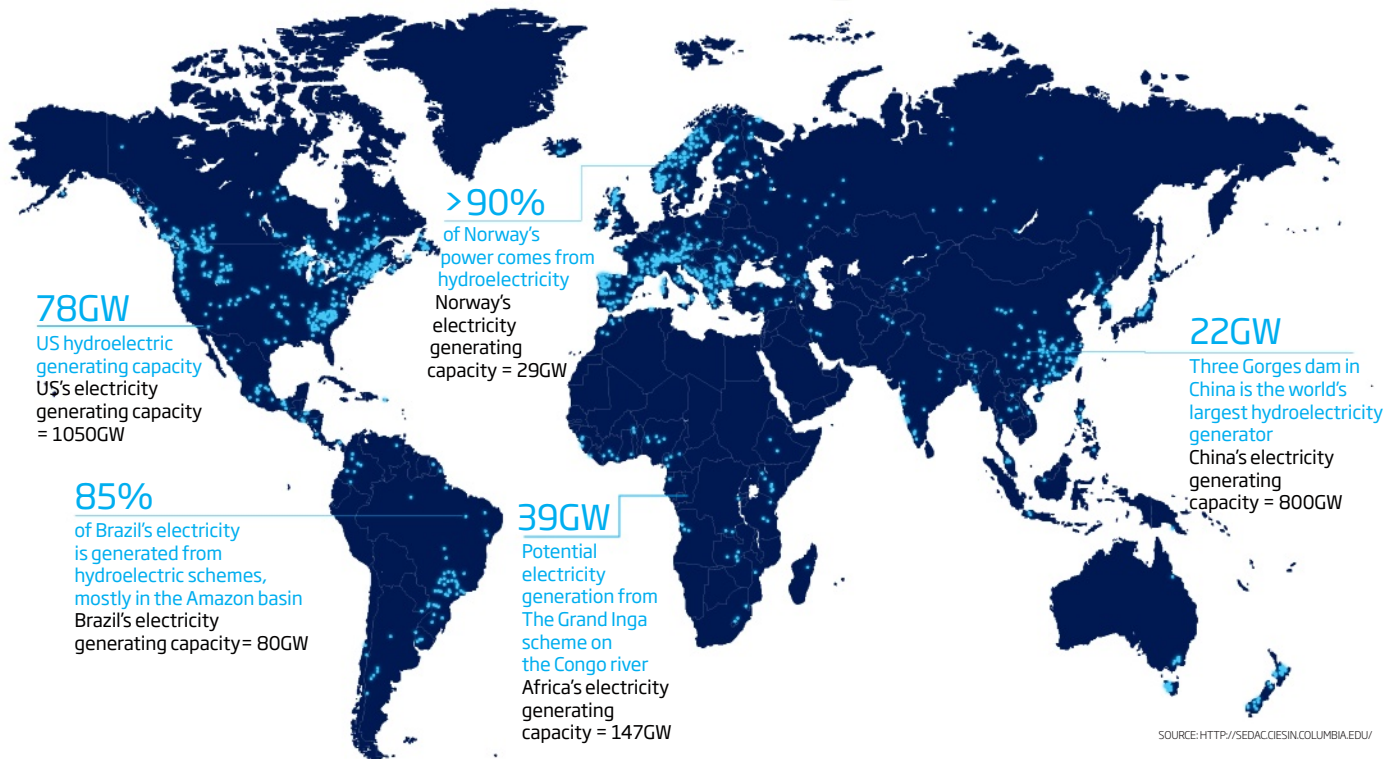
However, it would take 2500 dams of this size to provide the same amount of energy as England and Wales extracted from coal at the beginning of the 19th century. To match coal consumption in 1850, it would take another 8000 dams. And what do you construct them with, asks Siefert. Building materials like cement and bricks became cheap in our world only because we could use coal to produce lime for cement and to fire bricks. Then there's

The Bazacle dam in Toulouse, France, was constructed in 1177 to power mills



Generating a water world

About 16 per cent of the world's electricity comes from [hydroelectric dams](#), 852 gigawatts out of a global total of 5330 GW



the energy needed to transport materials. Building hydroelectric dams takes a lot of planning and labour and energy, and yet the dams don't provide energy until they are finished. The economics might not add up.

So could civilisations make the transition to advanced industrial economies without exploiting fossil fuels? "You cannot exclude this, of course," says Sieferle, but he doesn't

think it likely. Historian Kenneth Pomeranz, author of the *The Great Divergence: China, Europe, and the making of the modern world economy*, is more optimistic. "My guess would be slower growth," he says. "But there are obviously a lot of unknowns." And slower growth is not without its dangers. Regional civilisations are vulnerable to epidemics, famine, earthquakes, war and volcanic eruptions – the downfall of many. The longer it takes for a global industrial society to emerge, the more chance that disaster will strike.

All this hints at a universal truth: wherever technologically advanced civilisations develop, most – perhaps all – do so by exploiting fossil fuels. "You can't change anything without expending energy," says Wrigley. "Energy is an absolute prerequisite."

Fossil fuels probably exist on most worlds where carbon-based life might thrive (see "Do alien worlds have fossil fuels?", left). Perhaps there are aquatic alien civilisations that have progressed technologically without exploiting fire, or even some that flourish on worlds with no oxygen in the atmosphere, but it's hard to imagine how this could happen.

If fossil fuels are key to developing advanced technology, global warming may not be a uniquely human problem but an issue for petrol-heads across the universe. The laws of physics apply everywhere, after all. "The downside of access to a stock of energy in fossil fuels is very great," says

Wrigley. "And making the transition to other energy sources is far from easy."

How many alien civilisations have wrecked their planet or run out of fossil fuels – or both – before they managed to make the transition to sustainable energy sources? This could even be the "great filter", says James Kasting of Pennsylvania State University, who studies what makes planets habitable. Kasting

By 1920, hydroelectric power accounted for a quarter of US electricity production. By 1940, this had risen to 40 per cent

refers to the idea that our failure to discover intelligent life elsewhere despite the vast number of stars – the Fermi paradox – is due to some bottleneck that either stops intelligent life evolving, or makes it go extinct.

After such a collapse occurs, there would be no easily exploitable fossil fuels left. There might a brief window of opportunity for a civilisation to re-establish itself using more sustainable energy sources, before all knowledge and resources have been lost. But after that, it will be too late.

If this is right, each planet essentially offers one chance to make the transition to an advanced and sustainable state. We had better not waste ours. ■

Michael Le Page is a features editor at *New Scientist*



Golden opportunity

Many species are heading for oblivion but it's not too late to save them, reports **Caroline Williams**

BETWEEN a third and a half of all species will go extinct... by the year 2000. That was the dire prediction made in the 1980s. Thankfully, it was wrong. While populations of wild animals have halved, only about 1 to 2 per cent of species have been lost so far – at least in well-studied groups such as mammals and birds.

But don't go sighing with relief just yet: the main problem with this prediction may be the timing. There can be a long lag between cutting down a forest, say, and losing the species that lived there. Decades or even centuries may pass before the extinction follows. Put another way, many of the species around today may be the walking dead.

Take the golden lion tamarin. A member of the marmoset family, it is native to the coastal forests of Brazil. Only 1000 or so are left, trapped in the few fragments of forest that remain. Such small, isolated populations are essentially doomed: even if the forest fragments survive, sooner or later dwindling gene pools or disasters such as forest fires and disease outbreaks will wipe them out.

Luckily for the tamarins, conservationists are trying to stop this happening. For instance, Stuart Pimm noticed that a 100 hectares of cattle pasture was all that separated one of these isolated groups from a much larger patch of forest nearby. So in 2007 he set up a charity, Saving Species, to buy the land and reforest it. Within just six years the golden lion tamarins began to exploit this "marmoset motorway". Even as saplings, the new trees

already provide the protection from ground predators that tamarins need to travel. There are plans to create more corridors (see map, page 42)

Efforts like this are greatly boosting the tamarins' survival chances. The point is that although half of all species really may be heading for extinction, it is not too late to save them. "If extinction is a slow process then you do have time to do something about it," says Rob Ewers, a conservation scientist at Imperial College London.

While the tamarins' plight was clear, working out which of the world's species are in trouble is not always easy. We still don't even know how many species there are, after

all, let alone where most live and what they need to survive. Many of the factors that will determine their fate, from the severity of poaching to the introduction of invasive species, are not really predictable.

The greatest threat to plants and animals, though, is habitat loss, which can be measured. To work out the resulting species loss, biologists have turned to an ecological rule of thumb called the species-area relationship: a way of estimating the number of species in a given area. "The reason it works is that if you're in a 10-hectare area of forest it's likely to be more or less all the same," says Ewers. "If you go to 100-hectares of forest you're more likely to encompass a ridge and a gully. If you go to 1000 hectares, you might have a lake system in there; you might have a small mountain." More area means more variety, which is always good for diversity.

While the species-area relationship might work for pristine areas, using it to estimate extinctions has become controversial. This was the method used to produce the half-of-all-species-gone-by-2000 prediction, and some argue that it always overestimates extinctions. Others argue it underestimates them. Paradoxical as it sounds, both views may be right – it all depends on the time scale.

For instance, Stefan Dullinger and Franz Essl, conservation scientists at the University of Vienna, Austria, and their colleagues recently looked at how many plants and animals are threatened in 22 European countries. They compared this with factors linked to habitat loss, such as population density, GDP and land-use intensity over the past century. They found that what was happening around 100 years ago was a better predictor of today's extinction rate than what is happening today.

Slow fuse: there's a long lag between habitat loss and species loss



RIGHT: MINT IMAGES/REX FAR RIGHT: CLAUD MEYER/MINDEN PICTURES

In other words, there can be a long time-lag between habitat loss and extinction: species are being lost today because of what happened a century ago. When habitat is lost, only a few species may go extinct straight away. But an “extinction debt” is created that results in many more disappearing over the following decades and centuries. “As socio-economic activities in Europe continue to increase, the debt is increasing in scale,” Essl says.

What’s more, says Dullinger, simply preventing any further habitat loss isn’t enough to protect Europe’s endangered species. “Preserving the status quo will not halt species loss, which will continue until the debt is paid,” he says.

“Within six years, the golden lion tamarins started using the ‘marmoset motorway’”

What causes the lag? When, say, an area of rainforest in the Amazon is cut down, many animals will escape to neighbouring areas. But with less food to go round, they cannot all survive. Population sizes will fall, and the smaller a population becomes, the more vulnerable it is to being wiped out by random events. “Low population sizes are just unsustainable,” says Ewers. “Something happens – your dominant male is infertile, or a jaguar comes through and eats all the babies that year, but it takes time for those events to accumulate to drive you to extinction.”

How long? In the 1970s, biologist Thomas Lovejoy persuaded cattle farmers clearing forest in the Amazon to help him find out. Lovejoy arranged for 11 islands of forest, covering 1, 10 or 1000 hectares to be left intact, but completely isolated from each other.

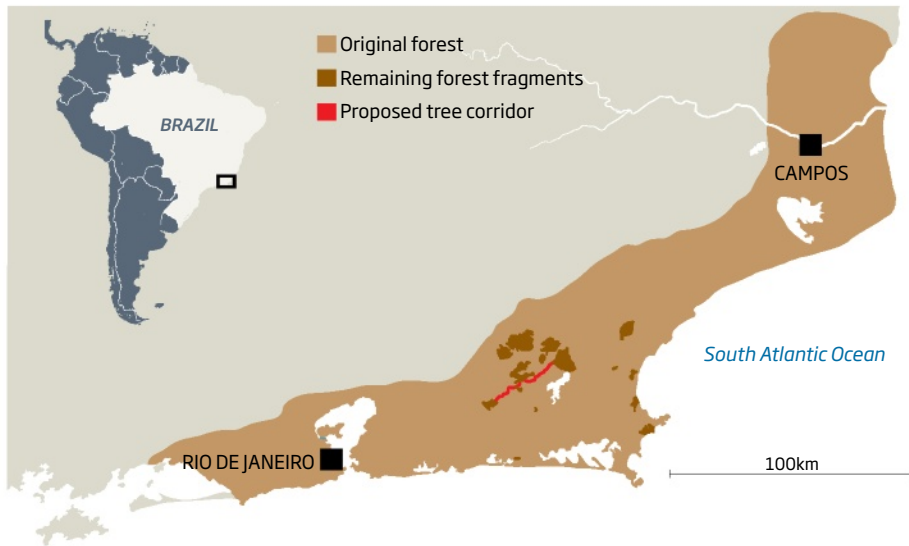
Three decades on, it was very clear that the rate of loss depended on the size of the habitat (*PNAS*, vol 100, p 14069). “With 1000 hectares it was taking decades for species to be lost,” says Pimm, a conservation ecologist at Duke University in Durham, North Carolina, who was involved in the project. “Below 100 hectares it’s pretty brutal,” he adds, taking less than 15 years for a forest fragment to lose half of its species. “If you get down to a hectare or 10 hectares, the species go within a year or two,” he says.

The failure to take into account these lags, then, may be the main reason why some predictions based on the species-area relationship appear to have got it so wrong. Instead, Ewers and his colleagues have ➤



Join the dots

Reconnecting the isolated pockets of forests in which golden lion tamarins survive could save them from extinction



developed an alternative approach that predicts both the scale and timing of extinctions, based on studies of about 50 sites across the world.

They applied this to the Amazon, where about 1 per cent of animals like birds, mammals and amphibians had been lost by 2008. Their conclusion was that these extinctions are only a fifth of the number we can expect due to the deforestation that has taken place (*Science*, vol 337, p 228).

That may not sound too bad, but of course deforestation has not stopped. If it continues at its current rate, the team calculates 40 per cent of species will be lost by 2050. That is the actual loss expected by 2050, not counting the remaining extinction debt.

Only time will tell if these recent predictions will prove to be more accurate than those made in the 1980s. But there are reasons to think they are underestimates. For starters, Ewer's method does not include factors like global warming, which will be bad news for species trapped in isolated pockets, unable to migrate to a place with more suitable conditions.

Nor do predictions of this kind include the effects of invasive species, like the grey squirrels pushing out the UK's native red squirrels. Their full impact may only become clear after centuries or millennia, in part because of knock-on effects due to the linkages between species. On New Zealand's North Island, for instance, the introduction of rats wiped out local populations of birds including

the bellbird and stitchbird. In 2011, biologists discovered that these birds play an important role in pollinating the flowers of the shrub *Rhabdothamnus solandri*. With the birds gone, the plants' numbers are slowly declining.

For biologists, though, the whole point of studying extinction debt is not to produce gloomy headline figures about how dire the

situation is. Instead, it is about understanding which species are most at risk and what's needed to save them. "Extinction debt is a window when you can see that your actions have done something, but it's not yet fatal, so you've got an opportunity to get in there and be proactive," says Ewers.

"It's a real problem with conservation – everyone wants to talk about how we're all going to die," says Pimm. "The fact is, yes,

"We poked extinction debt in the eye and said: 'We're not having that'"

we know how fast species are going extinct, but I spend most of my days looking for solutions – and there are solutions."

These include creating wildlife corridors that help maintain genetic diversity, as the Saving Species charity is doing to save the golden lion tamarin. "I am very proud of this example," Pimm says. "It basically pokes extinction debt in the eye and says 'We're not going to have that.'"

Once an extinction debt has been identified, a species becomes easier to save. Take *R. solandri*. Conservationists plan to reintroduce the pollinating birds, which survive on nearby islands. Because the shrub can live for a century or more, there is still time to save it.

Ewers' work, too, shows there is still a window of opportunity to save many species in the Amazon. Applying environmental laws more stringently could reduce the extinctions to 30 per cent by 2050, rather than 40 per cent, his team calculated. Greater efforts to save forests in key areas could limit it to 15 per cent. "Those kinds of interventions have a real positive effect. When you extrapolate out to 2050 you can see – it's a different future," says Ewers.

So what can we take from all of this? The clearest message from these studies seems to be that we have made a shocking mess of the world's biodiversity, but – importantly – it doesn't have to be all doom and gloom just yet.

As Ewers points out, we have put quite a lot of effort into destroying species. "It is hard to drive a species extinct," he says. "They don't just fall over and die, you've really got to work pretty hard to knock them out."

So perhaps it's time to start working just as hard in the opposite direction. And the sooner the better. ■

Caroline Williams is a science writer based in Surrey, UK



The actions of our great-grandparents are the cause of most extinctions today

QUANTUM COMPUTING BEST BUYS



Fed up of failing to factorise? Is your optimisation not optimal? Simulations running slow? **Michael Brooks** is here to solve your problems

IS THERE anything more to quantum computers than talk, talk, talk? You might have given up waiting – after all, it’s been more than 30 years since physicist Richard Feynman came up with the idea. He wanted to harness spooky quantum effects to seriously surpass the processing power of any normal computer. In that time, normal computers have become around a billion times faster. Quantum computers, by contrast, are still struggling with primary school arithmetic.

At long last, though, there’s good news. In laboratories around the world, researchers have been beaver away, and they can’t help feeling there’s magic in the air. “Some aspects of this field are getting tantalisingly close,” says Matthias Steffen of IBM’s quantum

computing division based in New York. You can even buy a quantum computer right now – maybe – but you’ll need deep pockets. It doesn’t matter what apps you’re planning to run, this much computational horsepower doesn’t come cheap.

With that warning in place, let *New Scientist* help you make an informed choice – whether you’re an online game freak looking to take multiplayer to a whole new level, an engineering powerhouse looking to stay one step ahead, or a security service worried about keeping the nation’s secrets under lock and key. Over the next five pages you’ll find out what they can do, what different kinds are on offer, and whether you’ll have to turn the back bedroom into a cryogenic coolant plant. ➤

GETTING STARTED

Baffled by how a quantum computer is supposed to work? Don't worry, some of the biggest brains in physics can't figure it out either. Some say such computers run in a swathe of parallel universes; others claim they transcend all normal notions of space and time. Whatever the truth, here's a rundown of the basics.

QUBIT:

Ordinary computers use "bits" to process information. The basic unit of quantum computing is the qubit. These are physical systems that can exist in two different

"Superconductor or spin? That's like deciding between Apple or Android"

states, so they can represent the 1s and 0s that make up the binary code computers run.

A qubit might be an electron held in a magnetic field, or a photon that is polarised so its spin can be easily manipulated. Preparing qubits, as well as reading and writing to them, involves some hardcore hardware. Depending on your choice of technology, you might need a ruby laser, a non-linear crystal or even a pink diamond.

SUPERPOSITION:

This is where the magic happens! The advantage a qubit has over a normal bit is that it can be put into a superposition state, being 0 and 1 at the same time. But this is tricky to pull off – any stray heat, electromagnetic noise or physical bump can knock it out again. So you'll have to invest in some serious refrigeration, tinfoil shielding and tiptoe around your quantum computer, or invest in a state of the art vibration containment system.

Even then, you can only run the computer for a limited time before the superposition collapses. You'll want to check out this "coherence time" carefully, as well as evaluating how many errors are created.

ENTANGLEMENT:

Okay, we lied, this is where the magic really happens. Thanks to what Einstein termed spooky action at a

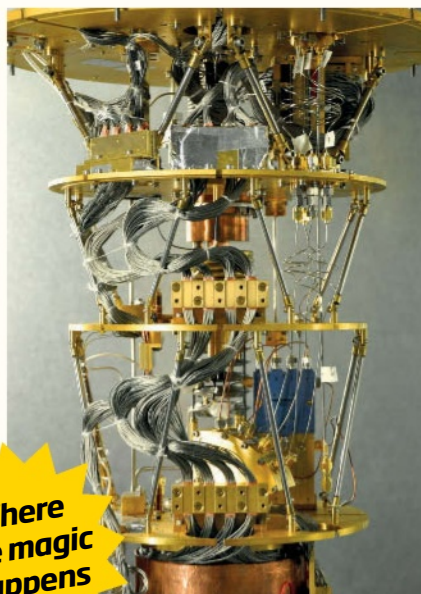
distance, two subatomic particles can become inextricably interlinked, or entangled. The link lets you manipulate multiple qubits at once. That's what makes quantum computers so kickass: just eight qubits, held in superposition and entangled, can simultaneously represent every number from 0 to 255, letting you carry out many operations at once.

So that's the other thing to look for when weighing up a purchase: how many entangled qubits can your chosen machine manage at once? Don't set your sights too high. At the moment, 14 is the record, achieved in 2012 by Rainer Blatt's group at the University of Innsbruck in Austria.

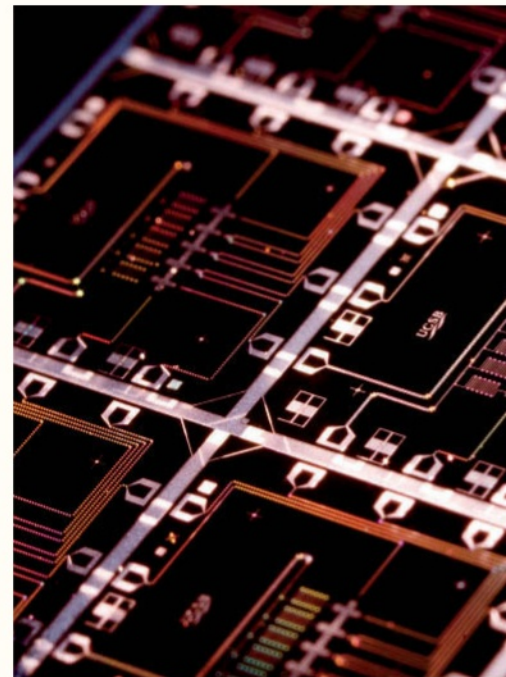
ERROR CORRECTION:

Even normal computers make mistakes. Sometimes a bit can be buffeted by a voltage spike or a passing cosmic ray, changing it from a 0 to a 1, say. Processors deal with this by keeping copies, but this isn't an option for qubits, thanks to a law called the no-cloning theorem.

Fortunately there are error correction algorithms to get around this. The drawback is that these need a lot of qubits, anything between 100 and 10,000 times as many as needed for the actual computation you're trying to perform. Happily, our ability to assemble arrays of qubits for error correction has come on leaps and bounds. And error rates have been creeping downwards too. In June, IBM unveiled error correcting code that is well suited to the



Where the magic happens



large arrays of qubits expected to outperform regular machines. Essentially we're where we need to be to start building interesting quantum computers.

HARDWARE

Spin or superconductor? That's the "Apple or Android?" of the quantum computing world. Superconducting qubits have been around longer, but spin's the ultracold new thing – and there are a few wild-card options to boot. Here's what you need to know.

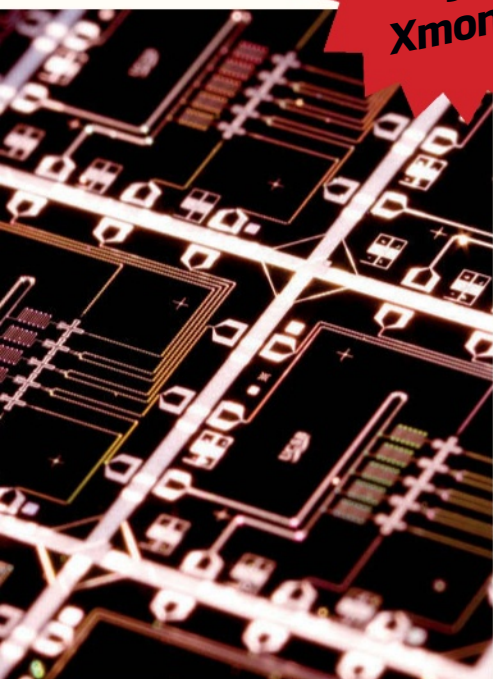
SUPERCONDUCTING QUBITS:

This is the granddaddy of all quantum computer tech. Back in 1962, Cambridge physicist Brian Josephson showed that putting a small gap into a strip of superconductor – a material that has zero resistance to the flow of electricity at low temperatures – has a surprising effect. For example, superconducting loops incorporating such a "Josephson junction" let current flow clockwise and anticlockwise simultaneously. That's a superposition of states – just what you need for a qubit.

What's more, these systems are manufactured on the mainstay material of the tech industry: silicon. "That allows you to use standard lithographic tools," says Steffen. "You're not in thrall to natural systems, and once you can do a handful of

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qubits on a chip reliably, you should be able to put many more onto the same chip.” That makes superconducting a good choice for the buyer looking for a tried-and-tested solution to their quantum computing needs.

If you’re sold on this approach, you still have a choice to make: transmon or Xmon? Transmons are loop-shaped and, at the moment, up to five of them can be linked together. A standard transmon can maintain its coherence for around 50 microseconds – long enough to be used in quantum circuits. What’s more, coherence times twice that length, and transmon arrays of 10 to 20 loops, are just around the corner, according to Göran Wendin of Chalmers University in Gothenburg, Sweden.

The Xmons created by a team at the University of California, Santa Barbara (UCSB), are cross-shaped superconducting qubits made from sapphire sitting on aluminium. The UCSB group can connect up five of these to create an array that corrects its own errors, and are working on a nine qubit array. UCSB’s John Martinis, who has just embarked on a collaboration with Google, thinks they can power ahead now: “My challenge to the group is to double the number of qubits every year.” That’s a big ask: the architecture and the kinds of algorithms the machine will run still need work.

SPIN QUBITS:

If you’re more of an early adopter, you might check out what Andrea Morello’s group is up to at the University of New South Wales (UNSW) in Sydney, Australia. Their single atom of phosphorus sitting inside a silicon chip may not sound as impressive as a quintuplet of superconducting loops, but it certainly has its advantages.

Morello’s team is able to put the atom’s spin in a superposition, manipulate this blurred quantum state and then read it out by applying a microwave pulse. Morello says the team has maintained coherence for “tens of seconds” – plenty of time to run the kinds of quantum apps being dreamed up. There’s scope for going longer, too. Researchers at Simon Fraser University in Burnaby, Canada, have managed to get their phosphorus-in-silicon rig to hold for nearly 40 minutes at room temperature. They also preserved the superposition while cycling the material between room temperature and 4.2 kelvin.

At the moment, the UNSW group is squeezing two qubits out of a single atom, using the phosphorus nucleus as the first and one of its electrons as the second. In June, they announced that they could now couple two atoms together and read out all four spins, although they haven’t yet managed to manipulate them. Once they can, they aim to have a handful of qubits that will let them start making quantum calculations. But that will take three to four years, and the wait for apps will be even longer.

Some researchers are looking for a more high-end solution – which is where those diamonds come in. When certain diamonds are formed, a nitrogen atom can sneak into the place of a carbon atom to give the gem a slight pink colouring and, at the same time, leave an empty space nearby in the crystal lattice. This combination of nitrogen plus “vacancy” (NV) can be used to create a qubit; the vacancy has distinct quantum energy levels that can be put into superposition

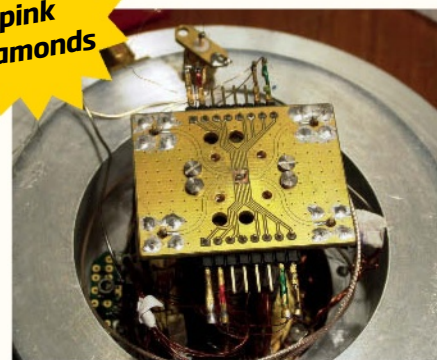
using a pulse of laser light. Further pulses can manipulate the state and read out the result of the operation.

In May this year, researchers from the Delft University of Technology in the Netherlands managed to teleport quantum information between two diamonds that were 3 metres apart. This is a baby step towards quantum computing in the cloud and a quantum internet.

Before we get ahead of ourselves, there’s a catch. You can’t manufacture these blingtastic NV qubits to order. Putting hundreds of them together, as would be necessary for a useful quantum computer, would give a noisy output. But that’s not a deal-breaker. Last year, a team led by Simon Benjamin at the University of Oxford showed that you can put just a few NV qubits together in a “cell”, then link those cells together with photons that act as the input and output bits. Even at room temperature, the cell can maintain coherence for around a second, and the noisy photon network that connects cells

can tolerate a 10 per cent error rate without crashing.

Blingtastic
pink
diamonds



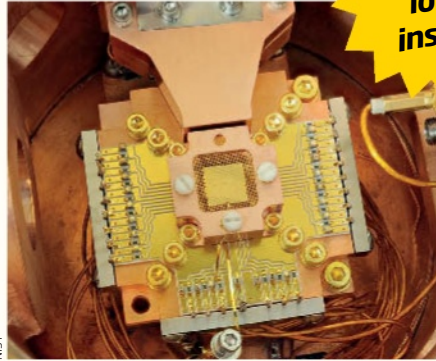
ALSO AVAILABLE:

If you’re really into bleeding-edge technology, there are a few other options to consider. Ion trap quantum computing is actually the market leader when it comes to entanglement. This technique has linked together a whopping 14 qubits made from ions – typically ytterbium – held in carefully shaped electromagnetic fields and manipulated with laser or microwave pulses. But that’s still a long way from a useful computer, and researchers are finding it tricky to scale up.

You would have to be brave to put all your money on photonic quantum computing, ➤

“Information has
been quantum
teleported between
two diamonds”

Trapped ions inside!



NIST

too. Photons look like they would make good qubits: they are easily superposed and stay coherent for good lengths of time. But although it's possible to work with particles that move at the speed of light, it isn't easy.

Topological quantum computing, where qubits are encoded in the way subatomic particles move past one another, has its pluses too – it's particularly resistant to environmental disturbances for one thing. Microsoft is beginning to invest heavily in it, but it won't be in the shops any time soon. Maybe one to consider when your first quantum computer starts to look a little vintage.

VERDICT: Superconducting qubits might attract those who like to play it safe, but spin could just overtake it during the next decade. Everything else is for die-hard experimenters only.

APPS

Hardware is important, but what really matters is the software. So what will you be able to run on your quantum computer? Here's our pick of the best apps in the pipeline.

FACTORISATION:

This is the killer app for quantum computers: finding the factors of a large number. Why? To find a factor, normal computers have to try every possible combination, which takes an incredibly long time. Because of this, factorisation algorithms are used to protect data in situations ranging from banking to internet databases.

Twenty years ago, mathematician Peter Shor devised an algorithm that could break such security with ease. However, Shor's algorithm only works on quantum computers and so far the largest number

that has been factorised is 21. Don't you dare sneer – when this app takes off it'll put the revelations of WikiLeaks and the capabilities of the NSA to shame.

GOOD FOR: Anyone who wants to read other people's secrets.

BACKWARD SEARCH:

It's no wonder Google's PageRank algorithm has been such a money-spinner; searching through an unsorted database is a colossal task for ordinary computers. If there are N possibilities, a standard computer will, on average, find what you're looking for in a time related to $N/2$. Bell Labs researcher Lov Grover showed in 1996 that a quantum computer with the right algorithm can speed up the process, taking a time that is related to the square root of N . It works by fiddling with the qubits to make the object of the search the most likely outcome of a measurement on their superposition.

GOOD FOR: Budding dot-com billionaires, people in need of plumbers.

QUANTUM SIMULATION:

Where it all started. If you want to simulate a complex quantum system – a large molecule, say – there's just too much detail for a normal computer, no matter how

powerful. So as Richard Feynman realised in 1982, you need a quantum computer. For example, if you have one photon to represent each particle in the system you want to simulate, such as an atomic nucleus, then you can put them through a series of quantum gates that mimic interactions. Handy if you don't have the maths or equipment to try it for real.

GOOD FOR: Impoverished chemistry students, entrepreneurs searching for everyday superconductors, nuclear warhead designers.

OPTIMISATION:

If you want to baffle a computer, ask it to work out the best shape for the front end of an aeroplane. There are so many variables to consider that you'll be dead and gone long before it spits out an answer. This kind of problem is perfect for quantum "annealing",

"You can buy a quantum computer today – if you have \$15 million spare"

Which quantum computer is right for you?

There are many types to choose from. Here's how they compare and our all-important verdict

	D-Wave 2	Superconducting qubits	Spin qubits	Trapped ion qubits	Topological qubits	Photonic qubits
Estimated time before useful (years)	1	10	15	10	25	20
Apps	Factorisation	Factorisation, Backward search, Optimisation, Quantum simulation	Factorisation, Backward search, Optimisation, Quantum simulation	Factorisation, Backward search, Optimisation, Quantum simulation	Factorisation, Backward search, Optimisation, Quantum simulation	Factorisation, Backward search, Optimisation, Quantum simulation
Room temperature operation in future	No	No	Yes	Yes	No	Yes
Error correction	No	Yes	Yes	Yes	Yes	Yes
Upgradeability	5/5	5/5	5/5	3/5	3/5	5/5
Quantumness	2/5	4/5	4/5	4/5	4/5	4/5
Ease of use	2/5	4/5	3/5	4/5	2/5	3/5
New Scientist says	2/5	4/5	4/5	4/5	2/5	4/5

Available
to buy
now!

named after the process of shaping materials by cycles of heating and cooling.

Annealing is a way of representing all the different possibilities and their consequences as a landscape of hills and valleys; the ideal solution is the lowest point in that landscape. A quantum computer can survey the whole landscape at once, while a classical machine must run through it repeatedly. That's the idea, anyway – no one really knows if it'll actually work that way.

QUANTUM OR QUICKSILVER?

Can't wait to get your hands on a shiny new quantum computer? The good news is that you can buy one today, if you have \$15 million to spare. The bad news is nobody knows if it actually is one.

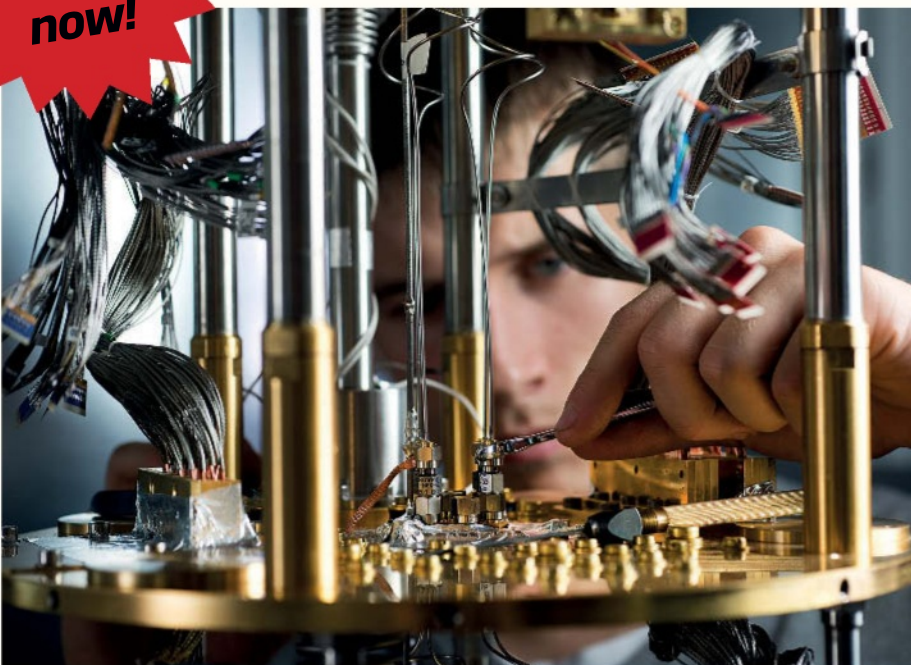
D-Wave Systems of Burnaby, Canada, is the upstart breaking in on the quantum action. Its flagship model, known as D-Wave Two, or Vesuvius, contains 512 superconducting loops of niobium metal, each containing a Josephson junction.

But be warned, this is no quantum laptop. The whizzy-looking black box it's housed in, along with its supporting cryogenic system and supercomputer interface, fills a room 10 metres squared. Perhaps surprisingly then it runs on just 15 kilowatts, less than a thousandth of the power devoured by Tianhe-2, the world's fastest supercomputer.

A full 512-qubit performance would leave rivals in the dust, but D-Wave doesn't worry about being able to address each qubit individually, with having all the qubits entangled together or even operating properly as Josephson junctions. So it's not clear that they actually are qubits, and tests have proved inconclusive as to whether it really outperforms ordinary computers.

"We're not in the business of trying to prove whether it's quantum or not," says Bo Ewald, CEO of D-Wave USA. "We don't know how much coherence we've got, but we've shown that eight qubits were entangled and some external work showed 40 were entangled." He believes all the loops are entangled, but doesn't want to spend megabucks proving it: "Trying to measure this means turning it into an experimental physics device. We're more focused on just using it as a computer."

It's a computer with only one application: an optimisation algorithm that searches for the best solution to a given problem. That's enough for D-Wave's first two customers. Google is using it in machine learning for its



D-WAVE

head-mounted display Google Glass; so far it has put the D-Wave machine to work finding quicker ways to recognise certain objects in an image. Those can be transplanted back into traditional computers, making them more efficient at the task.

Lockheed Martin is using the machine to find out where its aircraft software might go wrong. The company gives its aircraft control system a bad result – such as the aircraft nose going in the wrong direction when the pilot pulls up on the stick – and

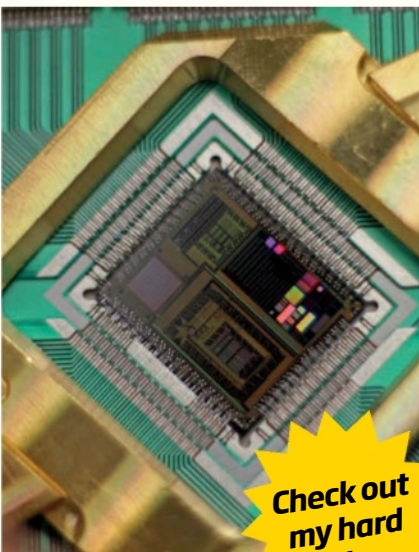
asks the D-Wave machine to look for input scenarios that might lead there.

D-Wave thinks it'll find more customers in medical imaging, financial planning and delivery scheduling, but the company is open to offers. It might also be worth noting that Google has now started investing in other quantum technologies: in September the company announced a partnership with UCSB to build an Xmon-based quantum computer.

THE VERDICT

So what's right for you? Right now the field is wide open. The experts say it's not clear which platform will win out and make it to market, but the smart money is on a hybrid that uses one technology for the computing and another for the networks to connect it up. Exactly when that will happen – D-Wave and a few experimental and very specialised machines aside – is up in the air. Insiders say you might not be taking delivery of your general-purpose quantum computer until 2024 or even later. But it'll be worth the wait to get hold of a machine that can wipe the floor with anything we have today. Don't forget, though: such power comes with a hefty price tag. Better start saving. ■

Michael Brooks is a consultant for *New Scientist*. His latest book is *At the Edge of Uncertainty: 11 discoveries taking science by surprise* (Profile)



D-WAVE

Check out
my hard
drive

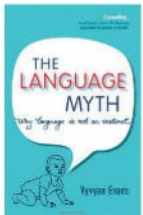


RICHARD KALVAR/MAGNUM PHOTOS

Breaking the rules

Our much cherished ideas about language being innate face being swept away, finds **Alun Anderson**

The Language Myth: Why language is not an instinct by Vyvyan Evans, Cambridge University Press, £17.99



IS THE way we think about language on the cusp of a revolution? After reading *The Language Myth*, it certainly looks

as if a major shift is in progress, one that will open people's minds to liberating new ways of thinking about language.

I came away excited. I found that words aren't so much things that can be limited by a dictionary definition but are encyclopaedic, pointing to sets of concepts. There is the intriguing notion that language will always be less

rich than our ideas and there will always be things we cannot quite express. And there is the growing evidence that words are rooted in concepts built out of our bodily experience of living in the world.

Its author, Vyvyan Evans, is a professor of linguistics at Bangor University, UK, and his primary purpose is not so much to map out the revolution (that comes in a sequel) but to prepare you for it by sweeping out old ideas. The book is sure to whip up a storm, because in his sights are key ideas from some of the world's great thinkers, including philosophers Noam Chomsky and Jerry Fodor.

Ideas about language that have entered the public consciousness are more myth than reality, Evans argues. Bestsellers by Steven Pinker, the Harvard University

professor who popularised Chomsky in *The Language Instinct*, *How the Mind Works* and *The Stuff of Thought*, come in for particular criticism. "Science has moved on," Evans writes. "And to end it all, Pinker is largely wrong, about language and about a number of other things too..."

The commonplace view of "language as instinct" is the myth Evans wants to destroy and he attempts the operation with great verve. The myth comes from the way children effortlessly learn languages just by listening to adults around them, without being aware explicitly of the

"Ideas about language that have entered the public consciousness are more myth than reality"

governing grammatical rules.

This "miracle" of spontaneous learning led Chomsky to argue that grammar is stored in a module of the mind, a "language acquisition device", waiting to be activated, stage-by-stage, when an infant encounters the jumble of language. The rules behind language are built into our genes.

This innate grammar is not the grammar of a school textbook, but a universal grammar, capable of generating the rules of any of the 7000 or so languages that a child might be exposed to, however different they might appear. In *The Language Instinct*, Pinker puts it this way: "a Universal Grammar, not reducible to history or cognition, underlies the human language instinct". The search for that universal grammar has kept linguists busy for half a century.

They may have been chasing a mirage. Evans marshals impressive empirical evidence to take apart different facets of the "language instinct myth". A key criticism is that the more languages are studied, the more

their diversity becomes apparent and an underlying universal grammar less probable.

In a whistle-stop tour, Evans tells stories of languages with a completely free word order, including Jiwari and Thalanyji from Australia. Then there's the Inuit language Inuktitut, which builds sentences out of prefixes and suffixes to create giant words like *tawakiquitiqarpiit*, roughly meaning: "Do you have any tobacco for sale?" And there is the native Canadian language, Straits Salish, which appears not to have nouns or verbs.

An innate language module also looks shaky, says Evans, now scholars have watched languages emerge among communities of deaf people. A sign language is as rich grammatically as a spoken one, but new ones don't appear fully formed as we might expect if grammar is laid out in our genes. Instead, they gain grammatical richness over several generations.

Now, too, we have detailed studies of how children acquire language. Grammatical sentences don't start to pop out of their mouths at certain developmental stages, but rather bits and pieces emerge as children learn. At first, they use chunks of particular expressions they hear often, only gradually learning patterns and generalising to a fully fledged grammar. So grammars emerge from use, and the view of "language-as-instinct", argues Evans, should be replaced by "language-as-use".

The "innate" view also encounters a deep philosophical problem. If the rules of language are built into our genes, how is it that sentences mean something? How do they connect to our thoughts, concepts and to the outside world?

A solution from the language-as-instinct camp is that there is an internal language of thought called "mentalese". In *The Language Instinct*, Pinker explains: "Knowing a language, then, is knowing how to translate

mentalese into strings of words." But philosophers are left arguing over the same question once removed: how does mentalese come to have meaning?

Here, Evans switches from demolishing the old world order to previewing the new. He roots language in the things we do as living, moving creatures. Take the task of hammering in a nail. Unsurprisingly, a part of our motor cortex will leap into action as we work. The surprise is that, when you use or hear an expression such as "he hammered the nail", then the same bit of the brain lights up as when we see or do hammering. Our thoughts aren't taking place in an abstract mentalese but are "embodied", arising directly in and from experience.

That is a starting point. Evans maps out how we might get from these basic concepts to much

"There's a surprise in the new view: there is no systematic distinction between words and rules"

more abstract ones, like love. And he goes on to show how different a "language-as-use" grammar will be. We expect that "words" and "grammar" – that is, rules for combining words – are wholly separate, but there's a surprise in the new view: there is no systematic distinction between words and rules.

Hopefully your first reaction to that is "What!" and your second is to reach for the book, because, time and again, it will give you the particular thrill of questioning received wisdom. Whether the new view will lead to a revolution in linguistics, or whether the empire will strike back with overwhelming force we don't yet know. But we are assured that Evans has a further episode, provisionally titled *The Meaning Making Engine*, in production. ■

Alun Anderson is a consultant for *New Scientist*

Could this bee love?

If you want to know how humans are doing, just ask the hive, says **Adrian Barnett**

Bee Time: Lessons from the hive by Mark L. Winston, Harvard University Press, £18.95/\$24.95



MARK WINSTON knows his bees. As an entomologist, he was part of the first team to study Africanised killer bees in the field in the 1970s.

As a beekeeper, he has 30 years' experience making and selling honey (the profits provide student scholarships). As an academic, he studies human dynamics, relating our behaviour to hive-based interactions and communications. This is clearly a recipe for a unique and informed perspective, and Winston doesn't fail us. He writes lovingly of the rhythms and quiddities of the apiary.

The reasons and repercussions of global losses of entire honeybee hives to *Varroa* mites and colony collapse disorder are looked at from multiple perspectives. Winston considers

how the collateral effects of our environmental abuse swung round to bite us in a society-wide soft spot – the need for bees to pollinate many of our crops.

And then there are all the honey cultures to explore: from makers of artisanal honeys who capture flavour snapshots of a particular time and place, to toxin-tainted honeys from the murkier corners of the globe, and commercial providers who have been known to lace honey with corn syrup.

In a highly personal style, Winston steps between reportage, scientific exactitude and a deep, poetically expressed love of bees, beekeeping and the cultural forms that bees inspire. People and bees have been working together for millennia – a synergy that Winston, sensitised by his work as a communications specialist, clearly feels brings out the best and the worst in humanity. His take on the situation makes *Bee Time* an insightful delight. ■

Adrian Barnett is a rainforest ecologist at Brazil's National Institute of Amazonian Research in Manaus



HEIDI & HANS / JÜRGEN KOCH/MINDENPICTURES

A mystery to savour

Losing our sense of smell can blunt our emotions, but it inspires moving art, finds **Mick O'Hare**

Anosmia: Lives Without a Sense of Smell by Éléonore de Bonneval, Kenzo Parfums showroom, Paris
17 to 21 September. European and US tour in 2015

WHEN an aroma drifts your way, are you ever transported to childhood, maybe to a specific room or place? Have you any idea why or how that happens? What if it never happened?

More than 1 in 20 people have an olfactory disturbance, from anosmia – no sense of smell at all – through phantom smells to sensing aromas that are horribly distorted. UK-based photojournalist Éléonore de Bonneval explores our relationship with our olfactory systems in a multi-sensory exhibition, which concluded recently and is travelling around Europe and the US in 2015.

There are three parts to the exhibition. In the first, de Bonneval worked with Scentsy, a French firm that specialises in perfuming public and commercial venues. As visitors approach a series of unlabelled cylinders, Scentsy's diffusion system releases a series of aromas: these range from a public lavatory, through baby products, to cut grass and other aromas of everyday life.

In the second room, visitors are invited to match what they smelled to de Bonneval's images of mundane yet visually arresting items such as a pile of pencil shavings or the Paris Metro. This is unnervingly hard to do.

"What is interesting with any odorant is its ability to convey

emotion," says Evelyne Boulanger, a perfumer at German company Symrise who is collaborating with de Bonneval. "People with no sense of smell are detached from this mental faculty."

This point is explored in the exhibition's third space, a large greenhouse hung with photographs of people who live without a sense of smell, or with distorted olfaction. The captions accompanying the photographs are deeply emotive: one subject is depressed that they will never smell a flower again; another is painfully aware of never having experienced the aroma of fresh bread. The greenhouse setting echoes the sentiments of a subject who lost their sense of smell following a head injury, and describes life since the accident as "like looking through a window".

Neuroscientist Arnaud Aubert at the University of Tours in France says people with anosmia are prone to depression. "Loss of

smell deprives the limbic system of some of its sensory input," he says, "and this can lead to emotion-related disorders."

Marisa Denos, a neuropsychologist at Pitié-Salpêtrière Hospital in Paris, has developed odour-memory workshops for patients with neurological disorders. She is now collaborating with de Bonneval

"Someone who lost their sense of smell after a head injury describes life as like looking through a window"

on interactive elements for the exhibition's forthcoming tour. She says that the experience of being transported to a childhood memory by an odour relies, oddly enough, on the elusiveness of that odour. A smell that is easily identified is not a powerful memory trigger.

"When we attempt to recognise an odour, our hippocampus is

activated," Denos says. "That's the same region that's activated when we memorise or retrieve personal information." People with Alzheimer's exhibit a general memory loss, hippocampal dysfunction and impaired odour memory, suggesting that this brain region is important for the memory of smells, past events and the link between them, she says.

"I wanted to discover what life is like without smell; its link with emotions, food, social life and the world around us," says de Bonneval. Her show distorts the world in subtle ways: gallery-goers leave her rooms mildly confused, but also enlightened.

Shattering the link between odour and memory can, we discover, bring people great unhappiness. De Bonneval gives us just a hint of what that shattering must be like, makes smell a little bit mysterious – and makes us aware of the potential tragedy of its passing. ■



ÉLÉONORE DE BONNEVAL

An everyday miracle, but you don't know what you've got until it's gone



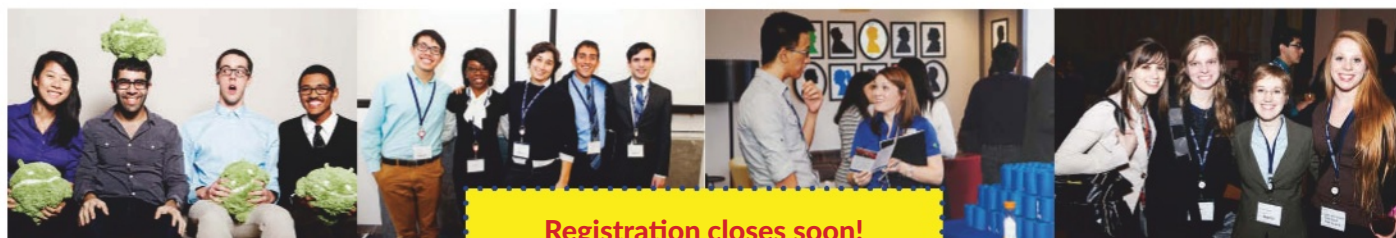
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IOWA STATE UNIVERSITY

The Roy J. Carver Department of Biochemistry, Biophysics and Molecular Biology at Iowa State University in Ames, IA has embarked on a transformational expansion of its structural biology research enterprise through a large philanthropic gift from the Roy J. Carver Charitable Trust. This major research initiative in Biomolecular Structure includes long term investment in new instrumentation, endowed funds for graduate student training, and a series of new faculty hires working at the forefront of any aspect of structural biology.

As part of the faculty positions associated with this initiative, and as part of the interdisciplinary effort across the Iowa State University campus to expand structural biology research, the Department seeks two new tenure-track Assistant Professors to establish vibrant, externally funded research programs of international prominence and participate in graduate and undergraduate teaching.

Applicants should have a PhD or equivalent degree and research accomplishments indicative of the ability to establish an independent research program of national prominence.

To view the entire vacancy #140747 and apply, create an electronic application at <https://pa139.peopleadmin.com> or <http://www.iastatejobs.com>



To guarantee consideration the applications must be received by
November 15, 2014.

Iowa State University is an EO/AA employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, or protected Vets status.

Opportunities for Informatics Research at

HARVARD MEDICAL SCHOOL

The Biomedical Informatics Research Training (BIRT) Program is a consortium of leading informatics laboratories at Harvard. It is supported by a grant from the National Library of Medicine, National Institutes of Health. For United States citizens and permanent residents, this post-doctoral fellowship provides stipend, tuition, and travel funds. Selected fellows are provided with many opportunities for training, research, interaction, and collaboration. All fellows also pursue the two-year Harvard Medical School Biomedical Informatics MMSc.

The MMSc is a post-doctoral degree program that consists of course work and mentored research. Fellows in our program choose from one of four possible tracks: Bioinformatics; Clinical Informatics; Imaging Informatics; and Population Health Informatics.

To learn more, visit: informaticstraining.hms.harvard.edu/

In addition to the BIRT program, the Center for Biomedical Informatics (CBMI) offers a number of other training and research opportunities.

For more information about our programs, contact
Aimee Doe, Program Coordinator, at Aimee_Doe@hms.harvard.edu



POSTDOCTORAL POSITION – acute lung injury

Postdoctoral position available within a pulmonary research group to study mechanisms of lung injury and epithelial repair. Projects include studying chemokine receptors, focal adhesion kinase, cell migration, and protein-protein interactions in the context of acute lung injury and mechanobiology. Experience with cell culture, molecular biology, animal models of lung injury, mechanical ventilation, fluorescence microscopy, and pulmonary physiology are desirable.

Required qualifications include a PhD or MD in a related field and good communication and writing skills.

Send curriculum vitae and names and addresses of 3 references to Dr. Christopher M. Waters, PhD, Professor and Vice Chair, Department of Physiology, University of Tennessee Health Science Center, 894 Union Avenue, Memphis, TN 38163, USA. cwaters2@uthsc.edu. <http://physio1.uthsc.edu/~watersc/index.php>

The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA employer.

Berkeley

Department of Chemistry
UNIVERSITY OF CALIFORNIA Faculty Position in Chemistry

The Department of Chemistry at the University of California, Berkeley invites applications for one faculty position at the assistant professor level with an expected start date of July 1, 2015. Preference will be given to candidates in the broadly defined fields of experimental physical chemistry, analytical chemistry, and inorganic chemistry. However, we will consider creative and energetic candidates who show extraordinary promise or accomplishment in research and teaching in any area of chemistry. The basic qualification for this position is the completion of all Ph.D. or equivalent degree requirements in Chemistry or a related field except the dissertation at the time of application. A Ph.D. or equivalent degree in Chemistry or a related field is required by date of hire.

All applicants should submit their most recently updated curriculum vitae and a statement of research and provide at least three but no more than five letters of recommendation. A cover letter and a statement of teaching are optional. Applications should be submitted electronically through our web-based system at: <https://aprecruit.berkeley.edu/apply/JPF00537>.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (<http://apo.berkeley.edu/evaltr.html>) prior to submitting their letters.

The deadline for receipt of application material is November 3, 2014. Please direct questions to Lauren Nakashima (lnakashima@berkeley.edu).

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: <http://policy.ucop.edu/doc/4000376/NondiscrimAffirmAct>.

UC Berkeley is committed to diversity in all aspects of our mission and to addressing the family needs of faculty, including dual career couples and single parents.

For more information on
courses and further education
opportunities please go to
www.NewScientistStudy.com

NewScientist Jobs



Faculty Position

University of Pittsburgh Cancer Institute and Department of Pharmacology & Chemical Biology

Applications are invited for a tenured faculty position at the level of Associate Professor at the University of Pittsburgh Cancer Institute (UPCI). Candidates who have a PhD, MD or equivalent graduate degree are being recruited to expand expertise in cancer biology and treatment. The incumbent will have primary appointment in the Department of Pharmacology & Chemical Biology, University of Pittsburgh School of Medicine (UPSOM).

The UPCI has consistently been among the top NCI-funded and NCI-designated Comprehensive Cancer Centers located within the academic environment of the University of Pittsburgh and University of Pittsburgh Medical Center and has an active and highly interactive community of basic, translational and clinical research scientists. The institution has several state-of-the-art facilities with varied capabilities including cell and tissue imaging, high-throughput drug discovery and a cancer biomarkers facility with mass spectrometry, genomics and proteomics platforms.

In order to develop an outstanding, extramurally-supported research program, the applicants must have excellent communication skills, publications in high-impact journals and a proven track record of extramural funding.

The incumbent will have the opportunity to mentor graduate students through the Department of Pharmacology and Chemical Biology and UPSOM Integrated Biomedical Graduate Program and will have progressive involvement in the teaching of graduate and medical students. Salary and benefits will be commensurate with experience.

Interested candidates should send curriculum vitae, brief description of research interests and contact information for three references to:

UPCI Search Committee/Pharmacology
Dr. Maryann Donovan
Associate Director for Research Administration, UPCI
C/O Lola Thompson
5150 Centre Avenue, Suite 532, Pittsburgh, PA 15232
Email : thompsonla3@upmc.edu

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UNIVERSITY OF WISCONSIN-MADISON

Assistant Professor of Chemistry

The Department of Chemistry of the University of Wisconsin-Madison anticipates an opening for a faculty position to begin in August 2015. We seek outstanding candidates at the Assistant Professor level (tenure track) in all areas of chemistry; candidates with research interests in organic chemistry are particularly encouraged to apply. The position requires development of an internationally recognized program of scholarly research as well as excellent teaching at both the undergraduate and graduate levels. Please submit a curriculum vita and concise description of research plans on-line at www.facrecruit.chem.wisc.edu. Three letters of recommendation will also be required through the on-line service directed to: Chair, Faculty Search Committee, Department of Chemistry, University of Wisconsin-Madison, 1101 University Ave., Madison, Wisconsin 53706-1322. To guarantee full consideration, all materials must be received by October 31, 2014. Please reference PVL 80879.

The University of Wisconsin is an equal opportunity affirmative action employer; applications from qualified women and minority candidates are encouraged. Unless confidentiality is requested in writing, information regarding the identity of the applicant must be released on request. Finalists cannot be guaranteed confidentiality. A background check may be required prior to employment.



UNIVERSITY OF UTAH
HEALTH SCIENCES

University of Utah Huntsman Cancer Institute Department of Oncological Sciences

The Department of Oncological Sciences and Huntsman Cancer Institute (HCI) invite applications for a tenure-track faculty position at the **assistant or associate professor** level. We seek an outstanding cancer biologist with a program focused in **genomics/genome sciences**. The ideal candidate develops genome-wide assays and/or analysis approaches that utilize high-throughput sequencing to make novel biological discoveries. Areas of interest include gene regulation, epigenetics, RNA biology, cancer genetics, somatic mutation analysis, or the use of genomics in cancer diagnostics. Requirements include a PhD or MD/PhD, experience analyzing genome-scale datasets, and a track record of scientific excellence. Departmental strengths include transcriptional regulation, epigenetics, human cancer genetics, stem cell biology, mouse and zebrafish models of cancer, cell signaling pathways, apoptosis, DNA repair, cell motility and cancer metabolism. HCI is an NCI-designated cancer center with state-of-the-art laboratories and shared resources, including core facilities for imaging, genomics, drug screening and in vivo testing, and population studies. We offer a collegial and interactive research environment that fosters the development of junior faculty and robust graduate programs for training PhD and MD/PhD students.

Inquiries may be submitted to Recruitment Director at hci.recruitment@hci.utah.edu

Please apply by November 10, 2014 at the following link:
<http://utah.peopleadmin.com/postings/35110>

The University of Utah Health Sciences Center is a patient focused center distinguished by collaboration, excellence, leadership, and Respect. The University of Utah HSC values candidates who are committed to fostering and furthering the culture of compassion, collaboration, innovation, accountability, diversity, integrity, quality, and trust that is integral to the mission of the University of Utah Health Sciences Center.

The University of Utah is an Affirmative Action/Equal Opportunity employer and does not discriminate based upon race, national origin, color, religion, sex, age, sexual orientation, gender identity/expression, status as a person with a disability, genetic information, or Protected Veteran status. Individuals from historically underrepresented group, such as minorities, women, qualified persons with disabilities and protected veterans are encouraged to apply. Veterans' preference is extended to qualified applicants, upon request and consistent with University policy and Utah state law. Upon request, reasonable accommodations in the application process will be provided to individuals with disabilities. To inquire about the University's nondiscrimination or affirmative action policies or to request disability accommodation, please contact: Director, Office of Equal Opportunity and Affirmative Action, 201 S. Presidents Circle, Rm 135 (801) 581-8365.

The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a demonstrated commitment to improving access to higher education for historically underrepresented students.



University of Pittsburgh

The Department of Pediatrics of the University of Pittsburgh School of Medicine is seeking faculty for clinical programs, biomedical and health sciences research programs.

Opportunities are available in the following subspecialties:

Adolescent Medicine	Gastroenterology
Allergy	General Academic Pediatrics
Bone Marrow Transplantation	Hematology/Oncology
Cardiology	Infectious Diseases
Child Advocacy	Newborn Medicine
Child Development	Neurology
Hospitalists	Pulmonology
Emergency Medicine	Rheumatology
Endocrinology	

Assistant, Associate or Professor positions in tenure or non-tenure tracks at the University of Pittsburgh with rank and salary commensurate with experience and academic credentials

Positions are open to all applicants who hold doctoral level education (MD, DO, PhD), are board certified or board eligible, are qualified for medical licensure in the Commonwealth of Pennsylvania and meet the minimum position credentials.

Interested candidates should forward their CV to rebecca.longo@chp.edu and indicate the position of interest.

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RADCLIFFE INSTITUTE
FOR ADVANCED STUDY
HARVARD UNIVERSITY

Academic Fellowships

The Radcliffe Institute Fellowship Program at Harvard University welcomes fellowship applications in natural sciences and mathematics. The Radcliffe Institute for Advanced Study provides scientists the time and space to pursue their career's best work. At Radcliffe you will have the opportunity to challenge yourself. Meet and explore the work of colleagues in other fields. Take advantage of Harvard's many resources, including the extensive library system. Radcliffe Institute Fellowship Program invites applications from people of all genders, and from all countries. We seek to build a diverse fellowship program.

Scientists in any field who have a doctorate in the area of the proposed project (by December 2013) and at least two published articles or monographs are eligible to apply for a Radcliffe Institute fellowship. The stipend amount of \$75,000 is meant to complement sabbatical leave salaries of faculty members. Residence in the Boston area and participation in the Institute community are required during the fellowship year.

Applications for 2015-2016 are due by November 1, 2014.

For more information, please visit www.radcliffe.harvard.edu
or email sciencefellowships@radcliffe.harvard.edu.

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Washington University School of Medicine, St. Louis, MO

Department of Biomedical Engineering
Department of Cell Biology and Physiology

Postdoctoral Position in Ion Channel Dysfunction in Autism

POSTDOCTORAL POSITION focusing on synaptic dysfunction in autism spectrum disorders using cutting-edge electrophysiological measurements is available at Washington University School of Medicine, St. Louis, MO. Position is fully funded for at least 3 years with an option to extend for additional fully funded 1-2 years.

Research in this position will rely extensively on patch-clamp measurements, with emphasize on biophysical studies at single-channel level, to study the molecular mechanisms of excitability defects in a mouse model of Fragile X syndrome, the leading genetic cause of autism.

Applicants with extensive experience in single-channel recordings are particularly encouraged to apply.

More information can be found on the lab website:
www.klyachkolab.wustl.edu

Qualified applicants are expected to hold a doctoral degree in neuroscience, biophysics, physics, or biomedical engineering, and have extensive experience in electrophysiology and familiarity with MATLAB programming. Trainee will work in a highly interactive multidisciplinary research environment at Washington University, which has been consistently ranked among the top five Medical Schools in the country. Highly competitive salary and benefits are available and will commensurate with experience.

Interested applicants should provide their CV and the names of two/ three references via email to:

Vitaly Klyachko, PhD
Assistant Professor
Department of Biomedical Engineering
Department of Cell Biology and Physiology
Washington University School of Medicine
E-mail: klyachko@wustl.edu
Website: www.klyachkolab.wustl.edu



Monterey Bay Aquarium Research Institute

2015 POSTDOCTORAL FELLOWSHIP PROGRAM

Applications for the postdoctoral fellowship program at the Monterey Bay Aquarium Research Institute (MBARI) are currently being accepted. MBARI is dedicated to the development of state-of-the-art instrumentation, systems, and methods for scientific research in the oceans. Ongoing programs in marine robotics, ocean physics, chemistry, geology, and biology as well as information management and ocean instrumentation research and development exist at MBARI. Located in Moss Landing, California at the head of Monterey Canyon, MBARI enjoys convenient access to diverse oceanographic environments. The institute operates research vessels equipped with remotely operated vehicles, autonomous underwater vehicles, and diverse oceanographic equipment. In addition, MBARI operates the MARS seafloor cabled observatory. MBARI is a non-profit oceanographic research institute supported by the David and Lucile Packard Foundation.

Offers will be made to candidates from the fields of biological, chemical, and physical oceanography; marine geology; and ocean engineering. Candidates must be awarded the Ph.D. degree prior to commencing the two-year appointment and start during the 2015 calendar year. Applicants are encouraged to communicate with potential research sponsors at MBARI for guidance on project feasibility, relevance to ongoing research projects, and resource availability (http://www.mbari.org/about/postdoc_mentors.htm).

Application deadline: Wednesday, December 10, 2014

Selected candidates will be contacted in early March 2015.

Application requirements:

1. Curriculum vitae
2. At least three professional letters of recommendation
3. Succinct statement of the applicant's doctoral research
4. Potential research goals at MBARI
5. Supplemental information online form (http://www.mbari.org/oed/jobs/forms/postdoc_form_2015.htm)

Address your application materials to:

MBARI, Human Resources

Job code: Postdocs-2015

7700 Sandholdt Road, Moss Landing, CA 95039-9644

Submit by e-mail to jobs_postdocs@mbari.org (preferred), by mail, or by fax to (831) 775-1620.

EOE

MBARI Welcomes Diversity

MBARI is an equal opportunity and affirmative action employer. MBARI considers all applicants for employment without regard to race, color, religion, sex, national origin, age, disability, or covered veteran status in accordance with applicable federal, state, and local laws.

Competitive compensation and benefits package.

UAB THE UNIVERSITY OF ALABAMA AT BIRMINGHAM



Postdoctoral Positions

The University of Alabama at Birmingham (UAB) is one of the premier research universities in the US with internationally recognized programs in AIDS & bacterial pathogenesis, bone biology & disease, cancer, diabetes & digestive & kidney diseases, free radical biology, immunology, lung disease, neuroscience, trauma & inflammation, and basic & clinical vision science among others. UAB is committed to the development of outstanding postdoctoral scientists and has been consistently ranked in recent years as one of the top locations among US universities for training postdoctoral scholars.

UAB is recruiting candidates for postdoctoral positions in a variety of research areas. UAB faculty are well funded (top 25 in NIH funding), utilize multidisciplinary approaches, and provide excellent research training environments that can lead exceptional candidates to entry level positions in academia, government or the private sector. Full medical coverage (single or family), competitive salaries/stipends, sick leave, vacation, and maternity/paternity leave are offered with every position as well as AD&D, disability & life insurance. Depending on the source of funding, retirement benefits may also be available. Birmingham is a mid-size city centrally located in the southeast near beaches and mountains and enjoys a moderate climate for year round outdoor activities and a cost of living rate lower than most metropolitan areas.

Visit our website at www.postdocs.uab.edu, **Openings**, to view positions. See info also on MERIT Program, an NIH IRACDA program. Send your CV to the contact name for the positions that you are interested. University of Alabama at Birmingham, Office of Postdoctoral Education, 205-975-7020.

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Fellowships for Postdoctoral Scholars

Woods Hole Oceanographic Institution



New or recent doctoral recipients with research interests associated with the following are encouraged to submit scholarship applications prior to January 5, 2015.

Departments - Awards related to the following areas are anticipated: Applied Ocean Physics & Engineering; Biology; Geology & Geophysics; Marine Chemistry & Geochemistry; Physical Oceanography; and in cooperation with the USGS laboratory located on the WHOI campus.

Institutes - Each Institute fosters interdisciplinary research addressing critical issues, and we will award a scholarship to support related research: Ocean and Climate Change Institute; Coastal Ocean Institute; Ocean Exploration Institute; Ocean Life Institute.

The Center for Marine and Environmental Radioactivity (CMER) will award a fellowship for research on natural and human-made radioactive substances in the environment including the study of their sources and fate or use as tracers of ocean processes.

Awards are competitive, with primary emphasis placed on research promise. Scholarships are 18-months with an annual stipend of \$58,000, a research budget and eligibility for health and dental insurance. Recipients are encouraged to pursue their own research interest in association with resident staff. Communication with potential WHOI advisors prior to submitting an application is encouraged.

Further information may be obtained at:

www.whoi.edu/postdoctoral

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WHILING away half an hour after the rigmarole to get on to the Eurostar train in Brussels, Feedback resorted to the internet. Of course we were asked to "accept and understand the terms and conditions" of the Wi-Fi service. Unlike almost every user, and having only an economics journal for non-electronic diversion, we decided to read these. All 1676 words.

And what's this? "You declare, at your own cost, to defend and protect 10SA HOTSPOTS, and all its branch offices, employees and directors, against any costs, damages and legal costs resulting from any damage claims made through the use of the Services which may have violated the rights of any third party or any law."

Any law? This reminds us of photographers' reports that *The Scotsman* newspaper required them not to breach "any law of any country" - when photography was illegal in Afghanistan.

Rereading those terms with our pedant-meter turned up to 11, we discovered that we appear to be liable only if the way a claim was made violates a right or law - not necessarily for its content. So we lied when we said we understood. Our relief is tempered by the further realisation that by clicking on the dotted line, we accepted "any future versions" of the conditions: who knows what they may turn out to be?

TERMS and conditions like those discussed above tempt Feedback towards the policy adopted by a mathematical physicist of our acquaintance. This entails setting up a system to automatically delete all emails that end with alleged contracts asserting, "by reading this you agree..." Our friend reasons that understanding such alleged agreements is above their pay grade - which is now

professor, despite the difficulty that their university's Human Resources department may have had getting in touch with them.

POSSIBLY, just possibly, the above terms and conditions were an example of Belgian humour, which appreciates the surreal nearly as much as does this column. They were, however, trumped by the security researchers who gained wide coverage for setting up a sham public Wi-Fi service and persuading six Londoners to sign away their firstborn child in return for internet access. Their company headquarters are in Helsinki and their "Herod clause" is consistent with some of the Finnish humour we have heard.

ARRIVING at London's lovely St Pancras Station, after that journey from Brussels spent studying terms and conditions, Feedback was bashfully approached by a young person in a branded tabard who muttered "hydration tablets". They thrust into our hand a small sachet that, by feel, contains two quite dry tablets.

This appears to be the closest we have come to dehydrated water, a substance whose marketing has intrigued Feedback since at least 10 May 2003. Well done, Clinova of Southampton for selling 44 grams of glucose and a pinch of salts and flavour for £6.99. We rapidly found straight glucose on sale at £5.98 a kilo - one-twenty-seventh the price.

THE much-publicised Apple watch will undoubtedly play many modern tricks (20 September, p 22). But an old-style engineer known to Feedback is puzzled by how it will tell the time.

At the launch, Apple boss Tim Cook stood in front of a giant image of the watch. Its face showed the time as exactly 10.09. But the second hand was very precisely on 6, and thus a full 30 seconds out of sync with the minutes.

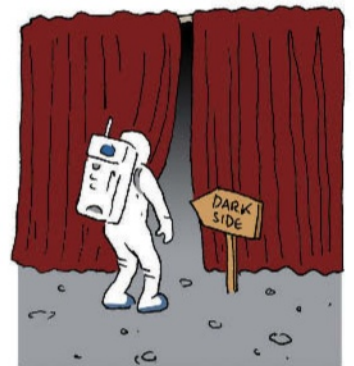
Then we looked at an advert for a very pricey non-Apple watch. It had the same issue. So are the ritzier watch hands no longer geared to

show where we are in the continuum of time? Are they now merely a quasi-analogue representation of digital time?

Feedback plans soon to revisit the corridor at Geneva airport that is decorated entirely with images of improbably expensive watches. We plan to take photos to analyse their displays. If we suddenly disappear, please make representations to the Swiss airport security service to help explain that our intentions were entirely scientific.

FINALLY, Danny Collins reminds us of another strange feature of watch marketing. Omega has run many ads for its Speedmaster watch, as famously used by the Apollo astronauts.

The ads' slogan is "The Dark Side of the Moon". As Danny explains in some detail, what the Apollo astronauts saw was the far side of the moon: there is no such thing as "the dark side".



After attracting even stranger looks than usual by shunting a mango, an avocado and a tomato around the kitchen table to represent the celestial bodies, we see his point. So is this a watch with non-existent attributes? Or will it keep time with the rotation of the avocado round the mango?

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.

Andrew Doble sends a photo of a pot of maraschino cherry yogurt "with other natural flavours". So is the lurid maraschino totally innocent of brine, colouring and glucose syrup?

Furry berry

My 6-year-old daughter Victoire wants to know why raspberries are covered with little hairs, unlike other berries.

■ The hairs on raspberries are the remains of the female parts of the raspberry flower, which have not fallen away. In the flower, the female hair-like styles are collected in the centre with the male anthers arranged around the edge. Each style, topped by a stigma, is connected to one ovary, forming a pistil.

After pollination, the petals, anthers and other parts of the flower wither away, and each ovary swells to produce a segment



Bugging the forest

I found this creature on the forest floor, on the Carp Ridge in Ontario, Canada (see photo). It was about 4 millimetres long. It didn't appear to be moving, but I took it home and left it on a plastic dish with some leaves and water for sustenance. When I checked a few hours later, it had disappeared. What was it?

■ The image is of a crowned slug caterpillar (*Isa textula*). It is a widespread species found across North America. Although the caterpillar is impressive, the moth it hatches into is pale brown and much less remarkable.

In its caterpillar stage, it feeds off a range of tree species, including oak and elm. The caterpillar should be handled with care because it has spines that can sting.

"Each segment of a raspberry is a drupelet. The entire collection of these is known as a drupe"

of the final fruit. Each of these segments is, botanically speaking, a drupelet, and a raspberry is a drupe (a collection of these segments) rather than a berry.

The plants that I grow in my garden often have raspberries at all stages of development, from flower bud to ripe fruit, so the full cycle can be seen clearly throughout the same plant.

In fact, raspberries are very easy to grow, and very productive, but you do need to take steps to contain them.

Dylan Brewis
London, UK

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submitted by readers in any medium or in any format and at any time in the future.

Send questions and answers to The Last Word, New Scientist, Lacon House, 84 Theobald's Road, London WC1X 8NS, UK, by email to lastword@news scientist.com or visit www.news scientist.com/topic/lastword (please include a postal address in order to receive payment for answers). Unanswered questions can also be found at this URL.

In North America, such moths are known as slug moths because of the slug-like appearance of the caterpillar. There are only a few species in Europe, in particular the festoon moth, *Apoda limacodes*.

"Although this caterpillar is impressive, the moth it hatches into is pale brown and much less remarkable"

Apoda means without feet.

The species pictured appears to be the crowned slug caterpillar. It seems, too, that your correspondent did not handle it, otherwise I'm sure they would have noted that this insect is armed with stinging spines. The species is present in the eastern part of the US, up to southern Ontario in Canada.

Caterpillars are often found in the process of moulting, when they cease feeding for a time and settle down to shed their skin. This caterpillar's legs are hidden underneath its body so, unconstrained as it was, it simply wandered off. Had it been kept in a suitable mesh cage, it might have been possible to rear it.
Terence Hollingworth
Blagnac, France

It is likely that the creature ignored the water provided for it because there should be enough moisture in the leaves it eats. As for the leaves provided, they may have been of the wrong species or slightly wilted. As a result, the caterpillar probably moved on looking for better foliage to eat. It seems this individual was in its early stages as a caterpillar – a full-sized version is around 15 millimetres long.

Peter Scott
Hove, East Sussex, UK

■ Although I've never been to the New World, I immediately recognised the creature in the picture as a caterpillar of the family Limacodidae. At 4 millimetres long, it appears to have been an early instar, since a fully developed caterpillar of this species would have been at least four times that length.

This week's question

A COLD FRONT

I've noticed that when showering, water falling on my back feels hotter than on my front. Why?

Tony Sandy
Kilmarnock, Ayrshire, UK

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