NewScientist
WEEKLY 23 July 2011

THE EXISTENTIAL ISSUE

The staggering mysteries of being
(and how to cope with them)

HOW COULD OUR COSMOS HAVE COME FROM NOTHING?
WHY IS THE UNIVERSE JUST RIGHT FOR LIFE?
ARE WE UTTERLY ALONE?
WHAT'S THE ORIGIN OF MY CONSCIOUSNESS?
HOW DO I KNOW THAT EVERYBODY ELSE ISN'T A ZOMBIE?
AM I A HOLOGRAM?
HOW DO I EVEN KNOW I EXIST?
WILL HUMANS EVOLVE INTO ANOTHER SPECIES?
ARE THERE PARALLEL UNIVERSES?
HOW WILL IT ALL END?

Introduction by
Stephen Hawking

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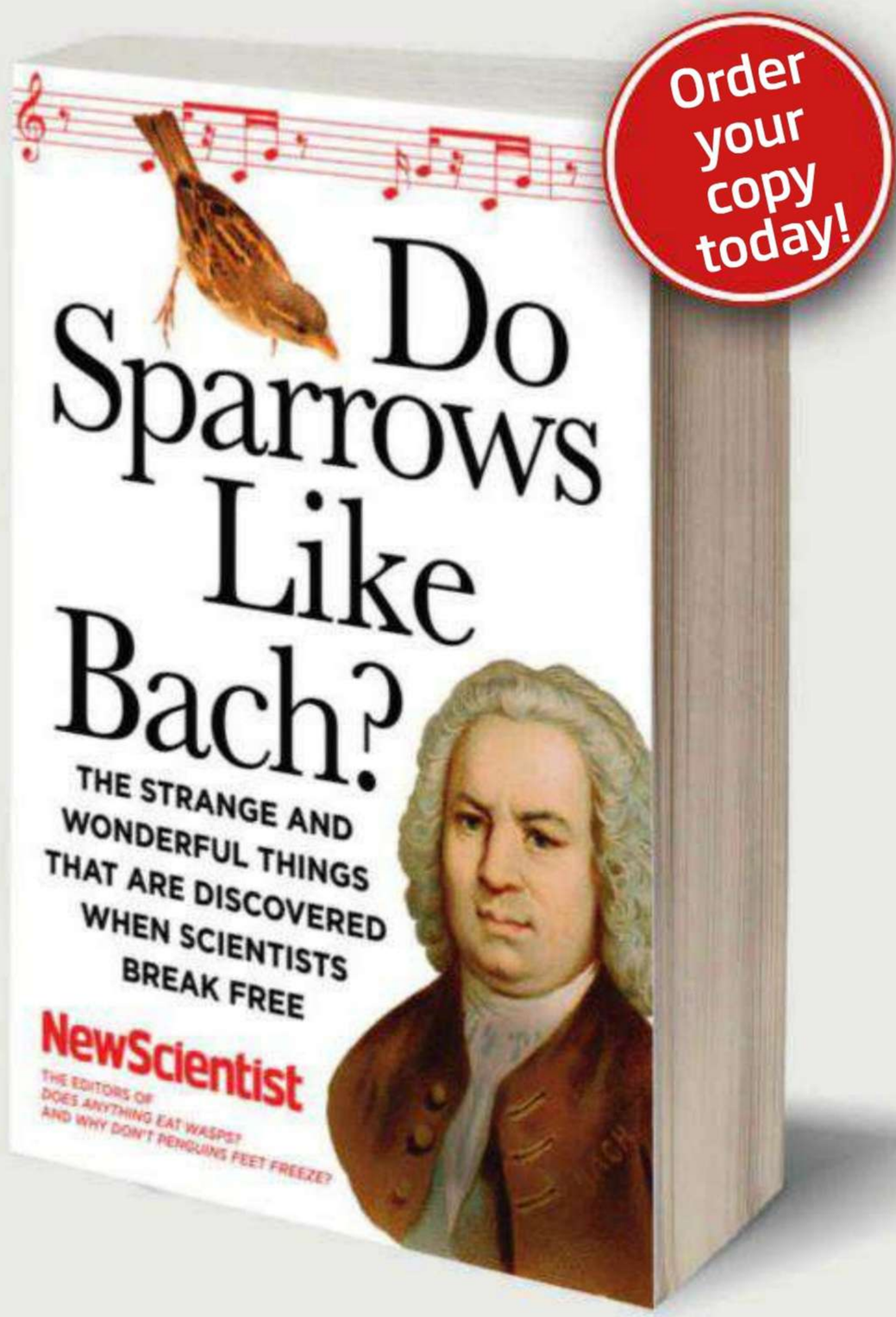
Do Sparrows Like Bach?

Ever wondered what happens if scientists were to break free? The latest book from New Scientist delves into the strange and wonderful things that happen when scientists are let loose!



Anything from producing a fireproof umbrella that doubles as a parachute to using 'glow-in-the-dark' toothpaste to reflect the headlights of oncoming cars, 'Do Sparrows Like Bach?' is an extraordinary collection of scientific endeavor and is a brilliant reminder that even at its most misguided, science is intensely creative, often hilarious, and can fire imagination like nothing else!

Available in stores and online at Amazon.com

NewScientist

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Where did we come from?

There is only one way to find the answer, says Stephen Hawking

WHY are we here? Where did we come from? According to the Boshongo people of central Africa, before us there was only darkness, water and the great god Bumba. One day Bumba, in pain from a stomach ache, vomited up the sun. The sun evaporated some of the water, leaving land. Still in discomfort, Bumba vomited up the moon, the stars and then the leopard, the crocodile, the turtle, and finally, humans.

This creation myth, like many others, wrestles with the kinds of questions that we all still ask today. Fortunately, as will become clear from this special issue of *New Scientist*, we now have a tool to provide the answers: science.

When it come to these mysteries of existence the first scientific evidence was discovered about 80 years ago, when Edwin Hubble began to make observations in the 1920s with the 100-inch telescope on Mount Wilson in Los Angeles County.

To his surprise, Hubble found that nearly all the galaxies were moving away from us. Moreover, the more distant the galaxies, the faster they were moving away. The expansion of the universe was one of the most important intellectual discoveries of all time.

"If the early universe had been completely smooth, there would be no stars and life couldn't have arisen"

This finding transformed the debate about whether the universe had a beginning. If galaxies are moving apart now, they must therefore have been closer together in the past. If their speed had been constant, they would all have been on top of one another billions of years ago. Was this how the universe began? At that time many scientists were unhappy with the universe having a beginning because it seemed to imply that physics had broken down.

DIMITRIOS KAMBOURIS/WIREIMAGE/GETTY

PROFILE
Stephen Hawking is the director of research at the Department of Applied Mathematics and Theoretical Physics, University of Cambridge. His next book, written for children with his daughter Lucy Hawking, is *George and the Big Bang*

One would have to invoke an outside agency, which for convenience one can call God, to determine how the universe began. They therefore advanced theories in which the universe was expanding at the present time, but didn't have a beginning. Perhaps the best known was proposed in 1948, and called the steady state theory.

According to this theory, the universe would have existed for ever and would have looked the same at all times. This last property had the great virtue of being a prediction that could be tested, a critical ingredient of the scientific method. And it was found lacking.

Observational evidence to confirm the idea that the universe had a very dense beginning came in October 1965, with the discovery of a faint background of microwaves throughout space. The only reasonable interpretation is that this background is radiation left over from an early hot and dense state. As the universe expanded, the radiation would have cooled until it is just the remnant we see today.

Theory backed this idea too. With Roger Penrose I showed that if Einstein's general theory of relativity is correct, there would be a singularity, a point of infinite density and space-time curvature, where time has a beginning.

The universe started off in the big bang, expanding faster and faster. This is called inflation and it turns out that inflation in the early cosmos was much more rapid: the universe doubled in size many times in a tiny fraction of a second.

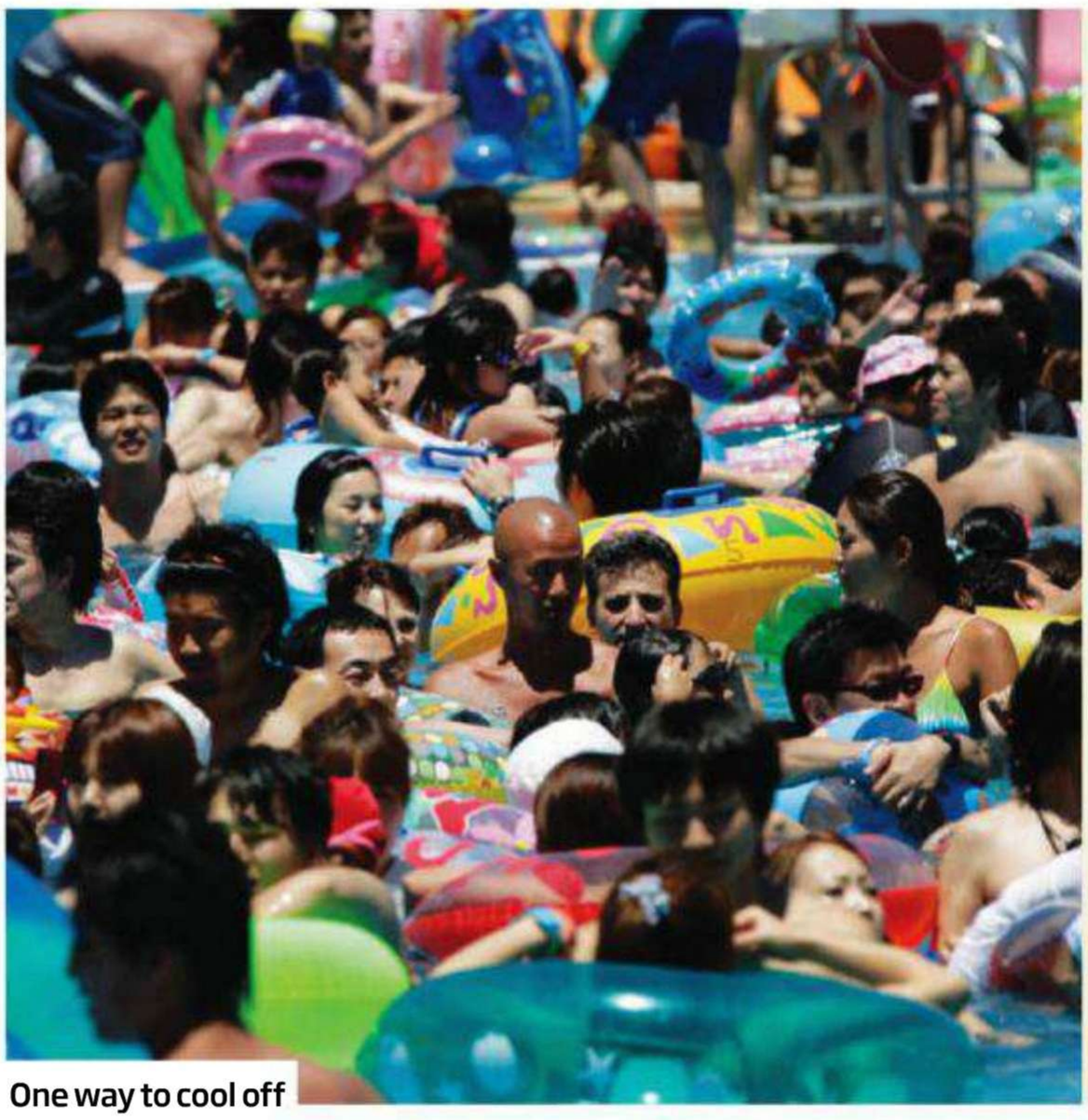
Inflation made the universe very large and very smooth and flat. However, it was not completely smooth: there were tiny variations from place to place. These variations caused minute differences in the temperature of the early universe, which we can see in the cosmic microwave background.

The variations mean that some regions will be expanding slightly less fast. The slower regions eventually stop expanding and collapse again to form galaxies and stars. And, in turn, solar systems.

We owe our existence to these variations. If the early universe had been completely smooth, there would be no stars and so life could not have developed. We are the product of primordial quantum fluctuations.

As will become clear (see page 27), many huge mysteries remain. Still, we are steadily edging closer to answering the age-old questions. Where did we come from? And are we the only beings in the universe who can ask these questions? ■

ITSUO INOUYE/AP PHOTO



One way to cool off

Japan is feeling the heat

EARTHQUAKE, tsunami, nuclear disaster... now heatwave. Across Japan, 35 people have died from heatstroke since June, prompting fears that people are putting their lives at risk by cutting back on air conditioning. With 35 of its 54 nuclear power stations shut down, Japan is struggling to conserve power – and to stay cool in the sweltering summer.

In June the number of people taken by ambulance to hospitals for heatstroke tripled compared with June last year. The number of people taken by ambulance for heatstroke in July is predicted to be up 20 per cent on last year, says Hasegawa Manabu of the Fire and Disaster Management Agency. However, Nobuyuki Miyatake at Kagawa University in Takamatsu says it's unclear whether energy-saving is responsible for the extra deaths, since summer came early this year, with temperatures soaring after 21 June rather than in early July.

Nevertheless, the government is concerned. Last week, prime minister Naoto Kan advised people "to save electricity to the extent that the efforts are reasonable and people do not suffer from heatstroke".

The Japan Meteorological Agency says temperatures this summer are unlikely to match last year's, which were the highest since records began in 1898.

The US is also sweltering in a heatwave, with temperatures predicted at over 45 °C in places. Mostly focused on the Midwest, the heat is heading east with some 40 states expected to be affected.

Wash your hands

MUD may be the least of your worries at festivals across Europe this summer: food poisoning may lie in wait.

The outbreak of a rare strain of *E. coli* in Germany in May seems to have subsided, with no new cases since 11 July, after 3918 people fell ill and 42 died. The outbreak was traced to Egyptian fenugreek seeds used to grow sprouts, a frequent source of food-borne bacteria. The European Union has banned the seeds.

The trouble is that the bacterium has been knocking around Germany for a decade, and may still lurk in people who are symptom-free. Earlier this month German health authorities tested stool samples from a school in Paderborn, where there were four known infections. They found 18 of the 30 children tested carried the strain, but had no symptoms. Worse, three kitchen workers at the school and three at a catering company supplying it were also carriers. The survey continues.

"Fatal *E. coli* has been in Germany for a decade and may still lurk in people who are symptom-free"

This "substantial proportion of subclinical infections is the main reason for concern at this stage", says the European Centre for Disease Prevention and Control in Stockholm, Sweden. "Considering the large number of summer festivals in the EU, with sometimes inadequate food hygiene standards", people should remember "the need for proper hand washing".

Big dish challenge

A RUSSIAN plan to create the world's biggest telescope has finally got off the ground. The RadioAstron space telescope, which was conceived during the cold war, successfully launched from Baikonur cosmodrome in Kazakhstan on Monday.

After it has travelled most of the way to the moon, the 10-metre telescope will sync up with radio antennas on the ground, effectively forming a "dish" spanning almost 30 times the Earth's diameter. That will give it a resolution about 10,000 times better than the Hubble Space Telescope.

But collecting the huge volume of data the telescope will produce will be a challenge. "The data needs to be transported continuously to the ground," says Ken Kellermann, who co-chairs RadioAstron's International Advisory Committee.

So far, only one 22-metre dish in a town south of Moscow has been set up to receive signals. Unless other receiver stations can be found, a good fraction of the telescope's data will be lost.

DANIEL LECLAIR/UPI/EYEVINE

Feelings running high

Impractical law

PARENTS should go to jail if they fail to report the death of their child within 2 hours. That is the proposal gaining support in the US after Casey Anthony, a mother charged with murdering her 2-year-old daughter Caylee, was found not guilty two weeks ago.

Yet scientists approached by *New Scientist* say such a law could not be feasibly upheld.

Much public outrage hinges on the fact that Anthony did not

report her child missing for a month. This would become a felony under the proposed law.

But is it possible to estimate time of death accurately enough soon after a death? "It's very unrealistic," says Ralph BouHaidar, a forensic pathologist at the University of Edinburgh, UK. "We tend to be good at determining time of death in the first 24 to 48 hours, but even then we estimate it plus or minus a couple of hours," he says.

What's more, this estimation is based on research on adults, making it less reliable for children. The proposed law is now under review in over 30 states.

Asteroid ho!

LIKE a Greek siren, the asteroid Vesta has lured the NASA probe Dawn into orbit around it. Yet despite the data the probe will collect, the asteroid will stymie attempts to understand the long-term fate of the solar system.

Dawn slipped into Vesta's orbit on Saturday. For the next year it will study Vesta's topography and composition before heading to a bigger asteroid called Ceres. Vesta has a core, mantle and crust, while Ceres seems to contain a lot of ice. Dawn could help astronomers learn why they are so different.

Meanwhile, Jacques Laskar of the Paris Observatory in France and colleagues have determined that chaotic interactions between Vesta and Ceres affect the orbits of the planets in our solar system. These tugs will prevent us from calculating the planets' paths more than 60 million years in the future (*Astronomy and Astrophysics*, DOI: 10.1051/0004-6361/201117504).

"Interactions between Vesta and Ceres affect the orbits of the planets in our solar system"

Hacks hacked

OF ALL the things we have learned from the News International (NI) hacking scandal, one is how not to choose a password.

On Monday, the hacking group LulzSec gained access to NI servers and redirected the website of *The Sun* newspaper to a fake news story claiming proprietor Rupert Murdoch had been found dead. The group also released email and password details for a number of NI staff, including former CEO Rebekah Brooks.

Sabu, the key LulzSec figure interviewed by *New Scientist*, tweeted what appear to be the login details for Brooks's email account when she was editor of *The Sun*, and known as Rebekah Wade. The password given was 63000, which is the number of *The Sun*'s text message tipline and is prominently displayed on the newspaper's website.

LulzSec cracked the passwords because they were poorly encrypted – stored as an MD5 hash, a cryptographic algorithm that the US Department of Homeland Security has dubbed "broken and unsuitable for further use". When encrypting data, it is combined with another value, called the salt, which should be random but in this case seems to have been rather easy to guess: "rebekah".

Ships set sail for a greener future

THE shipping industry is sailing against the tide by introducing global mandatory carbon dioxide standards – an industrial first. But the deal, agreed last week, applies only from 2019 – and there are no plans to extend the rules to existing ships.

The agreement reached at the UN's International Maritime Organization comes after years of negotiations. It is a rare step forward for climate negotiators at a time when an overall deal on global carbon emissions looks ever more remote.

The deal requires all new ships above 400 tonnes and delivered after 2015 to improve their energy efficiency by 10 per cent. The target rises to 30 per cent by 2024. However, developing nations can apply for a waiver until 2019.

The IMO said that if no waivers applied, the deal could reduce emissions by between 45 and 50 million tonnes a year by 2020. But a coalition of environmental groups, the Clean Shipping Coalition, warned the agreement may result in new ships registering with countries that get a waiver.

Peter Boyd, CEO of the Carbon War Room, an NGO set up by entrepreneur Richard Branson to find "gigatonne-scale emissions reductions", said the "real prize" was extending efficiency improvements to the world's existing 60,000 ships. They emit almost a billion tonnes of CO_2 a year, around 3 per cent of total human-induced emissions.

PAUL TAYLOR/STONE/GETTY

Emissions to be contained

60 SECONDS

Moon's new moons

A pair of probes designed to study Earth's auroras are now circling the moon. Mission controllers sent them there after they finished their original mission in Earth orbit. One entered lunar orbit on 27 June and the other arrived on 17 July. Now called ARTEMIS, the two spacecraft will study the moon's tenuous atmosphere and the solar wind's interactions with the lunar surface.

Steer clear, y'hear?

Passive smoking significantly increases teenagers' risk of hearing loss. A study of over 1500 American teens aged 12 to 19 suggests that exposure to second-hand tobacco smoke can cause infection and damage blood vessels in the ear (*Archives of Otolaryngology – Head and Neck Surgery*, DOI: 10.1001/archoto.2011.109).

Deep-sea dozen

The British Antarctic Survey has discovered a chain of 12 new volcanoes beneath the Southern Ocean. Some are as large as Mount Etna and seven are still active today, the BAS team told the International Symposium on Antarctic Earth Sciences in Edinburgh, UK, last week.

Light-bulb moment

Proposals to phase out incandescent light bulbs in the US in favour of more efficient ones have been derailed by a House of Representatives vote to withhold funding for the plans. The bulbs may waste 90 per cent of the power they consume as heat, but they are much cheaper, argue Republican representatives.

Radioactive Earth

Ghostly subatomic particles spewing from Earth's interior have enabled the most precise measurement of its radioactivity yet. These antineutrinos suggest that about half of Earth's heat – 20 terawatts – comes from the radioactive decay of uranium and thorium (*Nature Geoscience*, DOI: 10.1038/ngeo1205).

Daily pill can end HIV epidemic

Antiretroviral drugs are poised to transform HIV from a global killer into a rare disease

RUNGROJ YONGRIT/EPA/CORBIS

Andy Coghlan and Debora MacKenzie

IT COULD be the end of AIDS as a global epidemic. Antiretroviral drugs that block the spread of HIV are about to transform the battle against AIDS and in theory could even eliminate HIV from some parts of the world. "This is a watershed," says Robert Grant at the University of California in San Francisco. "We can now envision a world where HIV infection becomes rare."

Excitement is high in Rome, Italy, this week, which is playing host to the world's biggest scientific conference on HIV and AIDS, which kills almost 5000 people a day. Delegates will hear the first detailed evidence that antiretroviral drugs (ARVs) not only help those infected with HIV to stay alive but also stop the virus spreading in two ways.

The first approach is called pre-exposure prophylaxis (PrEP). Two independent groups working in Africa have announced that putting uninfected heterosexual people on low doses of ARVs reduced their risk of catching HIV by 63 to 68 per cent – on just one 25 cent pill a day. A constant level of ARVs in the bloodstream kills the virus before it can establish an infection, preventing HIV from taking hold. This worked for both men and women – the hardest group to protect in Africa partly because many are pressurised into having unsafe sex. "[The results are] really exciting, just super," says Catherine Hankins, chief scientific adviser to UNAIDS – the Joint United Nations Programme on HIV and AIDS.

"This is a watershed. We can now envision a world where HIV infection becomes rare"

Another major study using "treatment as prevention" (TasP) has had great success in giving ARVs to infected people earlier than usual, before the virus has destroyed many white blood cells. In a trial which covered 13 countries and involved 1763 heterosexual couples, early intervention with ARVs reduced the spread of HIV to uninfected partners by a massive 96 per cent. All the studies were halted early so the placebo groups could get the real treatments.

To put these approaches into

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Test and treat is a key strategy

practice, we will need cheap and plentiful ARVs. A groundbreaking deal struck last week may solve the problem (see "Cheap drugs for those in need" right).

"We now have a powerful package of preventive measures. We didn't have that a week ago," says Jared Baeten at the University of Washington in Seattle, leader of one of the PrEP studies. This is welcome news since HIV is spreading 2.5 times as fast as people are put on ARVs.

"Now the question is how each country should roll each of these measures out," says Baeten. That is tricky, as it means giving powerful drugs to two new groups, people who are uninfected or have yet to develop symptoms. Advocates of TasP worry that HIV-negative people, who vastly outnumber those with HIV, even in Africa, will consume limited supplies of ARVs that could otherwise be used to treat infected people. Baeten says PrEP should therefore be targeted at high-risk groups – sex-workers, vulnerable young women, uninfected partners of HIV carriers and men who have sex with men.

Drug resistance could be a problem, though. Infected people take three different ARVs to stop the virus becoming resistant; taking just one or two leads to resistance in six months. Uninfected people on PrEP get one or two ARVs, so they must be virus-free. The trouble is the tests are not always accurate: one person on PrEP in the African trials was already infected, and developed resistance.

PrEP is not 100 per cent effective either, especially as healthy people are more likely to forget their medicine than those with symptoms. So people on PrEP must be repeatedly tested, and switched to three-drug treatment if they do become infected, says Grant, who successfully tested PrEP in homosexual couples in the US last year. Long-lasting drugs that do not need to be taken every day are being developed, which could make compliance easier.

Jonathan Weber of Imperial College London, isn't convinced. "I can't see how on earth the benefits of PrEP can outweigh the detrimental aspects," he says. Weber is concerned that PrEP may change sexual behaviours for the worse. Computer models suggest PrEP can increase the spread of HIV if just 15 per cent of users feel protected enough to dispense with condoms.

Both Baeten and Grant are watching their study groups to see if that happens. Grant is optimistic. "Almost every prevention study has shown that if you use one method, it increases use of other ones too, possibly because there's increased awareness of the value of prevention." Indeed, studies have shown that circumcised African men increase their condom use.

"Early intervention reduced the spread of HIV to uninfected partners by a massive 96 per cent"

With TasP, infected people start taking ARVs before their white blood cells fall below 350 per microlitre of blood, while they can still block viral spread; the ARVs then take over by cutting blood levels of HIV. Besides cutting transmission, Myron Cohen at the University of North Carolina at Chapel Hill reported this week that this led to healthier HIV carriers, with fewer cases of tuberculosis *The New England Journal of Medicine* (DOI: 10.1056/NEJMoa1105243).

Being on ARVs for so long also leads to drug-resistant virus, however. Instead, they might lower HIV levels with a vaccine: this week Seek, a London-based company, announced that its vaccine cut blood levels of HIV in 55 carriers by 90 per cent.

At the extreme, TasP could even roll back the global HIV epidemic. In a mathematical model, testing everyone for HIV then immediately treating anyone who is positive cut transmission enough to eliminate the virus from some populations, says Chris Dye of the WHO.

It's not PrEP versus TasP, says Baeten. Combining all approaches "could have an effect much greater than the sum of what each could achieve separately".

The key is to target them right, depending on the local HIV situation. The question of where to start the onslaught is a debate that is just beginning in Rome. ■

CHEAP DRUGS FOR THOSE IN NEED

Rolling back AIDS with antiretroviral drugs that attack HIV will only work if cheap and plentiful supplies are available. As people develop resistance to the old drugs, they will need newer versions. But those are usually under patent, and too expensive.

Last week, though, there was a breakthrough: California-based pharmaceuticals firm Gilead reached an agreement with the UN-backed Medicines Patent Pool, based in Geneva, Switzerland. According to the deal Indian firms that make generic drugs will be allowed to make cheap copies of four important ARVs, including three new, patented ones. The drugs will go on sale in more than 100 poor countries.

In 2001 poor countries won the right to make such deals themselves, but few have, partly due to political pressure from industrialised countries, which have imposed numerous hurdles to limit the number of deals going through.

The patent pool aims to break the deadlock. Its head, Ellen 't Hoen, says that once Indian generics firms know they will be licensed to sell the product, they can start investing in the production facilities. Gilead won't even lose any sales: buyers of generics couldn't have afforded its patented product. Of the nine remaining holders of ARV patents, six are in "serious discussion" with the patent pool, she says. Only Johnson and Johnson, Merck and Abbott are so far holding out.

Only 36 per cent of people with HIV in poor countries now get treatment. Meeting the UN pledge to double that number by 2015 will mean doubling the amount of ARVs available. The same amount again will be needed to treat those people earlier in the infection, to prevent spread of the virus (see main story).

Life on track for a new genetic code

Ferris Jabr

THE genetic code of a bacterium has been rewritten, bringing us closer than ever to being able to write new code for living things.

The genome of *Escherichia coli* was transformed by systematically replacing one of its three-letter sequences with another, in the genetic equivalent of a search-and-replace in word processing.

"It's a tour de force," says Frederick Blattner of the University of Wisconsin-Madison, who was not involved in the study. "[It shows] the genetic code is totally arbitrary. We can manipulate the fundamental aspects of life."

Three-letter sequences in DNA, known as codons, either code for an amino acid or act as stop signals for the cellular machinery that links amino acids into proteins. Farren Isaacs of Yale University and his colleagues replaced nearly all the 314 TAG stop codons in the *E. coli* genome with TAA, another stop codon.

The first step in the process zaps bacteria with electricity to open their cell membranes and grant access to foreign bits of DNA. Some bacteria incorporated these bits into their genomes, giving the team 32 strains of *E. coli*, each with around 10 TAA codons instead of TAG codons.

The researchers then encouraged the bacteria to exchange DNA through the bacterial equivalent of sex – a process called conjugation. By pairing selected bacteria, they gradually increased the number of TAAs in each strain (*Science*, DOI: 10.1126/science.1205822). The team currently has four strains of *E. coli* in which nearly all TAG codons are now TAA codons, and are moving towards a single strain with nothing but TAAs.

"Once you have the final strain, TAG becomes a blank codon that you can use [to code] for unnatural amino acids with new properties," says Lei Wang of the Salk Institute for Biological Science in La Jolla, California. "That's the vision," says Blattner, "completely refactoring the genome to where it is quite substantially different from any other life forms."

"The genetic code is totally arbitrary. We can manipulate fundamental aspects of life"

Organisms whose genomes have a brand new genetic code could not mix with others if they escaped into the wild. A new code would also make the bacteria immune to viruses, which attack by mixing their genes into their host's DNA.

In future, the techniques could be adapted to expand not only the repertoire of amino acids, as Lei intends, but the building blocks of DNA itself. Natural DNA has just four letters – A, T, C and G – which represent the bases adenine, thymine, cytosine and guanine. In 2008, Floyd Romesberg of the Scripps Research Institute in La Jolla, California, and his team created two artificial letters that were accurately and efficiently replicated by a natural enzyme.

These letters could now be incorporated into a living cell. "As long as your main replication system is accepting of new bases, it's possible to install unnatural ones into new locations," says Isaacs's colleague Peter Carr at the Massachusetts Institute of Technology. If that happens, DNA will have a whole new alphabet. ■

KEVIN CURTIS/SCIENCE PHOTO LIBRARY

Letter-by-letter edits are possible

How to be in two places at the same time

AN AMBITIOUS experiment to make a glass sphere exist in two places at once could provide the most sensitive test of quantum theory yet. The plan is to place a sphere containing millions of atoms – making it larger than many viruses – into a superposition of states in different places.

Physicists have questioned whether large objects can follow quantum laws ever since Erwin Schrödinger's thought-experiment suggested a cat could exist in a superposition of being alive and dead.

The idea, published in *Physical Review Letters* (DOI: 10.1103/PhysRevLett.107.020405), is to zap a glass sphere 40 nanometres in diameter with a laser while it is inside a small cavity. This should force the sphere to bounce from one side of the cavity to the other. But since the light is quantum in nature, so too will be the position of the sphere, forcing it into a quantum superposition.

The experiment will have to be carried out in high vacuum and at extremely low temperatures so that the sphere is not disturbed by thermal noise or air molecules, says lead author Oriol Romero-Isart from the Max Planck Institute of Quantum Optics in Garching, Germany.

Last year Aaron O'Connell and colleagues at the University of California, Santa Barbara, demonstrated that it should be possible to create superpositions in a 60-micrometre-long metal strip. However, the physical separation associated with the two different states of the strip was only 1 femtometre, about the width of the nucleus of an atom.

The new experiment, in contrast, would put the glass sphere in two entirely distinct places at once, with no overlap. Observing the behaviour of relatively large objects obeying quantum laws offers our best hope of finding ways in which quantum theory breaks down. Michael Brooks ■

FIELDNOTES Nirranda South, Victoria, Australia

Burying the problem in a CO_2 graveyard

Wendy Zukerman

THERE are more cows than people here in Nirranda South, three hours south-west of Melbourne, making it the perfect spot to test a technology that remains hugely controversial.

I am at a facility run by Australia's Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC). If anyone can convince the public that carbon capture and storage can reliably reduce carbon dioxide emissions it's these guys. Even Friends of the Earth, Australia – which opposes the approach – has grudging respect for the research done here.

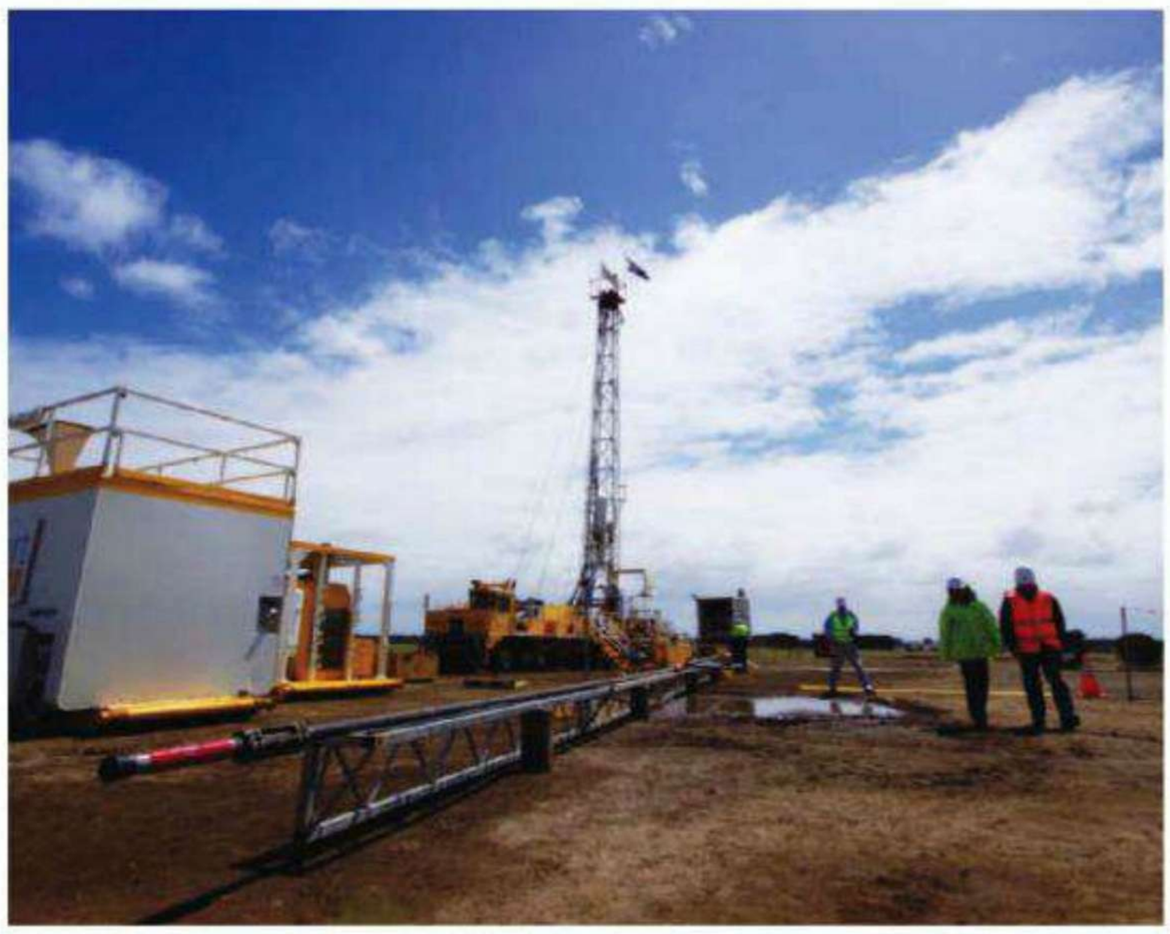
Wherever permeable and porous rock is capped by an impermeable layer, a natural gas store may form. Such stores can trap gas for tens of millions of years, making spent oil and gas fields a logical choice for industrial CO_2 storage.

But these spent fields are small, and can store only so much CO_2 – up to 900 gigatonnes worldwide, according to the Intergovernmental Panel on Climate Change. A more common type of subterranean structure – deep saline aquifers – has the potential to store up to 100,000 gigatonnes. The problem? It is not clear that these aquifers, which naturally house salty water, can keep hold of CO_2. "It's very difficult to predict how the gas will move underground," says Peter Cook, a hydrologist at Flinders University in Adelaide. That's where the Nirranda South facility comes in.

Above ground, the facility is just a few shipping containers, a series of pipes that snake around the muddy floor, and a large white container filled with CO_2. But beneath my feet, some 1500 metres down, is a saline aquifer.

At the end of June, two tracer gases – krypton and xenon – were injected into the saline aquifer, says Josie McInerney, the community liaison officer for CO2CRC. When I arrived last week, hydrologist Allison Hortle and colleagues were busy sucking up salty water samples every hour over a four day period to track how the tracers travelled through the aquifer. The results will help predict how CO_2 is likely to behave under similar circumstances, Hortle says.

Or so it is hoped. Matthias Raab, the programme manager of the site, tells me, euphemistically, that using the tracers "is highly experimental" – in other words, it is not clear that noble gases behave as CO_2 does. So this week the team will inject 150 tonnes of CO_2 into the aquifer, and compare its movements with the tracers.



CO2CRC

It doesn't look like much, but this facility is testing the future of CO_2

It's this slow-and-steady testing approach that has garnered respect from Friends of the Earth, Australia. "We have trust in the monitoring regimes of CO2CRC," says Cam Walker, a spokesperson for the organisation. "But it's sucking up a lot of the money that should be going to renewables."

Australia is spending A$1.6 billion over five years on carbon capture and storage technology. According to Walker, that cash could buy three large solar power stations.

Raab points out that solar power is not yet ready to fully replace fossil fuels, though. "Carbon capture cannot be the only solution to reducing carbon emissions, but it is has to be part of it," he says. ■

Hot water could have sorted primeval DNA

FRAGMENTS of DNA and RNA have been found to sort themselves according to their size. The process could have helped the first biological molecules organise themselves into a living organism.

The trick is an example of thermophoresis, by which particles in a liquid move along the temperature gradient that forms when the liquid is heated.

Albert Libchaber of Rockefeller University in New York City and colleagues discovered a twist on this process when they heated water that contained a high concentration of a long molecule called polyethylene glycol (PEG) as well as shorter molecules of DNA and RNA.

As expected, the PEG tended to move away from where the water was heated, but to his surprise Libchaber noticed that DNA and RNA formed discrete rings around the heat source.

Intrigued, he tried different-sized RNAs. The longer ones formed a central dot, while the smaller ones formed a ring around it. RNA also separated from DNA (*Physical Review Letters*, 10.1103/PhysRevLett.107.038301). It's as if the distribution of larger PEG molecules helps sort the smaller ones

Libchaber says the process could have been important if life began in hydrothermal vents, where geothermal energy heats water-saturated rocks on the seabed. Such vents have strong temperature gradients and so could have concentrated similar molecules in pockets within the rock.

Itay Budin of Harvard University has previously shown that thermophoresis can push all the organic molecules in a chamber to cluster at one end (*Journal of the American Chemical Society*, DOI: 10.1021/ja9029818). Libchaber's method also sorts them by size – though Budin questions whether something similar could have operated in the primeval seas, as he doubts whether long-chain molecules like PEG could survive the extreme conditions around hydrothermal vents.

"This could have helped biological molecules organise themselves into a living organism"

The new technique could also sort RNA molecules roughly according to their sequence, ensuring that RNAs performing the same function stay together. That's because the sorting process depends on the molecules' rigidity, which in turn depends on the sequence. Michael Marshall ■

Martian air makes for perfect storms

David Shiga

SNOWSTORMS more violent than any on Earth may have hit Mars – and could occasionally strike again, despite its extremely dry climate.

No rain or snowstorms have ever been observed on Mars, which has been mostly cold and dry for about 3.5 billion years. But mineral evidence suggests short-lived lakes have formed intermittently on the planet, sometimes inside craters. Lakes may form when meteorite impacts heat ice in the crust or when underground reservoirs of water kept liquid by geothermal heat leak onto the surface.

Edwin Kite of the University of California, Berkeley, and colleagues wondered how the planet's weather might change in the presence of such lakes. So they plugged Mars's present-day conditions – which may be much the same as they have been for the last 3 billion years or so – into weather-prediction software, and modelled what would happen if the planet had a 65-kilometre-wide lake near the equator.

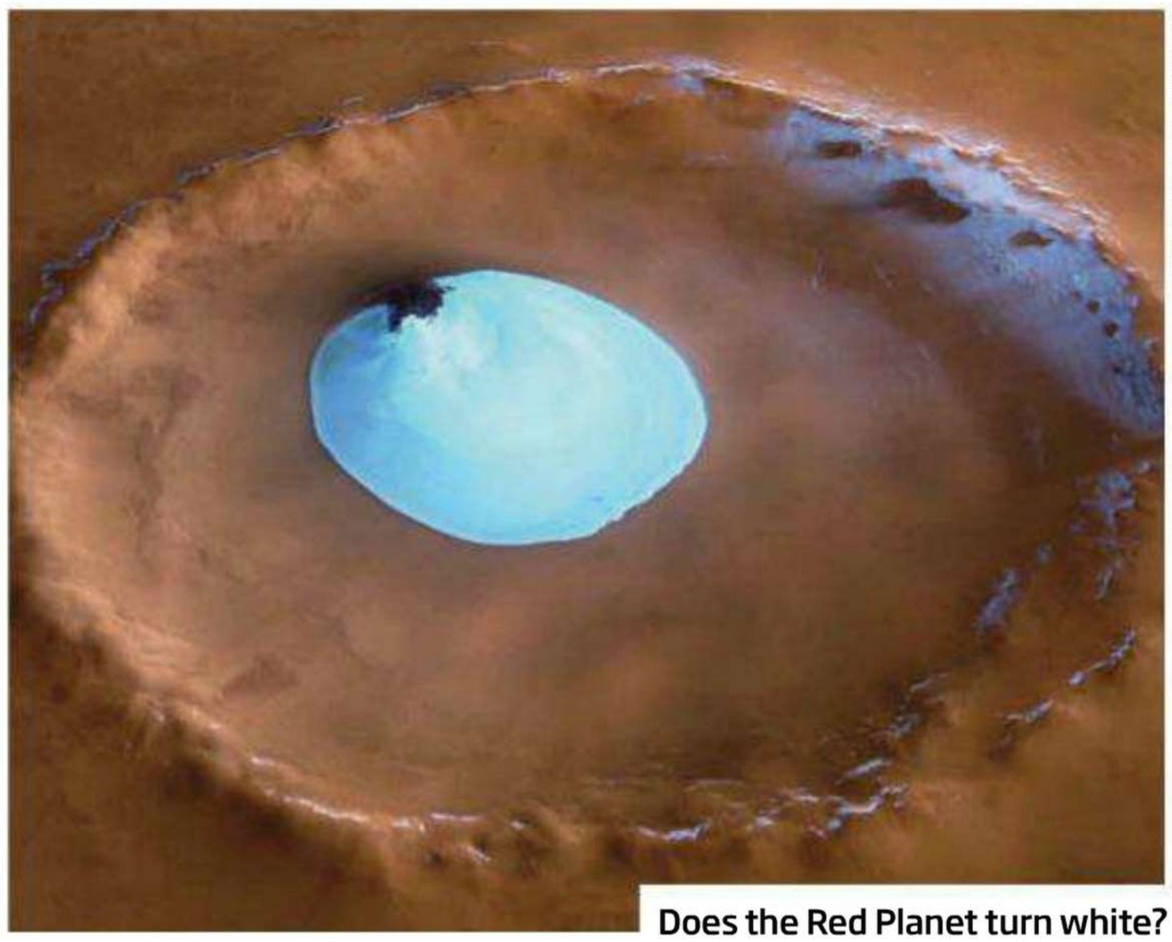
The results were dramatic. Heat from the lake, although minimal, stirred the thin Martian atmosphere vigorously. In the simulation, this caused a plume of warm, moist air to rise from the lake at a top speed of 194 kilometres per hour, similar to the updraft speed in thunderstorms on Earth.

As the rising water condensed to ice within the plume, it formed a storm cloud that stretched to 35 kilometres in altitude. Earth's storm clouds are stopped about 20 kilometres up by a layer of warm air heated by ozone, which absorbs the sun's ultraviolet rays. Mars has no ozone layer to heat its upper atmosphere, so clouds can rise higher there. The simulated storm cloud dropped about 10 centimetres of snow per hour, comparable to extreme snowstorms on Earth (*Journal of Geophysical Research*, DOI: 10.1029/2010je003783).

"Imagine being in the most severe thunderstorm you've been in, where it's really dark and ominous-looking," says team member Scot Rafkin of the Southwest Research Institute in Boulder, Colorado. "Then make it darker and more ominous, with snow coming down at an unbelievable blizzard-like rate."

Periodic changes in Mars's tilt – thought to occur due to gravitational tugs by Jupiter – could later melt the snow. That may explain the presence of water-formed minerals downwind of suspected former lakes, including one in a canyon called Juventae Chasma, the team say.

The study shows Mars's climate can vary dramatically depending on local conditions, says Anthony Colaprete of NASA's Ames Research Center in Moffett Field, California. ■



ESA/DLR/FU BERLIN (G.NEUKUM)

Does the Red Planet turn white?

Age is no bar to learning a new language

IT'S never too late to learn another language. Surprisingly, under controlled conditions adults turn out to be better than children at acquiring a new language skill.

It is widely believed that children younger than 7 are good at picking up new languages because their brains rewire themselves more easily, and because they use what is called procedural, or implicit, memory to learn – meaning they pick up a new language without giving it conscious thought. Adults are thought to rely on explicit memory, whereby they actively learn the rules of a language.

But some linguists now question whether this apparent difference in language-learning ability reflects our attitudes to young children and adults rather than differences in the brain. "If adults make a mistake we don't correct them because we don't want to insult them," says Sara Ferman of Tel Aviv University, Israel.

Ferman and Avi Karni from the University of Haifa, Israel, devised an experiment in which 8-year-olds, 12-year-olds and adults were given the chance to learn a new language rule. In the made-up rule, verbs were spelled and pronounced differently depending on whether they referred to an animate or inanimate object.

Participants were not told this, but were asked to listen to a list of correct noun-verb pairs, and then voice the correct verb given further nouns. The researchers had already established that 5-year-olds performed poorly at the task, and so did not include them in the study. All participants were tested again two months later to see what they remembered.

"The adults were consistently better in everything we measured," says Ferman. When asked to apply the rule to new words, the 8-year-olds performed no better than chance, while most 12-year-olds and adults scored over 90 per cent. Adults fared best, and have great potential for learning new languages implicitly, says Ferman. Unlike the younger children, most adults and 12-year-olds worked out the way the rule worked – and once they did, their scores soared. This shows that explicit learning is also crucial, says Ferman, who presented the results at the International Congress for the Study of Child Language in Montreal, Canada, this week.

> "Social attitudes rather than differences in the brain's wiring may be why young children do better"

The results are exciting, says David Birdsong from the University of Texas, Austin – particularly the finding that children's pronunciation is inferior to that of older subjects.

But Robert DeKeyser at the University of Maryland in College Park warns that artificial experiments like this do not necessarily transfer to the real world. Even if adults are better at implicit learning, children are more likely to get the chance to learn implicitly. Catherine de Lange ■

Chimp architecture has lasting foundations

WHEN a chimpanzee builds a tree house, it goes for the lazy option: prefab. Although they make a new nest every night, chimps often build them on branches that have previously been shaped into the perfect foundation.

While animals like beavers and birds are famous for their nest-building, the great apes – including chimpanzees – are the only primates to build such structures. Chimps start by climbing high into the trees, often tens of metres above ground. There they bend and break branches to form a circular platform, which they top off with a soft mattress of twigs and leaves.

Fiona Stewart of the University of Cambridge and colleagues spent three years studying chimp nests in the Issa region of west Tanzania. Of 275 nest sites, a quarter were re-used within nine months of being built and nearly half within 18 months. The main bulk of the nests tend to decay within six months, so the chimps often returned long after the materials had rotted away (*Journal of Human Evolution*, DOI: 10.1016/j.jhevol.2011.05.005).

Closer examination revealed that the chimps left scars at 79 per cent of sites: some branches were broken or ripped off, while others had been bent, forcing them to grow in a new direction. Branches were also often arranged in a horizontal triangle that acted as a nest support. In effect, the chimps left foundations in place to build on when they returned. This is further evidence that chimps can plan ahead, says Jill Pruetz of Iowa State University in Ames.

FLORIAN MÖLLERS/NATUREPL.COM

East, west, home is best

The findings may open a new avenue for studies into chimp archaeology, says Michael Haslam of the University of Oxford. Haslam studies the evolution of behaviour and culture and thinks archaeology has focused too much on the highly unusual human animal.

He is excavating stone tools used by Brazilian capuchin monkeys, and wonders if ancient trees may retain a record of evolving chimp architecture. Michael Marshall ■

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Sun's death rattle may hurl comets out of solar system

A DYING star deserves a last hurrah. It is fitting then, that our sun will throw many of its comets into interstellar space when it dies, according to new simulations.

In about 5 billion years, the sun will run out of hydrogen to burn in its core and will expand to become a red giant star. The red giant will blow off its atmosphere, leaving an ember-like core called a white dwarf.

It is generally accepted that planets inward of Earth and possibly Earth itself will be engulfed and incinerated during the red giant phase. But astronomers have paid little attention to more distant objects.

Now a study suggests that the sun's death throes will reverberate all the way to the vast swarm of comets called the Oort cloud, out beyond Pluto.

When the sun loses mass, its gravity will decrease. This change can eject orbiting objects, but only if it happens on a timescale not much longer than the object's orbital period. At the very end of the sun's red giant phase, astronomers think it will shed a sizeable fraction of its mass in just 100,000 years or so.

This would still be too gradual to eject the planets beyond Earth, but simulations show that it will cause the exit of up to 20 per cent of Oort cloud comets into interstellar space, say Dimitri Veras and colleagues at the University of Cambridge. The work is to be published in *Monthly Notices of the Royal Astronomical Society*.

Where did the Gulf's spilt oil and gas go?

THE puzzle over what happened to the oil and gas released during the Deepwater Horizon oil spill in the Gulf of Mexico last year has been partially solved.

Oil is composed of many thousands of different chemicals, but the plume that stretched through the Gulf contained just a few. Now chemists have worked out what happened to the rest.

Christopher Reddy, an environmental chemist at the Woods Hole Oceanographic Institution in Massachusetts, and colleagues, used a remotely operated submarine to collect samples directly from the leaking well in June 2010 and compared these with samples taken from elsewhere in the oil plume.

The team found that water-soluble compounds, including methane, benzene and toluene, dissolved in a layer of seawater about 400 metres above the wellhead. And in this layer they stayed.

By contrast, the compounds that reached the surface were mainly insoluble (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.1101242108).

The results show how deep oil spills differ from surface spills, where many toxic compounds quickly evaporate rather than contaminating the water.

Close your eyes to win the game

TO WIN at rock, paper, scissors try closing your eyes. It could help you to control an unconscious urge to imitate your opponent.

Richard Cook at University College London and colleagues asked 45 adults to play rounds of the game with either one or both players blindfolded. There were significantly more draws when one player was sighted, but when someone did win, it was more often a blindfolded player than a sighted one (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2011.1024).

Cook found that sighted players often gestured around 200 milliseconds after the blindfolded opponent, and suggests this reflects an automatic urge to imitate others. Peter Enticott, a psychologist at Alfred Hospital in Melbourne, Australia, says this type of imitation is "beyond our control" and shows we are "rapidly influenced" by those around us.

Entanglement, now and forever

ENTANGLEMENT, the spooky link that makes disparate quantum objects act as one, can now be topped up for as long as necessary.

Hanna Krauter at the Niels Bohr Institute in Copenhagen, Denmark, and colleagues used a laser to align the spins of two clouds of caesium atoms, entangling them. The clouds emitted photons, which allowed the entanglement to leak away. Their trick, described in a paper to appear in *Physical Review Letters*, was to replenish the entanglement as it escaped, maintaining the link for as long as the experiment ran. Previously, it had only been made to last for a few seconds using entangled ions.

The technique could lead to advances in quantum teleportation and computation.

Farinelli's lack of testes hit his skull

THERE was at least one downside to Farinelli's castration. The operation may have preserved the 18th-century singer's treble voice into adulthood, making him a musical legend, but it also condemned him to a skull deformity that may have affected his mind.

Farinelli was exhumed in 2006 so that his skeleton could be studied. Lead investigator Maria Giovanna Belcastro of the Alma Mater Studiorum University of Bologna, Italy, was able to identify two unusual features. Like those of other castrati, Farinelli's limb bones were unusually long. And the front of his skull had grown inwards in a lumpy mass, in places twice as thick as unaffected bone (*Journal of Anatomy*, DOI: 10.1111/j.1469-7580.2011.01413.x).

This is called hyperostosis frontalis interna (HFI). It is thought to be caused by hormonal disorders, particularly too much oestrogen, which explains why it is normally found in post-menopausal women and is rare in men.

HFI was thought to be harmless, says Israel Hershkovitz of Tel Aviv University in Israel, but is now linked to behavioural disorders, headaches and neurological diseases like Alzheimer's. Though any such symptoms probably would not have affected Farinelli until late in life, Hershkovitz says.

GETTY

Grappling with the problem of biofilm formation

LIKE tiny mountaineers, bacteria use grappling hooks to pull themselves across a surface – and can get an extra boost by releasing one of the taut lines to slingshot themselves forward. Thwarting them could help combat the biofilms behind hospital infections.

Fan Jin and Gerard Wong of the University of California, Los Angeles, filmed the bacterium *Pseudomonas aeruginosa* crawling through a viscous medium on a glass surface. They then analysed how it moved using an algorithm. This confirmed what biologists had long suspected: many bacteria use hair-like appendages called pili as grappling hooks to pull themselves along.

But the algorithms also picked up on something else: sometimes a bacterium's rear end performed a jittery but purposeful little dance. Instead of merely contracting their pili, the bacteria released one taut pilus from the surface altogether, sending their behinds skittering across the surface. This fired the cell forwards 20 times faster than contracting pili (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.1105073108).

This slingshot movement is so fast that the team thinks it reduces the local viscosity of the medium by a process called shear thinning. The lower the viscosity, the easier it is to move – a huge advantage if you are a bacterium rushing to join your brethren and form a biofilm.

"The goal now is to find a way to target how they move," says Wong, and prevent biofilms forming.

Drug driving test at your fingertips

A FINGERPRINT is all you need to determine whether someone is under the influence of drugs.

Paul Yates from Intelligent Fingerprinting, a company spun out from the University of East Anglia in Norwich, and colleagues, have developed a handheld device that police can use to detect breakdown products from drugs excreted through sweat pores in the fingertips.

The device applies gold nanoparticles coated with antibodies to a fingerprint. The antibodies stick to antigens on specific metabolites in the fingerprint. Fluorescent dyes attached to the antibodies will highlight the presence of any metabolites. The technique was first used to detect nicotine, but now works on a range of drugs, including cocaine, methadone and cannabis.

It is hard to prove that someone is drug driving, for example, says Yates, because existing tests are invasive, can be contaminated, or aren't sensitive enough. The new device could detect nanograms of metabolites in minutes, he says. The device was announced at the UCL International Crime Science Conference in London last week.

WALTER PACHOLKA, ASTROPICS/SCIENCE PHOTO LIBRARY

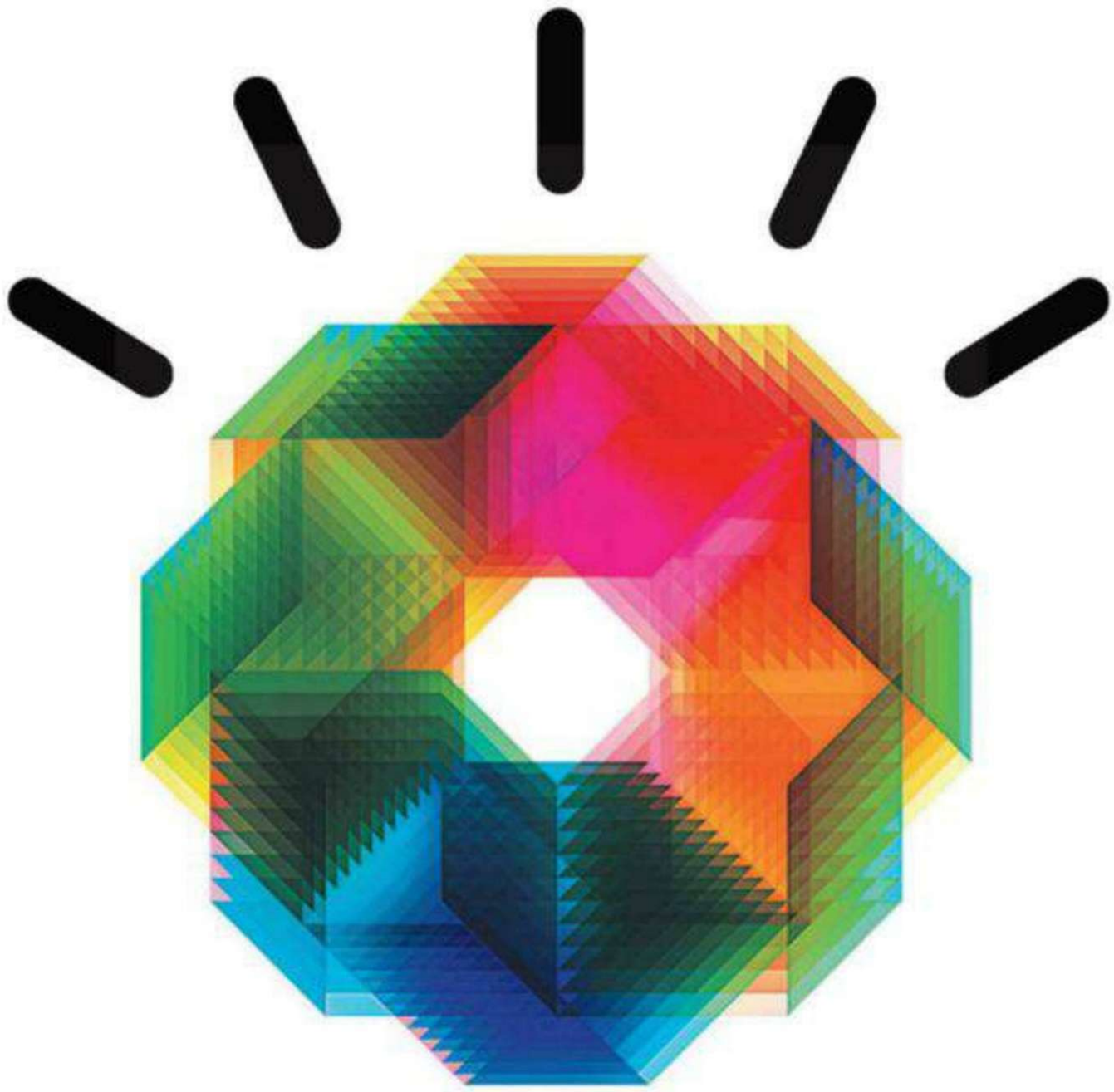
Shapely sperm lead to female babies

FORGET tall, dark and handsome – smooth, oval and symmetrical is what an egg wants in sperm. Now it seems that the sperm chosen on these grounds to use in assisted reproduction are more likely to carry an X chromosome than a Y.

Couples struggling to conceive may opt for a technique that involves extracting the woman's eggs and injecting each with a sperm, chosen after examining them at either 400x or 6600x magnification.

Daniela Braga at the Fertility-Assisted Fertilization Center in São Paulo, Brazil, examined 153 embryos fertilised using the lower magnification technique and 240 using higher magnification. She found that sperm had a 64.7 per cent chance of carrying an X chromosome if selected at 6600x magnification, but just a 53.8 per cent of carrying an X if picked at the lower magnification.

Braga cannot yet explain the effect. "X sperm is heavier than Y sperm, but that couldn't have made a difference." She presented the results at the annual meeting of the European Society of Human Reproduction and Embryology in Stockholm, Sweden, this month.



Building a Smarter Planet.

A new sustainability for a smarter planet.

As globalisation, population growth, rapid urbanisation and an expanding middle class intensify competition for scarce resources, a fundamental mindset shift is taking place. Sustainability – once seen as extremist thinking - is fast becoming mainstream, with increasing recognition that it is good for people and business, as well as for the planet.

Far from fearing that recovery and growth must always be at the expense of environmental stewardship and social equity, forward-thinking organisations are seizing the opportunity to drive strategic, cultural and behavioural change, and achieving a sustainability that is economically, socially and environmentally desirable. By using real-time data to identify and understand inefficiencies, they are building in sustainability and changing the way the business works.

Their success demonstrates that aligning sustainability to business strategy can deliver economic growth and long-term viability, reduce dependency on costly resources, and generate step changes in efficiency.

Convinced by the business benefits of sustainability, others are building end-to-end sustainable infrastructures and opening up data and insights to suppliers and partners. This enables interaction and collaboration, creates operational and environmental improvements along the supply chain and promotes more sustainable choices by customers.

In addition to lower costs and greater efficiency, this systemic sustainability gives us all a breathing space until new ways to use scarce resources or viable substitutes are available.

Among the organisations to elevate sustainability from a niche issue to the mainstream is global consumer goods company Unilever, whose Sustainable Living Plan aims to decouple future growth from environmental impact. This will involve halving the environmental footprint of its products, helping 1 billion people improve their health and well-being, and sourcing 100% of its agricultural raw materials sustainably.

Peterborough is the UK's Home of Environment Capital, delivering truly sustainable growth and investment. So it is demonstrating the role of shared data and collaboration by offering a real-time, integrated view of its sustainability performance online. This way, stakeholders can identify problems, modify behaviour and track progress.

Collaboration is also key at the Energy Technologies Institute, where in one of many projects to create a new energy future, a consortium of organisations is exploring how a mass market for electric and plug-in hybrid electric vehicles could be achieved in the UK and what energy infrastructure would be required. Its goal is to substantially reduce carbon emissions from personal transportation in a sustainable, secure and affordable way. Smarter integration is critical to enabling more effective demand management and resource utilisation.

The value of approaches like these is underlined in The Climate Group's SMART 2020 report, which estimates the potential of smarter, whole-system solutions to drive annual savings in excess of £500bn and 7.8 gigatons of CO_2 globally by 2020.

Sustainability is now such a major issue that when IBM hosted a 9-day Business Summit at Start (www.ibm.com/uk/start) on the role of business in sustainability, over 1,000 business leaders attended. This makes sense: business was the driving force of the industrial revolution, the guiding force behind the digital revolution and must now become the leading force in the sustainability revolution.

Let's build a smarter planet. Join us and see what others are doing at **ibm.com**/smarterplanet/uk

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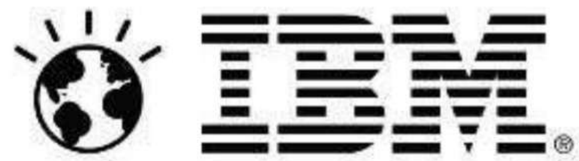
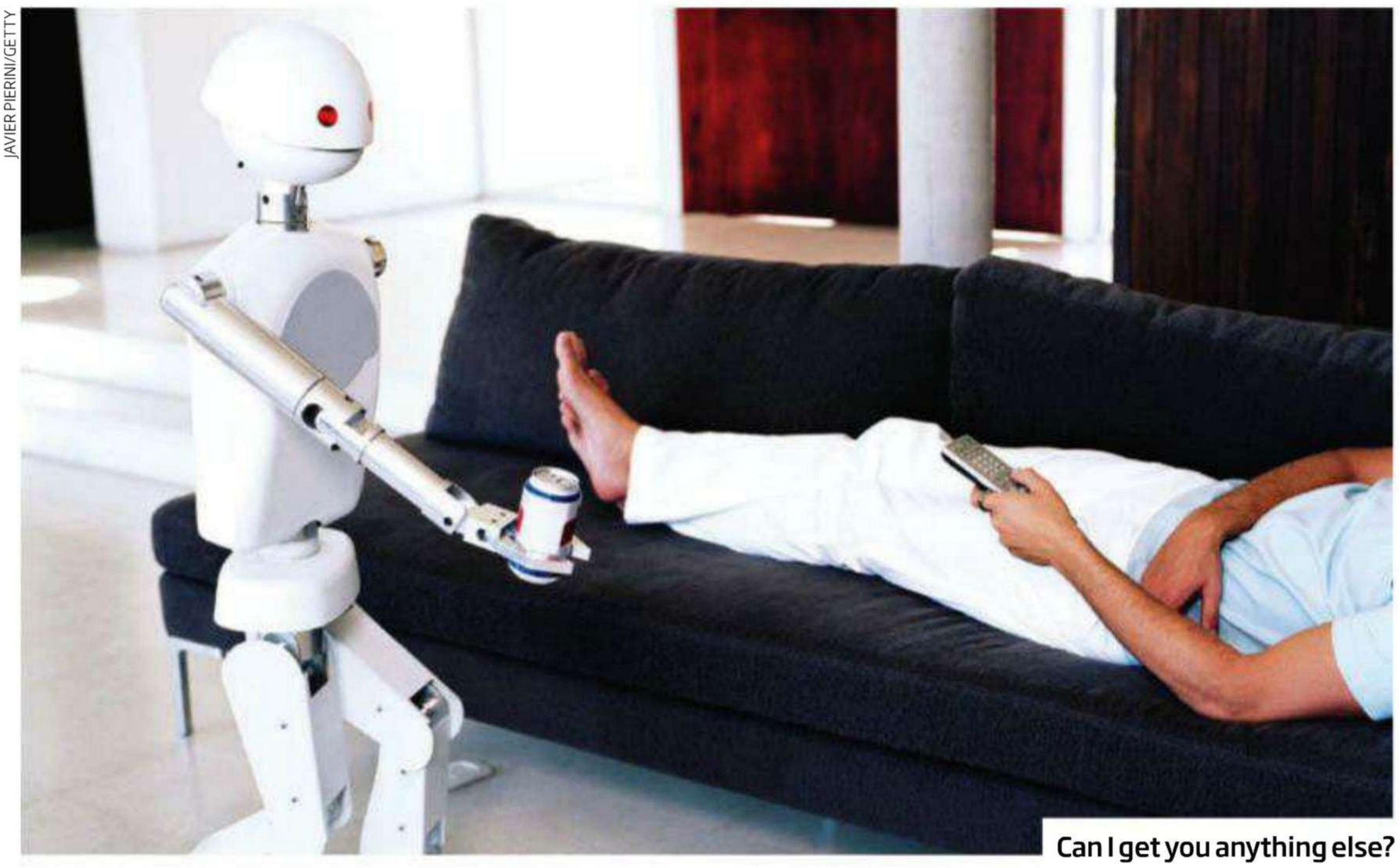


JAVIER PIERINI/GETTY



Can I get you anything else?

Robot see, robot do

With help from human teachers, robots can learn to perform complex tasks that used to be out of reach

Jim Giles

TWO robots named Rosie and James are making pancakes. It's a tough task that requires coordination, planning and a fine touch with a spatula. Midway through the process, Rosie slides the spatula under the half-cooked cake, lifts the pancake from the heat and carefully flips it over. The crowd breaks into cheers.

Rosie and James aren't quite the accomplished cooks they appear to be, however. As far as robots go, they are as flexible as they come, but they move haltingly, and their complex routine is the result of painstakingly crafted software instructions. Give Rosie and James a different recipe, for example, and their performance would suffer.

It's an age-old problem in robotics, but one that might just have a solution. Roboticists traditionally go to great lengths to coax automatons to perform highly specialised tasks, like cooking crêpes. But now they are turning to the crowd for help in giving robots more general skills. By allowing people to pilot real or simulated robots over the internet in trial experiments, they hope to recreate the fast and flexible behaviour that comes effortlessly to humans. "Crowdsourcing is a really viable path toward getting robots to do things that are useful for people," says Chad Jenkins, a robotics researcher at Brown University in Providence, Rhode Island.

The idea is inspired by successes in other areas of artificial intelligence. For example, online translation systems are trained on pairs of documents that have been translated by humans. By comparing translations with originals, the software learns how to translate words and phrases between different languages.

A similar approach could lead to better human-robot interactions, says Sonia Chernova at Worcester Polytechnic Institute in Massachusetts. To collect information on teamwork, social interaction and communication, she and colleagues created Mars Escape, an online game in which two people each control an avatar, one human and one robot, and work together to rescue objects from a doomed Martian research lab. After Mars Escape went online last year, Chernova logged the dialogue and action from over 550 sessions of the game.

> **"Crowdsourcing is a really viable way of getting robots to do things that are useful to people"**

The researchers first had to throw out unusual records, like dialogue between players who traded obscenities rather than working together. Then they looked for common patterns in the data, such as methods that players frequently used to retrieve objects, and phrases they exchanged when doing so. By having software watch how people tackled the game, the software learned how to work with a human. The technique could also find a use in the games industry (see "Build a better baddie", see below).

The real test came last January, when Chernova and colleagues mocked up a real-life version of the Martian lab at the Museum of Science in Boston. Visitors were paired with a robot powered by software based on the Mars Escape data. The results were encouraging, Chernova and colleagues say in a paper to be presented next week at the International Symposium on Robot and Human Interactive Communication in Atlanta, Georgia. Sixteen out of 18 visitors worked with the robot to complete the game and most said the robot behaved rationally and contributed to their success. ›

Build a better baddie

In Jeff Orkin's vision of the future, gamers doing battle in zombie-filled shoot 'em ups will be helping to build richer virtual characters. Orkin worked in the game industry before moving to the Massachusetts Institute of Technology. His system crafts artificial characters by observing how humans play.

The system makes recordings of dialogue and action from games, which are annotated so the software knows what is happening at each point. Then virtual characters in other games can tap into the annotated data to simulate human-like behaviour. Slain by a sarcastic swordsman or glib goblin? Next time, you might have to blame Orkin.

« Jenkins had similar success with a proof-of-principle experiment. Last year, he wired up a wheeled robot for online access and invited people to guide it through a simple maze. Over 270 people took up the challenge. He used the data they generated to build a navigation algorithm that allowed the robot to complete a maze it had not seen before.

His next experiment is more ambitious. His lab has a state-of-the-art PR2 – the same class of robot as James – that it plans to make available online. The robot will be placed in a kitchen and users will be invited to help it perform common tasks, like fetching objects from cupboards. The data they generate could help create better domestic robots, says Jenkins. The online interface will be demonstrated to researchers this August and should be available to the public by the end of the year.

The initial experiments have also flagged up some potential problems. Players in the real-life Mars Escape complained that the robot had poor communication skills, for example. This may be because the real robot often prompted different behaviour to its virtual version. For example, some visitors issued commands to move a specific distance. No players in the online game issued similar instructions, so the robot had no appropriate data to draw upon.

If such problems can be tackled, the technique has potential, says Jenkins. Many researchers focus on domestic tasks, but people in the outside world might prioritise other uses once they get control of robots. He draws an analogy with the early days of the internet: researchers built a data-sharing system and did not anticipate the emergence of Wikipedia and social networking. As for what those other uses are, Jenkins says we will have to wait: "If I had a good sense of other great applications, I would be doing them already." ■

Scanner to spot the living dead

A technique to spot whether fingerprints belong to a living person could prevent gruesome attacks

Paul Marks

IF AN invading zombie army is staggering towards your front door, don't worry: a fingerprint-activated door lock could save your bacon. That's because one group of researchers has worked out how a biometric scanner can keep the undead at bay.

OK, so they weren't specifically trying to stop zombies, but there is genuine concern about dead flesh being used to spoof fingerprint scanners. Severed fingers and even fingers cut from corpses can be used to give the bad guys entry to secure facilities, to steal cars or log on to computers.

It sounds outlandish, but the first reported case was in March 2005, when thieves stole a biometrics-activated Mercedes in Kuala Lumpur, Malaysia. Initially they took the owner with them so he could start the car, but they soon tired of his presence – and hacked off his digit before dumping him at the roadside.

To combat such bloody skulduggery, researchers at Dermalog Identification Systems in Hamburg, Germany, have developed a way for a fingerprint scanner to differentiate between live and dead tissue.

The trick is based on the way living tissue "blanches" – or changes colour – when blood is squeezed out of capillaries, as a fingertip is pressed against a surface, for example.

Clarissa Hengfoss and her colleagues at Dermalog found that living fingers absorbed LED light at 550 nanometres on first contact and then at 1450 nanometres as the skin blanched when fully contacting the sensor (*Forensic Science International*, DOI: 10.1016/j.forsciint.2011.05.014). In contrast, fingers from three cadavers showed no such change.

"The spectra for light and strong contact pressure were more or less identical for fingers from dead bodies," the Dermalog researchers say.

Chaos radar uses messy signals to see through walls

A NEW type of radar which harnesses chaos theory can see clearly through walls and could help find survivors in disasters. The technology could also make on-board radar a practical proposition for cars.

Ultra-wideband (UWB) radar is already used to "see" through walls. It can detect the presence of people on the other side of a barrier by distortions to the reflected radio waves caused by their breathing or heartbeat. However, the radar returns are often cluttered by interference, obscuring the signal.

Now, Henry Leung and colleagues at the University of Calgary in Alberta, Canada, have found a way to sharpen the signal, which gets lost among multiple reflections within walls, known as reverberation, and by returns bouncing back via different routes.

Existing UWB radars typically use a random noise signal to avoid interference between waves of the same wavelength. But because the outgoing signal is not known it takes more processing to match it to the return. A second approach is to use a wide range of sequential frequencies; this is easier to match but more prone to interference.

Leung's team are using a "chaotic oscillator" to generate their signal. The device creates what seems like random noise, but which is actually generated by a fixed algorithm. It is matched by a receiver using the same algorithm. Because the outgoing signal is known, it is as easy to process as spread-spectrum signals. It is also irregular, like random noise, meaning reflections are less likely to interfere with each other.

In tests, the chaotic signal produced better results than the other

"Vehicles could use chaos-radar sensors as part of a smart traffic-management system"

DNA/FIGMENT/FOX / THE KOBAL COLLECTION / MOUNTAIN, PETER

No entry for zombies

They hope their technique will find its way into future scanners to "serve as a criterion for authentication of a living finger".

Using a severed finger is not the only way to cheat a biometric test: fake fingerprints can be created by imprinting copies in rubbery gels or silicone plastic, says Marcela Espinoza of the Institute of Police Science in Lausanne, Switzerland.

So Espinoza is working to identify the factors that give away a fake based on the way fingerprint whorls are distorted by the different kinds of moulds used to cast them. Gel prints are made either from a direct impression of a fingerprint or by using a photo of a print to make a mould. Both methods can produce telltale spacings between ridges and furrows that mark the print as a counterfeit. "We are developing an algorithm that detects these forgeries," Espinoza told *New Scientist*.

"A living finger can be distinguished from a dead one by the way it blanches when pressure is applied"

The work both teams are doing is topical, says Tony Mansfield, a biometrics specialist at the UK's National Physical Laboratory in London. "The International Standards Organisation is drafting standards for secure biometrics – and liveness and forgery detection are among the anti-spoofing measures. This work will probably feed into their thinking." ■

approaches. "It captures the desired properties of these two systems," says Leung. This means the radar can see reliably through more layers.

Leung's colleagues suggest that chaos radar could be used as an on-board sensor for vehicles as part of a smart traffic-management system. As chaos signals do not interfere with each other, many could operate in the same area.

Karl Woodbridge, who researches radar systems at University College London, warns that there may be some way to go before practical hardware emerges. "There are many complications in a real-world scenario which are not easy to predict in simulations." David Hambling ■

MARTIN BERNETTI/AFP/GETTY IMAGES

Radar spy for survivors

ONE PER CENT

SCALED COMPOSITES

Rutan's flying car

When spacecraft designer Burt Rutan takes an outlandish aviation idea seriously it's time to sit up and take notice. The founder of Scaled Composites in Mojave, California, has designed and built his own "roadable aircraft" – a car that converts into a plane. Called the BiPod, the twin fuselage vehicle has two half-litre internal combustion engines that charge lithium-ion batteries in each nose. On the road, the BiPod's wings are stowed and the batteries power a 15-kilowatt electric motor to drive the rear wheels. In flight, four 15-kilowatt motors power the propellers. Meanwhile, Terrafugia of Woburn, Massachusetts, has just been granted road approval for the Transition, its own roadable aircraft.

Tangled leads begone

It's a problem that frustrates every music-lover: tangled headphone leads. Apple is proposing a solution in a patent application filed last week. The folks at Infinite Loop – that's their street in Cupertino, California – say the problem is the extreme floppiness of the wire in most headsets. Because the wire is hyperbendy, there's nothing to prevent it looping back on itself and getting knotted. Apple's answer is simple: stiffen lengths of the cable with extra layers of plastic between the protective sheath and the inner conductors to minimise looping. The stiffness can be varied along each lead so it is not merely rigid. Problem solved.

'Prodcast' tells you when to buy

Ever splurged on a costly item, only to see it cheaper mere weeks later? Microsoft aims to help you dodge buyer's remorse by predicting the best time to buy. It's only worth holding out for a price drop if the saving is worth more to you than the time spent without the latest model, but you can't do the calculation unless you know how much it is likely to cost in the future. Enter Prodcast, a system which looks at factors such as price history, sales volume and the time of year and then predicts for buyers when items are most likely to go on sale.

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INSIGHT

Move over Wi-Fi as info trips the light fantastic

FLICKERING lights are annoying but they may have an upside. Visible light communication (VLC) uses rapid pulses of light to transmit information wirelessly. Now it may be ready to compete with conventional Wi-Fi.

"At the heart of this technology is a new generation of high-brightness light-emitting diodes," says Harald Haas from the University of Edinburgh, UK. "Very simply, if the LED is on, you transmit a digital 1, if it's off you transmit a 0," Haas says. "They can be switched on and off very quickly, which gives nice opportunities for transmitting data."

It is possible to encode data in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. The LED intensity is modulated so rapidly that human eyes cannot notice, so the output appears constant.

More sophisticated techniques could dramatically increase VLC data rates. A team at the University of Oxford is focusing on parallel data transmission using arrays of LEDs, where each LED transmits a different data stream. Other groups are using mixtures of red, green and blue LEDs to alter the light's frequency, with each frequency encoding a different data channel.

Li-Fi, as it has been dubbed, has already achieved blisteringly high speeds in the lab. Researchers at the Heinrich Hertz Institute in Berlin, Germany, have reached data rates of over 500 megabytes per second using a standard white-light LED. Haas has set up a spin-off firm to sell a consumer VLC transmitter that is due for launch next year. It is capable of transmitting data at 100 MB/s – faster than most UK broadband connections.

Once established, VLC could solve some major communication problems. In 2009, the US Federal Communications Commission warned of a looming spectrum crisis: because our mobile devices are so data-hungry we will soon run out of radio-frequency bandwidth. Li-Fi could free up bandwidth, especially as much of the infrastructure is already in place.

One way to solve the bandwidth crisis, switch to light transmission

JOHN RENSTEN/GETTY

"There are around 14 billion light bulbs worldwide, they just need to be replaced with LED ones that transmit data," says Haas. "We reckon VLC is a factor of ten cheaper than Wi-Fi." Because it uses light rather than radio-frequency signals, VLC could be used safely in aircraft, integrated into medical devices and hospitals where Wi-Fi is banned, or even underwater, where Wi-Fi doesn't work at all.

"The time is right for VLC, I strongly believe that," says Haas, who presented his work at TED Global in Edinburgh last week.

But some sound a cautious note about VLC's prospects. It only works in direct line of sight, for example, although this also makes it harder to intercept than Wi-Fi. "There has been a lot of early hype, and there are some very good applications," says Mark Leeson from the University of Warwick, UK. "But I'm doubtful it's a panacea. This isn't technology without a point, but I don't think it sweeps all before it, either." **Jamie Condliffe** ■

Stegobot can steal passwords from your Facebook photos

THINK twice before uploading your holiday pictures to Facebook – you could be helping someone to steal information from your computer. A botnet called Stegobot was created to show how easy it would be for a crook to hijack Facebook photos to create a secret communication channel that is very difficult to detect.

Like most botnets, Stegobot gains control of computers by tricking users into opening infected email attachments or visiting suspect websites. But rather than contacting the botmasters directly, it piggybacks on the infected user's normal social network activity. "If one of your friends is a friend of a friend of the botmaster, the information transfers hop by hop within the social network, finally reaching the botmasters," says Amir Houmansadr, a computer scientist at the University of Illinois at Urbana-Champaign who worked on the botnet.

Stegobot takes advantage of a technique called steganography to hide information in picture files without changing their appearance. It is possible to store around 50 kilobytes of data in a 720 by 720 pixel image – enough to transmit any passwords or credit card numbers that Stegobot might find on your hard drive.

The botnet inserts this information into any photo you upload to Facebook, and then waits for one of your friends to look at your profile. They don't even have to click on the photo, as Facebook helpfully downloads files in the background. If your friend is also infected with the botnet – quite likely, since any email you send them will pass it on – any photo they upload will also pass on the stolen data.

"Stegobot can hide credit card numbers in picture files without changing their appearance"

From there, the data will eventually make its way to the account of someone who is also friends with the botmaster, allowing them to extract details on your identity. The botmasters can also send commands to the botnet through the reverse process – uploading a photo with hidden instructions that make their way to infected computers.

"It's scary because it's virtually undetectable," says Shishir Nagaraja of the Indraprastha Institute of Information Technology, New Delhi, India, who led the project.

Marco Cova, a computer scientist at the University of Birmingham, UK, says that criminals could employ a system like Stegobot, as it is hard to detect, but other methods allow them to steal much larger quantities of data. "It's not the most efficient or convenient way," he says. Jacob Aron ■

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NewScientist

The bog man

LIKE hundreds of other bodies found in Europe's peat bogs, this man poses haunting questions. Who is he? And how did he die?

The body was discovered on 6 May 1950 by a family from the village of Tollund who were digging for peat near Bjældskovdal, Denmark. They thought they had stumbled over a murder victim. In fact, the man dated from the 4th century BC – the Iron Age. Examination at the National Museum of Denmark in Copenhagen revealed he was 30 to 40 years old. Archaeologist Peter Glob christened him "Tollund Man".

The braided leather noose seen around his neck was strong enough to suspend a grown man. The loose end, which is about 1 metre long, was found rolled up and had been cut with a knife. Tollund Man had been hanged.

Yet he had been placed in the sleeping position, and his eyes and mouth had been closed after death – not what you would expect for a murder victim. This suggests he was sacrificed, says the Silkeborg Museum, where he now resides.

A noose may not mean he was hanged, however. A British bog body, Lindow Man, was found with a thong made of finely twisted animal sinew, but Robert Connolly of the University of Liverpool argues that he died after being "beaten up" and that the cord was ornamental: marks were left on his neck as his body bloated.

Bog bodies are well preserved, thanks to a bog's acidic water, low temperatures, lack of oxygen and the presence of *Sphagnum* moss. "Preservation is mainly due to 5-keto-D-mannuronic acid derived from the *Sphagnum* moss," says Connolly. "It is powerfully antimicrobial and preservative."

Even fingerprints can remain after millennia. Earlier this year, Günther Mull of the Institute for Dermatoglyphics in Hamburg, Germany, and colleagues took prints from the "Girl of the Uchter Moor", found in German marshlands. The prints of the teenage girl, who died around 650 BC, reveal ulnar loops – still the most common fingerprint pattern seen in Europe. Roger Highfield

Photographer
Robert Clark Institute

The war on science

Osama bin Laden may be dead, but the horrendous cost of pursuing the war on terror may give his followers cause for celebration, says **Lawrence Krauss**

WHEN Osama bin Laden was killed earlier this year, many commentators saw it as a turning point in the war on terror. However, a host of measures suggest that bin Laden's goal – to strike a long-lasting blow to the system of government of the US and to the health and well-being of its citizens – may have been achieved.

Last month, the Eisenhower Research Project at Brown University in Providence, Rhode Island, released a report entitled "Costs of War", which estimates the cumulative cost of the wars in Afghanistan and Iraq to be up to $4 trillion.

What has this vast amount of money achieved? Both Iraq and Afghanistan continue to rank low in political freedom, warlords continue to control much of Afghanistan, and gender and ethnic segregation in Iraq are now worse than they were before 2001.

At the same time, the US economy is in trouble. Unless the country's debt ceiling is raised by 2 August, the US will default on several of its major financial commitments. Many of the key programmes that contribute to the quality of life of most Americans are under threat.

From a scientific perspective, the appropriations bills now before Congress suggest that the US's dire fiscal straits will inflict long-term damage to its technical leadership.

The House of Representative's Committee on Science, Space and Technology has recommended cancelling the James Webb Space Telescope, the successor to the fabulously successful Hubble Space Telescope, because of a cost overrun of $1.6 billion. If this project is cancelled, once Hubble reaches the end of its working life in 2014 we will lose our chance to witness the first moment in cosmic history when the sky lit up with stars, less than a billion years after the big bang.

Beyond the direct loss to science, we need to ask what the next generation of bright minds will lose. The remarkable images captured by Hubble have inspired a generation of people to dream about the universe and its myriad possibilities, and have doubtless

Read all about it!

Our disingenuity towards celebrity tittle-tattle is part of our evolutionary legacy, says **John Hardy**

THERE are very few universal truths, but two relating to human behaviour are that farting is considered funny in all societies and that gossip occurs but is ostensibly always disapproved of. The evolutionary reason for the former is not clear, but the evolutionary reason for the latter becomes clear when one considers what is gossiped about.

Stripped down, gossip is largely about who is sleeping with who, who would like to sleep with who, and what the local pecking order is in terms of power and influence – which, of course, influences who is sleeping with who.

This explains the purpose of gossip and also the reason for its semi-secrecy and disapproval. In a society where there is competition for mates, it is clearly desirable to know who is available and who is not, who has power and who does not. It is also important not to convey your engagement in the process of assessing these factors since this would alert rivals to your interest. Deniability of interest is therefore part of the process.

Gossip is probably a large part of the reason for the evolution of our large cerebral cortex. In our evolutionary past, reproductive success depended in large part on our ability to navigate the complexities of tribal life. Those who were best at identifying mates without unnecessary conflict would have had a considerable advantage in reproduction.

Gossip evolved in a village society where everybody knew everybody else and successful navigation of local political complexities had a direct impact on reproductive success. In our global village, this need is now satisfied in part by the tabloid

"In our global village, the need to gossip is now satisfied in part by the tabloid press"

inspired youngsters to consider a career in science.

For those of a more practical bent, funding for energy efficiency and renewables could be cut by a whopping 27.3 per cent. It is hard to imagine an applied research programme that is more relevant and important to the health and security of our society.

Cutting that funding is likely to have economic consequences too. In this highly competitive world, the country that leads the research and development in these areas will gain a huge advantage. One only has to consider the fraction of the US's gross domestic product that resulted from R&D a generation or two ago into technologies ranging from the transistor to the microchip.

If, as a consequence of a decade of unprecedented military spending, we are prepared to give up our grandest intellectual dreams while at the same time cutting efforts to solve the chief technological challenges we face, have we not lost far more than we may have we won? ■

Lawrence Krauss is director of the Origins Project at Arizona State University in Tempe. His most recent book, *Quantum Man: Richard Feynman's life in science* was published in March (W. W. Norton & Co)

press. Our interest in the peccadilloes and misbehaviour of celebrities and politicians, and our purchase, sometimes surreptitiously, of tabloid newspapers and gossip magazines is an evolutionary hangover from a time when knowing who was sleeping with who in our village was important.

We might be ashamed of it, but our brains were designed to lap it up. In buying tabloid newspapers and celebrity magazines, we are satisfying a primal evolutionary need. ■

John Hardy is professor of neuroscience at University College London

One minute with...

Eli Pariser

Hidden filters control what we see online, says the campaigner fighting against the "dark side" of web personalisation

What is the "filter bubble" you talk about?
Increasingly we don't all see the same internet. We see stories and facts that make it through a membrane of personalised algorithms that surround us on Google, Facebook, Yahoo and many other sites. The filter bubble is the personal, unique universe of information that results and that we increasingly live in online.

You discovered the filter bubble when you noticed people were getting different results for the same Google search and Facebook friends with differing political views were phased out of your feed. Why is this harmful?
I take these Facebook dynamics pretty seriously simply because it's a medium that 1 in 11 people now use. If at a mass level people don't hear about ideas that are challenging or only hear about ideas that are likeable – as in, you can easily click the "like" button on them – that has fairly significant consequences.

We have long relied on content filters, in the form of publications or TV channels we choose. How is the filter bubble different?
Yes we've always used filters of some sort, but in this case we don't know we are. We think of the internet as this place where we directly connect with information, but in fact there are these intermediaries, Facebook and Google, that are in the middle in just the same way that editors were. This is invisible; we don't even see that a lot of the time there is filtering at work. It is hard to know what's being edited out. And it is not like reading a magazine where readers are seeing the same set of articles. Your information environment could differ dramatically from that of your friends and colleagues.

You've been called "alarmist" and have been accused of overstating the effects of web personalisation. What's your response?
There are two things. One is that I'm trying to describe a trend. I'm trying to make the case that it will continue unless we avert it. I'm not suggesting that it's checkmate already.

PROFILE
Eli Pariser is former executive director and current board president of liberal activism site MoveOn.org. His new book, *The Filter Bubble*, looks at the effects of internet personalisation

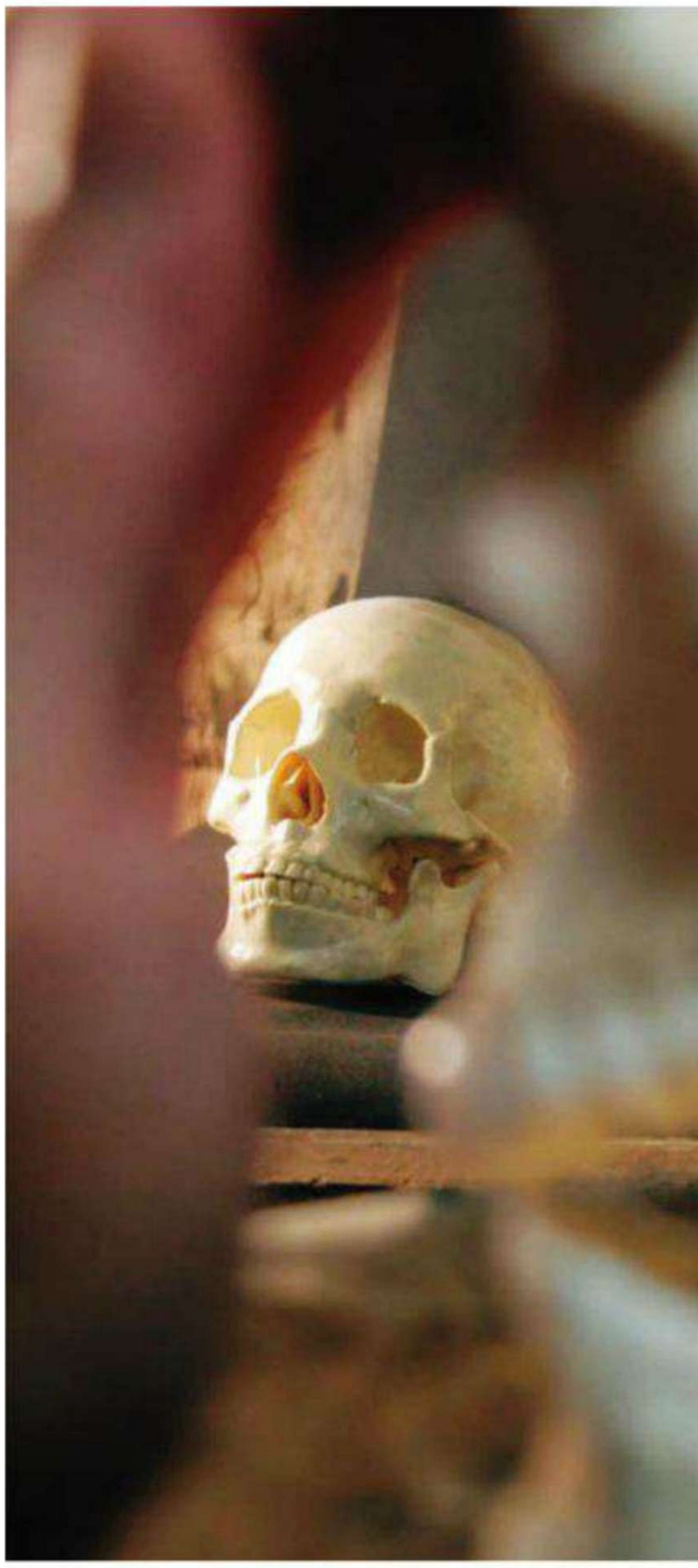
Second, recent research published in the peer-reviewed journal *First Monday* shows that the effects of personalisation on Google are quite significant: 64 per cent of results are different either in rank or simply different between the users they tested. That's not a small difference.

You offer tips for bursting the filter bubble, such as deleting cookies and clearing browser history. More broadly, what kind of awareness are you hoping to promote?
I want people to know that the more you understand how these tools are actually working the more you can use them rather than having them use you. My other objective is to highlight the value of the personal data that we're all giving to these companies and to call for more transparency and control when it comes to that data. We're building a whole economy that is premised on the notion that these services are free, but they're really not free. They convert directly into money for these companies, and that should be much more transparent.

Interview by Tiffany O'Callaghan

Taking the measure of Gould's skulls

Stephen Jay Gould was wrong about the inevitability of bias in science. Scientists may be biased, but results are not, argue **David DeGusta** and **Jason E. Lewis**



TRUTH is hard to come by, as personal lives and politics readily illustrate. Since science lays claim to providing some form of truth, it is bound to draw criticism on that count. Surprisingly, one of the sharpest attacks came from within, and from one of the giants, Harvard University's Stephen Jay Gould.

Gould was a man of many parts – invertebrate palaeontologist, evolutionary theorist, historian of science, crusader against creationism and a prolific populariser of science with a slew of bestselling books. He was an iconic scientist of the late 20th century, a stature confirmed by that arbiter of cultural relevance, *The Simpsons*, in which he was a featured guest star in one episode.

Even so, Gould harboured grave doubts about the ability of science to remain free from social pressures and bias. He made a series of statements in a 1978 *Science* paper that are startling given his role as a spokesperson for science: "...unconscious or dimly perceived finagling, doctoring, and massaging are rampant, endemic, and unavoidable in a profession [science] that awards status and power for clean and unambiguous discovery"; "unconscious manipulation of data may be a scientific norm"; "scientists are human beings rooted in cultural contexts, not automatons directed toward external truth". This was blasphemy from the pulpit.

To support these claims, Gould presented the case of Samuel George Morton, a 19th-century American physician and scientist famous for his measurements of human skulls, particularly their cranial capacity (the skeletal equivalent of brain size). Morton's aim in measuring skulls from a diverse range of human groups was not to get at intelligence differences, as is sometimes claimed. Instead, Morton hoped to determine whether different human populations were one species or many, and thus whether the divine creation had been singular or a play in several acts.

Gould reanalysed Morton's data, and famously argued in *Science* and in his prize-winning bestseller *The Mismeasure of Man*, that Morton had manipulated his samples, made analytical errors, and mismeasured cranial capacities as a consequence of a racist bias. Gould concluded that Morton's fudging was most likely unconscious, since Morton made no apparent attempt to cover his tracks, publishing all his raw data. Gould's study quickly became famous, and his view that science was inevitably biased became the consensus view in science studies. Gould's claims about Morton were rarely challenged, and never effectively.

There matters stood until one of us, Jason E. Lewis, decided to do what Gould had not – remeasure the skulls in Morton's collection, kept at the University of Pennsylvania, Philadelphia. Several colleagues advised and assisted us, particularly Marc R. Meyer, now at Chaffey College, Rancho Cucamonga, California. We remeasured 308 of the 670 skulls originally in Morton's collection – some had been reburied. Find our data at bit.ly/pmZlLL.

Next, we scrutinised every claim Gould made, redid every analysis Gould did, and then did the same for Morton. If Gould was right and Morton had mismeasured some skulls because of racial bias, we would expect the mismeasured crania to be non-randomly distributed by population: Morton's overestimates would be concentrated on the crania of "white" people, while his underestimates would be mostly "non-white". But we found Morton had only overmeasured "non-white" crania. Statistically, his errors were generally distributed randomly by population, with the exception of a possible tendency to overmeasure Egyptian crania. Morton considered Egyptian skulls "Negro", so his errors did not fit with his predicted bias.

Overall, we found no evidence that Morton's bias had affected his results. Gould, in contrast, made a number of clear errors, all connected with his own presumed bias towards there being a lack of differences between populations. For example, Gould

PROFILE
David DeGusta is at the Palaeoanthropology Institute in Oakland, California. **Jason E. Lewis** is in the anthropology department at Stanford University, California. This article is based on their recent paper in *PloS Biology*, entitled "The Mismeasure of Science" (vol 9, p e1001071)

DANIELLAI/AURORA PHOTOS

In the 1830s, Samuel Morton considered skull size crucial in establishing human origins

published an erroneously low Caucasian average cranial capacity, and an erroneously high Native American average, due to mistakes in how he used Morton's data.

With our collaborators, we published our results in the June issue of *PLoS Biology*, where we were careful to point out that, far from refuting Gould's well-known attacks on racism, we share his concerns. Gould's opposition to the pseudo-science of racism was not based on his analysis of Morton. Furthermore, the generally small cranial capacity differences within humans do not correlate with intelligence or much else other than hat size.

Even so, publishing that Gould has erred will inevitably bring joy to racists, much as the unmasking of the Piltdown man fossil as a hoax is a continuing source of glee to creationists, despite the abundant evidence falsifying both creationism and the pseudo-science of racism.

For us to abdicate from our responsibility to the self-correcting nature of science for fear of what some may make of the errors would be a tragic mistake, because it would transform science into the kind of advocacy-driven operation some mistakenly accuse it of being.

Some commentators have observed that Gould may have proven his own point about bias being inevitable in science, but with the bias merely being his own rather than Morton's. We note this possibility in our paper, but there is an important difference between what Gould was claiming of Morton and what Gould seems to have done himself.

With Morton, Gould claimed unconscious bias could impact even the most seemingly objective and straightforward part of science: basic measurements and averages. In contrast, Gould did not generate any measurements. Instead he manipulated Morton's data and summarised his work. That bias can influence the sort of secondary work Gould did is a different and a much less surprising claim than unconscious bias influencing actual measurements. Further, Gould's claim was about unconscious bias, rather than deliberate

"Publishing that Gould erred will inevitably bring joy to racists"

misconduct, the latter being a known hazard in science, though of uncertain frequency. So into which category do Gould's errors fall? We find it hard to see how to test hypotheses about his motivations, especially since those possible motivations are far from binary: there is a continuum between unconscious error and deliberate fraud. Ultimately, we consider the question of whether Gould's errors were deliberate, unconscious, or in-between, to be open to debate.

Morton, though, had clear racial biases, which are stated explicitly in his books. And Gould was certainly right that all scientists, as humans, have some sort of bias. But while biased scientists are inevitable, biased results are not, as illustrated by Morton (biased) and his data (unbiased, as far as we can tell). Science does not depend on unbiased investigators but on methods which limit the ability of the investigator's bias to influence the results. Morton's methods appear to have been sufficient in this regard.

Along with our reanalysis of the Morton case, we would counter Gould's claim of inevitably biased results with this thought experiment. A geneticist in his 20s with a family history of Huntington's disease – a fatal condition with a simple genetic basis and symptoms which typically manifest in middle age – decides to test himself for the disease gene. A greater bias regarding the outcome is unimaginable: it is literally life and death. Yet the method is so robust that even such an extreme bias cannot, short of fraud, influence the results.

Truth is hard, but it is sometimes obtainable despite even our strongest biases. What a marvellous thing, this science. ■

Rocky ground

From Carina Hoorn, geologist and former lecturer at Sultan Qaboos University, Oman

The article on the arrest and detention of meteorite hunters Michael Farmer and Robert Ward reads more like an adventure story than an account of how scientists would collect samples in foreign fields (2 July, p 28).

They did not seem to have engaged in partnership with academic or government authorities in Oman. There, as in many countries, the export of such materials is forbidden without agreement. Breaking this rule can sometimes lead to unpleasant situations.

The normal procedure before collecting rocky or biological material would be to establish cooperation with scientists. Prior to going into the field, this should be formalised through a memorandum of understanding or of agreement. Finally, export permits would need to be secured from the authorities.

It is sad that Farmer and Ward suffered hardship, terror even, in an Omani prison. However, it should be noted that Omanis are known as good hosts to invited – and even unexpected – guests.

The Hague, Netherlands

Mechanical cheat

From Alan Bundy, University of Edinburgh

Jim Giles and Zena Iovino described abuses of outsourcing website Mechanical Turk by those offering online jobs (9 July, p 20). Abuse frequently occurs in the opposite direction too.

Researchers paying turkers to fill in multiple choice questionnaires find that a large proportion try to bend the rules. In order to maximise income, they answer as quickly as possible by clicking the most convenient button. In order to exclude these responses from their data, researchers have to use a variety of devices, such as planting questions with obvious answers then ignoring responses from anyone who gets these wrong.

Researchers not taking such precautions will find that referees reject their results.

Edinburgh, UK

This race is run

From Colin Jowett

In talking of the post-shuttle era (9 July, p 3), one would have to question the point of crewed low-Earth orbit missions – low-Earth orbit being up to 2000 kilometres from the Earth's surface, and including the International Space Station. This is probably what the

US administration has figured out. Other than an extremely useful laboratory, functions such as communication, spying and possible missile systems can all be run without the need for humans in orbit, which is risky and costly.

Developing nations will see crewed missions as a game of the big players, in the same way as they view nuclear technology, and will always want a seat at the table. A few short and rather fruitless visits to the moon proved only that space travel is exceptionally difficult.

The space race? It ain't over, but it probably should be.

Auckland, New Zealand

Questioning g

From Nigel Sawyer

In your "Instant Expert" on intelligence (2 July), I was surprised at the uncritical acceptance of g, the general factor of intelligence. Author Stephen Jay Gould has dismissed it as an artefact of the mathematical method used to calculate it.

Readers who want a more sceptical view should read Gould's 1981 book *The Mismeasurement of Man*. In it, he highlights the misuse of intelligence tests, especially in the US during and just after the first world war, when testing of both immigrants and army recruits can probably be described as prime examples of institutionalised racism and bias.

Kingston, Surrey, UK

-. ..- -- -... . .-. ...

From Richard Horton

When Alex Bellos was asked if any strange suggestions came up in his exploration of favourite numbers (25 June, p 29), he said 73, because a character in the comedy show *The Big Bang Theory* had described it as the "Chuck Norris of numbers".

There may be another explanation for its popularity. In Morse code, abbreviations are used for common words to save time, such as TX for "transmitter" and RX for "receiver". In this list are some numbers, including 73 for "best wishes" and 88 for "love and kisses".

Not only are most of the 2.6 million radio amateurs in the world familiar with these, but also anyone who knows Morse code. It would be interesting to know if 88 gets a high score too.

Harrogate, North Yorkshire, UK

For the record

■ **Pharmaceutical firm Lundbeck, which has stopped supplying pentobarbital to US death row prisons (9 July, p 5), is based in Copenhagen, Denmark**

Enigma Number 1656

Five integers

RICHARD ENGLAND

I have written down five single-digit positive integers.

The sum of the five integers is divisible by the fifth integer, but not by any of the first four. The sum of the first four integers is divisible by the fourth but not by any of the first three. The sum of the first three integers is divisible by the third but not by either of the first two. The sum of the first two integers is divisible by the second but not by the first.

List the five integers in the order in which I have written them down.

WIN £15 will be awarded to the sender of the first correct answer opened on Tuesday 23 August. The Editor's decision is final. Please send entries to Enigma 1656, New Scientist, Lacon House, 84 Theobald's Road, London WC1X 8NS, or to enigma@newscientist.com (please include your postal address).

Answer to 1650 Some prime magic: CxHxJxL = 13,742,001

The winner Dean Witter III of Woodside, California, US

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THE EXISTENTIAL ISSUE

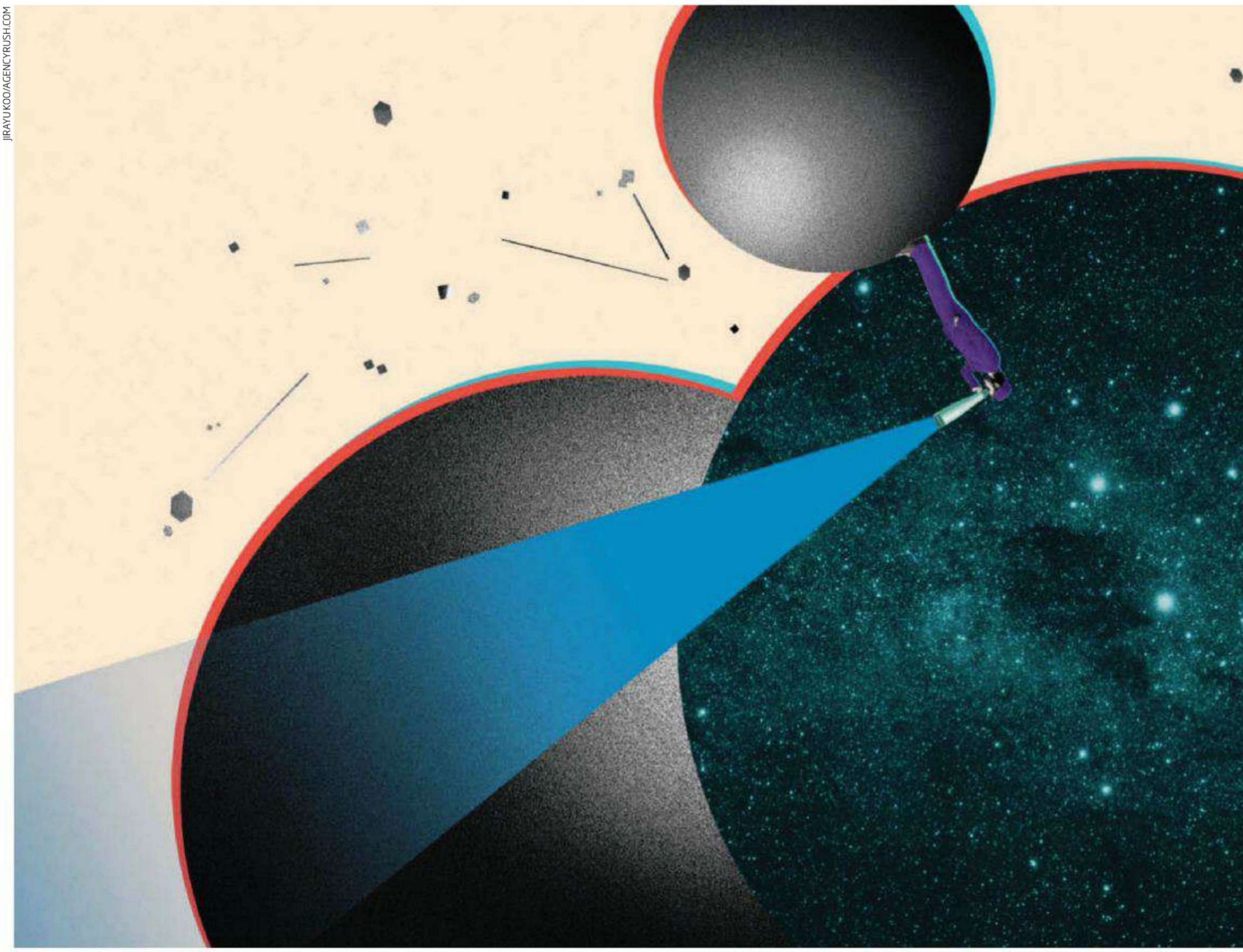
It's lucky you're here

13.7 billion years ago, the universe was born in a cosmic fireball. Roughly 10 billion years later, the planet we call Earth gave birth to life, which eventually led to you. The probability of that sequence of events is absolutely minuscule, and yet it still happened.

Take a step back from the unlikeliness of your own personal existence and things get even more mind-boggling. Why does the universe exist at all? Why is it fine-tuned to human life? Why does it seem to be telling us that there are other universes out there, even other yous?

In the next 16 pages, we confront these mysteries of existence and others, from the possibility that the universe is a hologram to the near-certainty that you are a zombie

JIRAYU KOO/AGENCYRUSH.COM



JIRAYU KOO/AGENCYRUSH.COM

Why is there something rather than nothing?

AS DOUGLAS ADAMS once wrote: "The universe is big. Really big." And yet if our theory of the big bang is right, the universe was once a lot smaller. Indeed, at one point it was non-existent. Around 13.7 billion years ago time and space spontaneously sprang from the void. How did that happen?

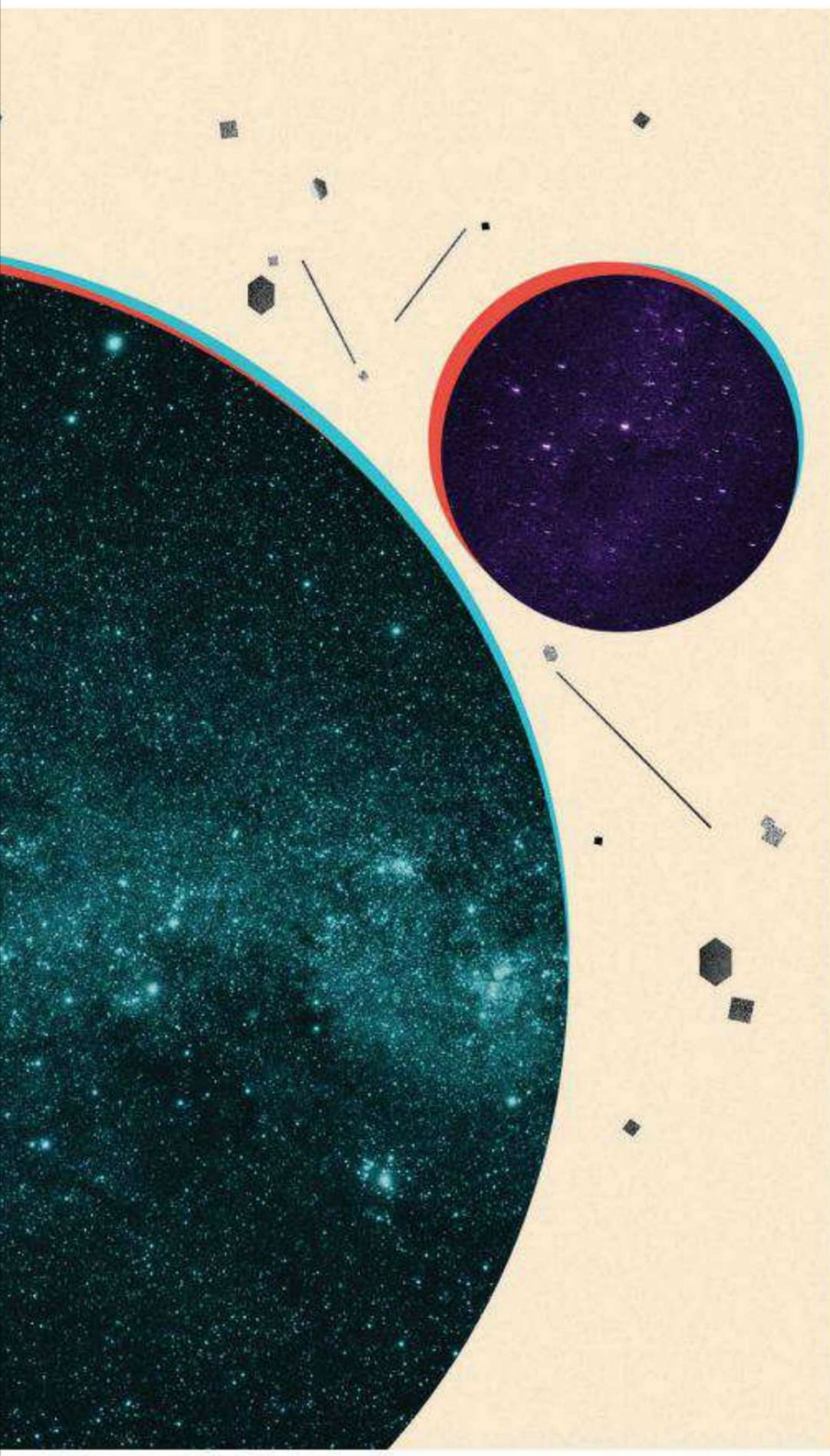
Or to put it another way: why does anything exist at all? It's a big question, perhaps the biggest. The idea that the universe simply appeared out of nothing is difficult enough; trying to conceive of nothingness is perhaps even harder.

It is also a very reasonable question to ask from a scientific perspective. After all, some basic physics suggests that you and the rest of the universe are overwhelmingly unlikely to exist. The second law of thermodynamics, that most existentially resonant of physical laws, says that disorder, or entropy, always tends to increase. Entropy measures the number of ways you can rearrange a system's components without changing its overall appearance. The molecules in a hot gas, for example, can be arranged in many different ways to create the same overall temperature and pressure, making the gas a high-entropy system. In contrast, you can't rearrange the molecules of a living thing very much without turning it into a non-living thing, so you are a low-entropy system.

By the same logic, nothingness is the highest entropy state around – you can shuffle it around all you want and it still looks like nothing.

Given this law, it is hard to see how nothing could ever be turned into something, let alone something as big as a universe. But entropy is only part of the story. The other consideration is symmetry – a quality

Also in this section
- Are we alone? page 30
- Am I a hologram? page 31
- How do I know I exist? page 36
- Is there more than one me? page 37
- Will we die out? page 39
- How will it all end? page 43



that appears to exert profound influence on the physical universe wherever it crops up. Nothingness is very symmetrical indeed. "There's no telling one part from another, so it has total symmetry," says physicist Frank Wilczek of the Massachusetts Institute of Technology.

And as physicists have learned over the past few decades, symmetries are made to be broken. Wilczek's own speciality is quantum chromodynamics, the theory that describes how quarks behave deep within atomic nuclei. It tells us that nothingness is a precarious state of affairs. "You can form a state that has no quarks and antiquarks in it, and it's totally unstable," says Wilczek. "It spontaneously starts producing quark-antiquark pairs." The perfect symmetry of nothingness is broken. That leads to an unexpected conclusion, says Victor Stenger, a physicist at the University of Colorado in Boulder: despite entropy, "something is the more natural state than nothing".

"Perhaps the big bang was just nothingness doing what comes naturally"

"According to quantum theory, there is no state of 'emptiness'," agrees Frank Close of the University of Oxford. Emptiness would have precisely zero energy, far too exacting a requirement for the uncertain quantum world. Instead, a vacuum is actually filled with a roiling broth of particles that pop in and out of existence. In that sense this magazine, you, me, the moon and everything else in our universe are just excitations of the quantum vacuum.

Before the big bang

Might something similar account for the origin of the universe itself? Quite plausibly, says Wilczek. "There is no barrier between nothing and a rich universe full of matter," he says. Perhaps the big bang was just nothingness doing what comes naturally.

This, of course, raises the question of what came before the big bang, and how long it lasted. Unfortunately at this point basic ideas begin to fail us; the concept "before" becomes meaningless. In the words of Stephen Hawking, it's like asking what is north of the north pole.

Even so, there is an even more mind-blowing consequence of the idea that something can come from nothing: perhaps nothingness itself cannot exist.

Here's why. Quantum uncertainty allows a trade-off between time and energy, so something that lasts a long time must have little energy. To explain how our universe has lasted for the billions of years that it has taken galaxies to form, solar systems to coalesce and life to evolve into bipeds who ask how something came from nothing, its total energy must be extraordinarily low.

That fits with the generally accepted view of the universe's early moments, which sees space-time undergoing a brief burst of expansion immediately after the big bang. This heady period, known as inflation, flooded the universe with energy. But according to Einstein's general theory of relativity, more space-time also means more gravity. Gravity's attractive pull represents negative energy that can cancel out inflation's positive energy – essentially constructing a cosmos for nothing. "I like to say that the universe is the ultimate free lunch," says Alan Guth, a cosmologist at MIT who came up with the inflation theory 30 years ago.

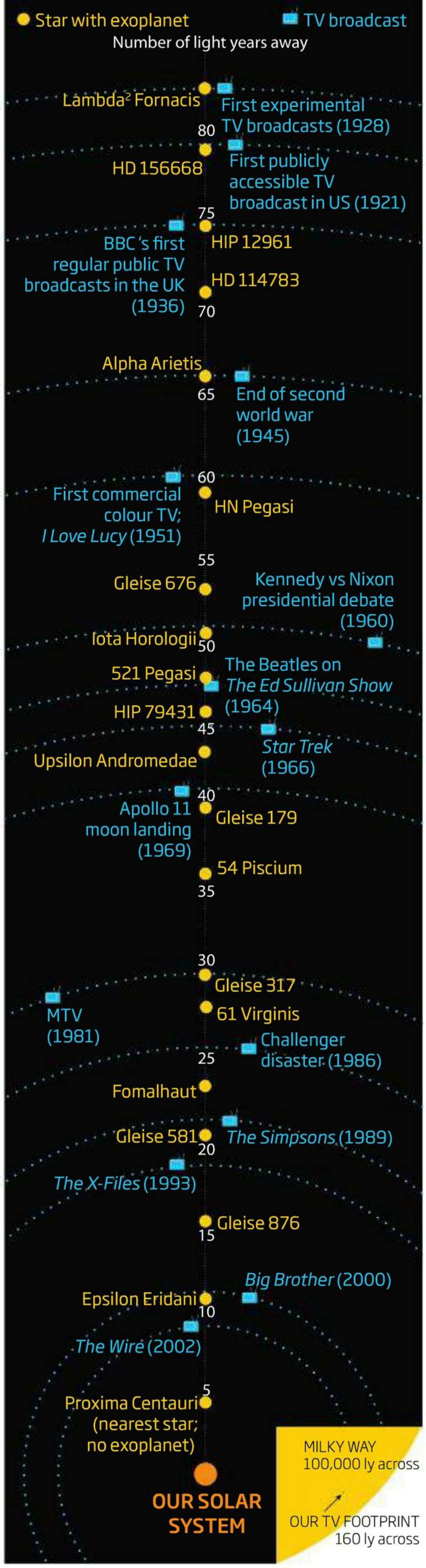
Physicists used to worry that creating something from nothing would violate all sorts of physical laws such as the conservation of energy. But if there is zero overall energy to conserve, the problem evaporates – and a universe that simply popped out of nothing becomes not just plausible, but probable. "Maybe a better way of saying it is that something *is* nothing," says Guth.

None of this really gets us off the hook, however. Our understanding of creation relies on the validity of the laws of physics, particularly quantum uncertainty. But that implies that the laws of physics were somehow encoded into the fabric of our universe before it existed. How can physical laws exist outside of space and time and without a cause of their own? Or, to put it another way, why is there something rather than nothing?

Amanda Gefter ■

BROADCASTING TO THE STARS

TV signals from Earth are travelling outwards at light speed. If aliens are out there, here's what they are watching



Are we alone?

HAVE you ever looked up at the night sky and wondered if somebody, or something, is looking back? If perhaps somewhere out there, the mysterious spark we call life has flickered into existence?

Intuitively, it feels as if we can't be alone. For every one of the 2000 stars you can see with your naked eye, there are another 50 million in our galaxy, which is one of 100 billion galaxies. In other words, the star we orbit is just one of 10,000 billion billion in the cosmos. Surely there is another blue dot out there – a home to intelligent life like us? The simple fact is, we don't know.

One way to estimate the number of intelligent civilisations was devised by astronomer Frank Drake. His equation takes into account the rate of star formation, the fraction of those stars with planets and the likelihood that life, intelligent life, and intelligent creatures capable of communicating with us, will arise.

It is now possible to put numbers on some of those factors. We know that about 20 stars are born in the Milky Way every year and we have spotted more than 560 planets around stars other than the sun. About a quarter of stars harbour a planet similar in mass to Earth (*Science*, vol 330, p 653).

But estimating the biological factors is little more than guesswork. We know that life is incredibly adaptable once it emerges, but not how good it is at getting started in the first place.

Unique planet

Some astronomers believe life is almost inevitable on any habitable planet. Others suspect simple life is common, but intelligent life exceedingly rare. A few believe that our planet is unique. "Life may or may not form easily," says physicist Paul Davies of Arizona State University in Tempe. "We're completely in the dark."

So much for equations. What about evidence? Finding life on Mars probably won't help, as it would very likely share its origin with Earthlings. "Impacts have undoubtedly conveyed microorganisms back and forth," says Davies. "Mars and Earth are not independent ecosystems."

Discovering life on Titan would be more revealing. Titan is the only other place in the solar system with liquid on its surface – albeit lakes of ethane. "We are starting to think that if there is life on Titan it would have a separate origin," says Dirk Schulze-Makuch at Washington State University in Pullman. "If we can find a separate origin we can say 'OK, there's a lot of life in the universe'."

Discovering alien microbes in our solar system would be some sort of proof that we are not alone, but what we really want to know is whether there is another intelligence out there. For 50 years astronomers have swept the skies with radio telescopes for any hint of a message. So far, nothing.

But that doesn't mean ET isn't there. It just might not know we're here. The only evidence of our existence that reaches beyond the solar system are radio signals and light from our cities. "We've only been broadcasting powerful radio signals since the second world war," says Seth Shostak of the SETI Institute in Mountain View, California. So our calling card has leaked just 70 light years into space, a drop in the ocean. If the Milky Way was the size of London and Earth was at the base of Nelson's Column, our radio signals would still not have left Trafalgar Square.

"It's probably safe to say that even if the local galaxy is choc-a-bloc with aliens, none of them know that *Homo sapiens* is here," says Shostak. That also works in reverse. Given the size of the universe and the speed of light, most stars and planets are simply out of range.

It is also possible that intelligent life is separated from us by time. After all, human intelligence has only existed for a minuscule fraction of Earth's history and may just be a fleeting phase (see page 39). It may be too much of a stretch to hope that a nearby planet not only harbours intelligent life, but that it does so right now.

But let's say we did make contact with aliens. How would we react? NASA has plans, and most religions claim they would be able to absorb the idea, but the bottom line is we won't know until it happens.

Most likely we'll never find out. Even if Earth is not the only planet with intelligent life, we appear destined to live out our entire existence as if it were - but with a nagging feeling that it can't be. How's that for existential uncertainty? **Valerie Jamieson** ■

TRENT PARKE/MAGNUM PHOTOS

"The entire 3D universe we experience may be encoded in a 2D surface"

Am I a hologram?

TAKE a look around you. The walls, the chair you're sitting in, your own body – they all seem real and solid. Yet there is a possibility that everything we see in the universe – including you and me – may be nothing more than a hologram.

It sounds preposterous, yet there is already some evidence that it may be true, and we could know for sure within a couple of years. If it does turn out to be the case, it would turn our common-sense conception of reality inside out.

The idea has a long history, stemming from an apparent paradox posed by Stephen Hawking's work in the 1970s. He discovered that black holes slowly radiate their mass away. This Hawking radiation appears to carry no information, however, raising the question of what happens to the information that described the original star once the black hole evaporates. It is a cornerstone of physics that information cannot be destroyed.

In 1972 Jacob Bekenstein at the Hebrew University of Jerusalem, Israel, showed that the information content of a black hole is proportional to the two-dimensional surface area of its event horizon – the point-of-no-return for in-falling light or matter. Later, string theorists managed to show how the original star's information could be encoded in tiny lumps and bumps on the event horizon, which would then imprint it on the Hawking radiation departing the black hole.

This solved the paradox, but theoretical physicists Leonard Susskind and Gerard 't Hooft decided to take the idea a step further: if a three-dimensional star could be encoded on a black hole's 2D event horizon, maybe the same could be true of the whole universe. The universe does, after all, have a horizon 42 billion light years away, beyond which point light would not have had time to reach us since the big ›

bang. Susskind and 't Hooft suggested that this 2D "surface" may encode the entire 3D universe that we experience – much like the 3D hologram that is projected from your credit card.

It sounds crazy, but we have already seen a sign that it may be true. Theoretical physicists have long suspected that space-time is pixelated, or grainy. Since a 2D surface cannot store sufficient information to render a 3D object perfectly, these pixels would be bigger in a hologram. "Being in the [holographic] universe is like being in a 3D movie," says Craig Hogan of Fermilab in Batavia, Illinois. "On a large scale, it looks smooth and three-dimensional, but if you get close to the screen, you can tell that it is flat and pixelated."

Quantum fluctuation

Hogan recently looked at readings from an exquisitely sensitive motion-detector in Hanover, Germany, which was built to detect gravitational waves – ripples in the fabric of space-time. The GEO600 experiment has yet to find one, but in 2008 an unexpected jitter left the team scratching their heads, until Hogan suggested that it might arise from "quantum fluctuations" due to the graininess of space-time. By rights, these should be far too small to detect, so the fact that they are big enough to show up on GEO600's readings is tentative supporting evidence that the universe really is a hologram, he says.

Bekenstein is cautious: "The holographic idea is only a hypothesis, supported by some special cases." Better evidence may come from a dedicated instrument being built at Fermilab, which Hogan expects to be up and running within a couple of years.

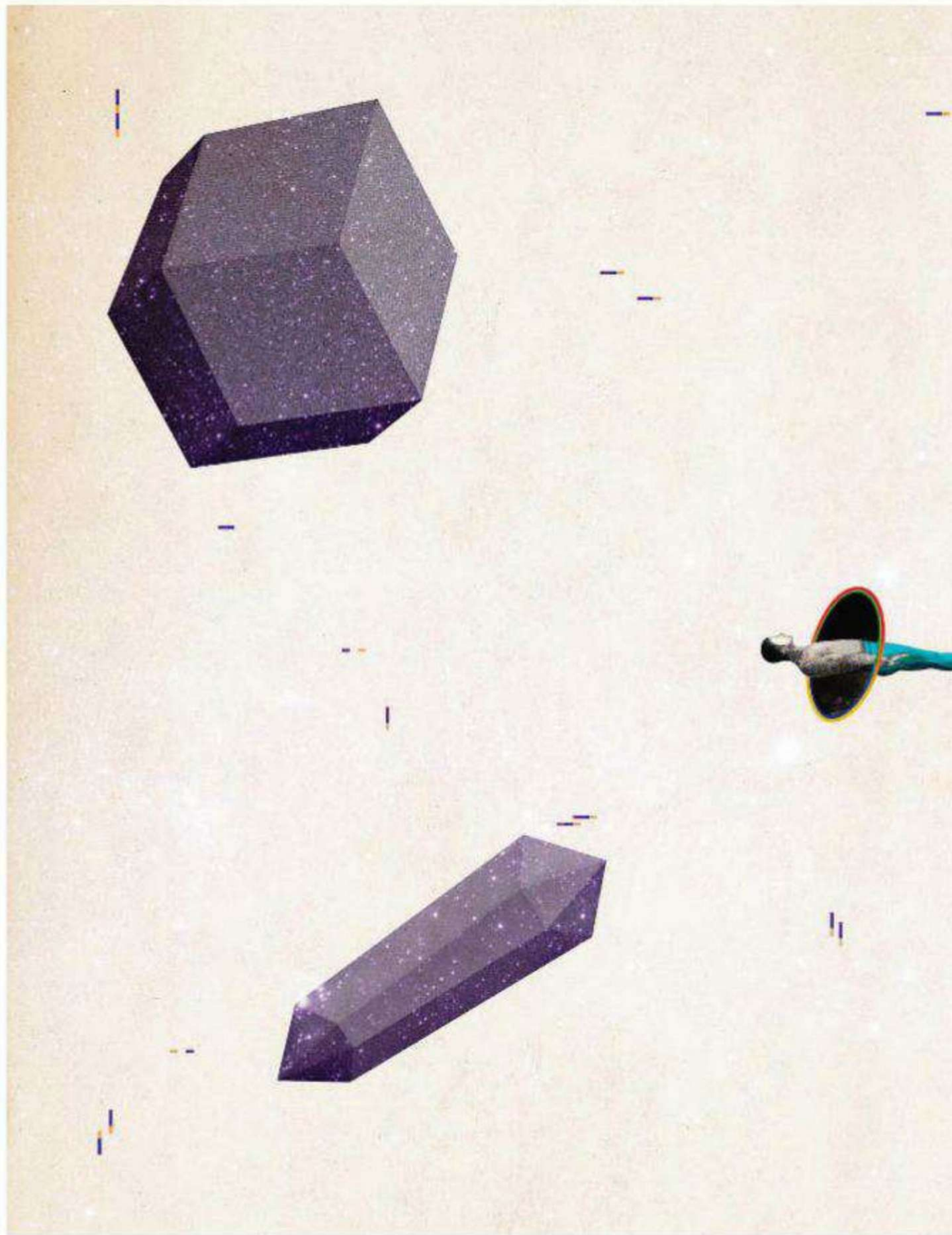
A positive result would challenge every assumption we have about the world we live in. It would show that everything is a projection of something occurring on a flat surface billions of light years away from where we perceive ourselves to be. As yet we have no idea what that "something" might be, or how it could manifest itself as a world in which we can do the school run or catch a movie at the cinema. Maybe it would make no difference to the way we live our lives, but somehow I doubt it. Marcus Chown ■

Why me?

THINK for a moment about a time before you were born. Where were you? Now think ahead to a time after your death. Where will you be? The brutal answer is: nowhere. Your life is a brief foray on Earth that started one day for no reason and will inevitably end.

But what a foray. Like the whole universe, your consciousness popped into existence out of nothingness and has evolved into a rich and complex entity full of wonder and mystery.

Contemplating this leads to a host of mind-boggling questions. What are the odds of my consciousness existing at all? How can such a thing emerge from nothingness? Is there any possibility of it surviving my death? And what is consciousness anyway?



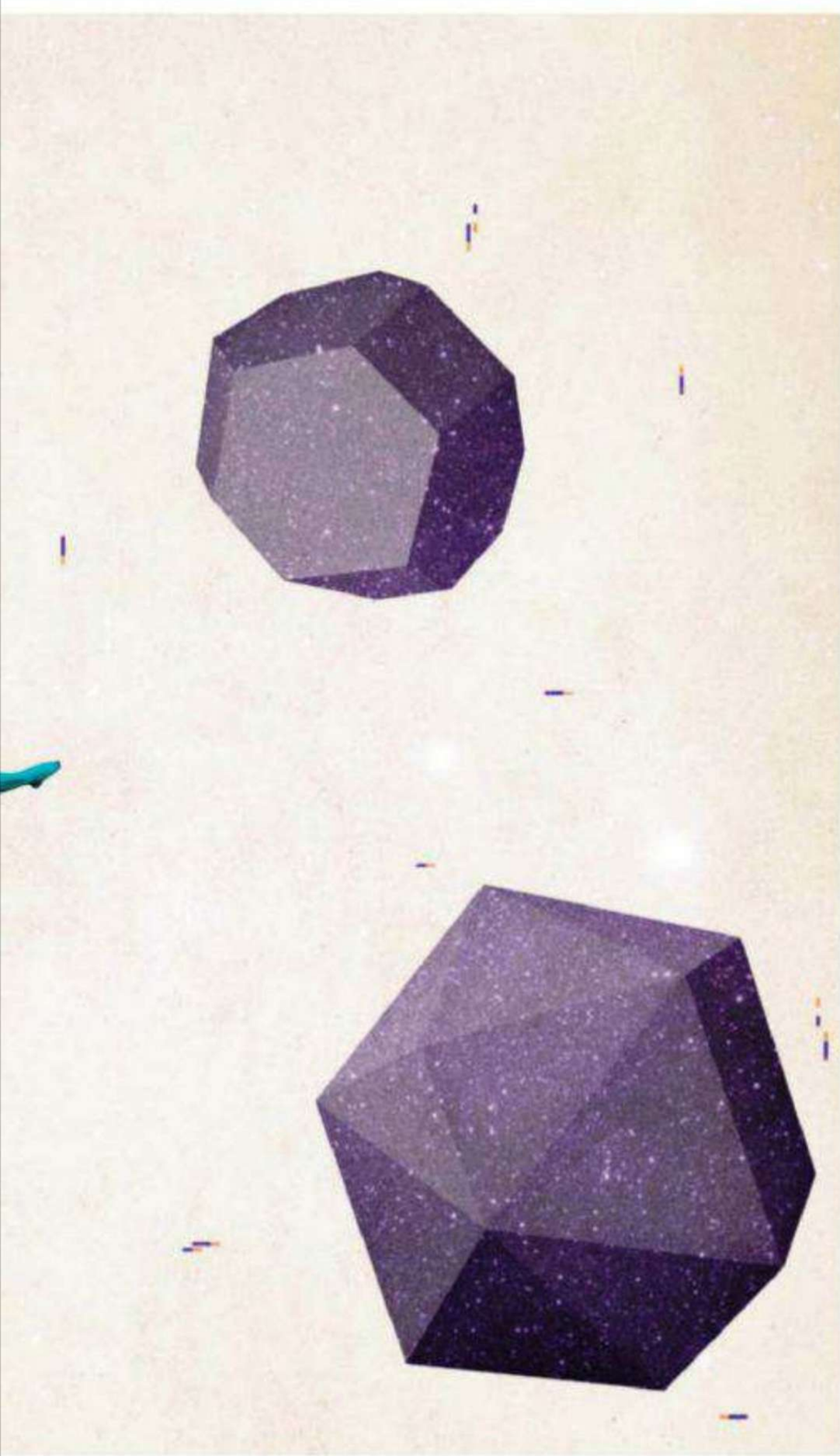
JIRAYU KOO

Answering these questions is incredibly difficult. Philosopher Thomas Nagel once asked, "What is it like to be a bat?" Your response might be to imagine flying around in the dark, seeing the world in the echoes of high-frequency sounds. But that isn't the answer Nagel was looking for. He wanted to emphasise that there is no way of knowing what it is like for a bat to feel like a bat. That, in essence, is the conundrum of consciousness.

Neuroscientists and philosophers fall into two broad camps. One thinks that consciousness is an emergent property of the brain and that once we fully understand the intricate workings of neuronal activity, consciousness will be laid bare. The other doubts it will be that simple. They agree that consciousness emerges from the brain, but argue that Nagel's question will always remain unanswered: knowing every detail of a bat's brain cannot tell us what it is like to be a bat. This is often called the "hard problem" of consciousness, and seems scientifically intractable – for now.

Meanwhile, "there are way too many so-called easy problems to worry about", says Anil Seth of the University of Sussex in Brighton, UK.

One is to look for signatures of consciousness in brain activity, in the hope that this takes us closer to understanding what it is. Various brain areas have been found to be active when we are conscious of something and quiet when we are not. For example, Stanislas Dehaene of the French National Institute of Health and Medical Research in Gif sur Yvette and colleagues have identified such regions in our frontal and parietal lobes (*Nature Neuroscience*, vol 8, p 1391).



"Once we understand the intricate workings of the brain, conscious experience will be laid bare"

Consciousness explained

This is consistent with a theory of consciousness proposed by Bernard Baars of the Neuroscience Institute in San Diego, California. He posited that most non-conscious experiences are processed in specialised local regions of the brain such as the visual cortex. We only become conscious of this activity when the information is broadcast to a network of neurons called the global workspace – perhaps the regions pinpointed by Dehaene.

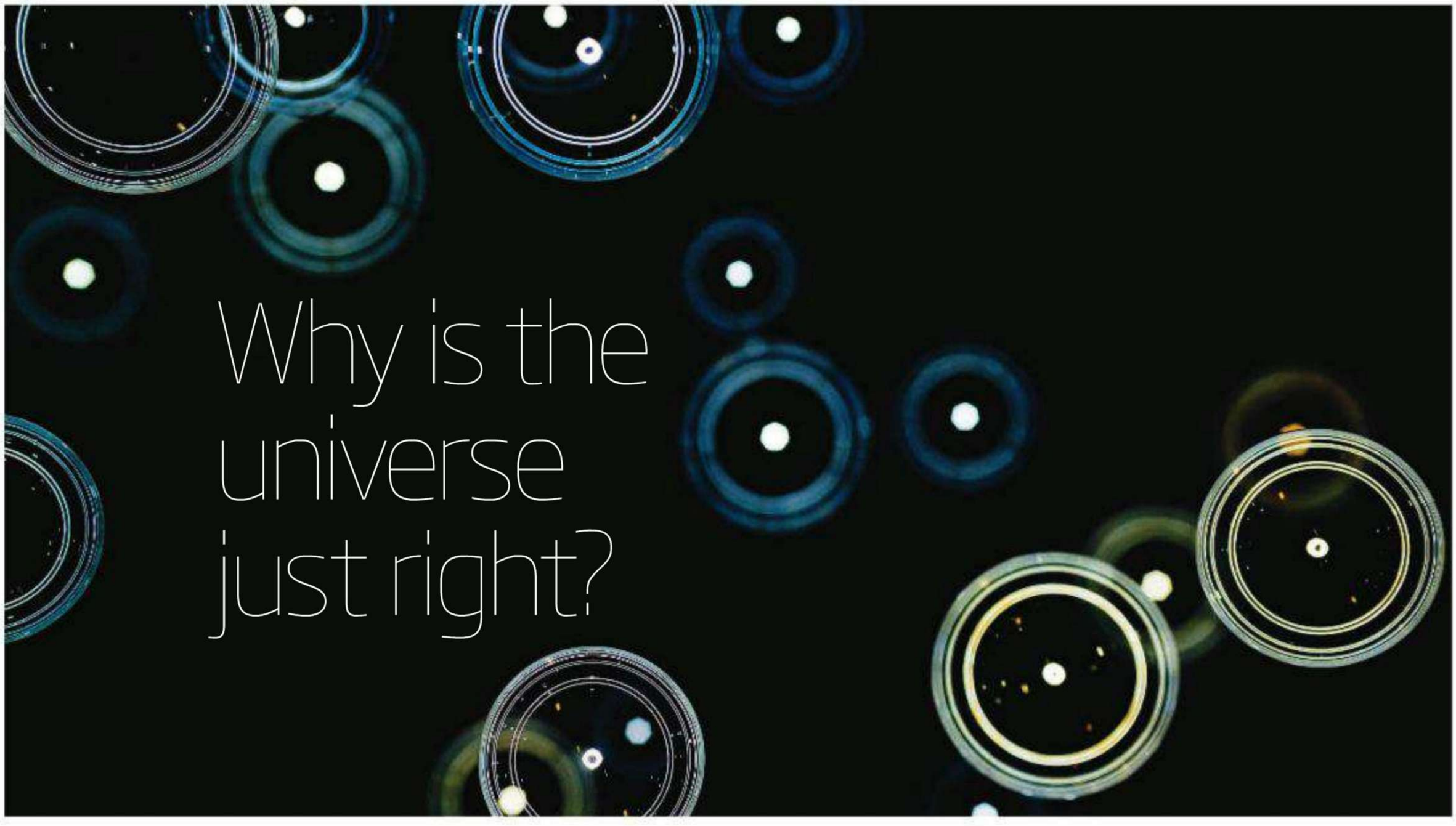
But others believe the theory is not telling the whole story. "Does global workspace theory really explain consciousness, or just the ability to report about consciousness?" asks Seth.

Even so, the idea that consciousness seems to be an emergent property of the brain can take us somewhere. For example, it makes the odds of your own consciousness existing the same as the odds of you being born at all, which is to say, very small. Just think of that next time you suffer angst about your impending return to nothingness.

As for whether individual consciousness can continue after death, "it is extremely unlikely that there would be any form of self-consciousness after the physical brain decays", says philosopher Thomas Metzinger of the Johannes Gutenberg University in Mainz, Germany.

Extremely unlikely, but not impossible. Giuilio Tononi of the University of Wisconsin-Madison argues that consciousness is the outcome of how complex matter, including the brain, integrates information. "According to Tononi's theory, if one could build a device or a system that integrated information exactly the same way as a living brain, it would generate the same conscious experiences," says Seth. Such a machine might allow your consciousness to survive death. But it would still not know what it is like to be a bat.

Anil Ananthaswamy ■



Why is the universe just right?

MARTIN SOEBY/GALLERYSTOCK

IT HAS been called the Goldilocks paradox. If the strong nuclear force which glues atomic nuclei together were only a few per cent stronger than it is, stars like the sun would exhaust their hydrogen fuel in less than a second. Our sun would have exploded long ago and there would be no life on Earth. If the weak nuclear force were a few per cent weaker, the heavy elements that make up most of our world wouldn't be here, and neither would you.

If gravity were a little weaker than it is, it would never have been able to crush the core of the sun sufficiently to ignite the nuclear reactions that create sunlight; a little stronger and, again, the sun would have burned all of its fuel billions of years ago. Once again, we could never have arisen.

Such instances of the fine-tuning of the laws of physics seem to abound. Many of the essential parameters of nature – the strengths of fundamental forces and the masses of fundamental particles – seem fixed at values that are "just right" for life to emerge. A whisker either way and we would not be here. It is as if the universe was made for us.

"The most likely explanation of fine-tuning is that our universe is merely one of many"

What are we to make of this? One possibility is that the universe was fine-tuned by a supreme being – God. Although many people like this explanation, scientists see no evidence that a supernatural entity is orchestrating the cosmos. The known laws of physics can explain the existence of the universe that we observe. To paraphrase astronomer Pierre-Simon Laplace when asked by Napoleon why his book *Mécanique Céleste* did not mention the creator: we have no need of that hypothesis.

Another possibility is that it simply couldn't be any other way. We find ourselves in a universe ruled by laws compatible with life because, well, how could we not?

This could seem to imply that our existence is an incredible slice of luck – of all the universes that could have existed, we got one capable of supporting intelligent life. But most physicists don't see it that way.

The most likely explanation for fine-tuning is possibly even more mind-expanding: that our universe is merely one of a vast ensemble of universes, each with different laws of physics. We find ourselves in one with laws suitable for life because, again, how could it be any other way?

The multiverse idea is not without theoretical backing. String theory, our best attempt yet at a theory of everything, predicts at least 10^{500} universes, each with different laws of physics. To put that number into perspective, there are an estimated 10^{25} grains of sand in the Sahara desert.

Fine-tuned fallacy

Another possibility is that there is nothing to explain. Some argue that the whole idea of fine-tuning is wrong. One vocal critic is Victor Stenger of the University of Colorado in Boulder, author of *The Fallacy of Fine-tuning*. His exhibit A concerns one of the pre-eminent examples of fine-tuning, the unlikeliness of the existence of anything other than hydrogen, helium and lithium.

All the heavy elements in your body, including carbon, nitrogen, oxygen and iron, were forged inside distant stars. In 1952, cosmologist Fred Hoyle argued that the existence of these elements depends on a huge cosmic

coincidence. One of the key steps to their formation is the "triple alpha" process in which three helium nuclei fuse together to form a carbon-12 nucleus. For this reaction to occur, Hoyle proposed that the energy of the carbon-12 nucleus must be precisely equal to the combined energy of three helium nuclei at the typical temperature inside a red giant star. And so it is.

However, Stenger points out that in 1989 a team at the Technion-Israel Institute of Technology in Haifa showed that, actually, the carbon-12 energy level could have been significantly different and still resulted in the heavy elements required for life.

There are other problems with the fine-tuning argument. One is the fact that examples of fine-tuning are found by taking a single parameter – a force of nature, say, or a subatomic particle mass – and varying it while keeping everything else constant. This seems very unrealistic. The theory of everything, which alas we do not yet possess, is likely to show intimate connections between physical parameters. The effect of varying one may very well be compensated for by variations in another.

Then there is the fact that we only have one example of life to go on, so how can we be so sure that different laws could not give rise to some other living system capable of pondering its own existence?

One example of fine-tuning, however, remains difficult to dismiss: the accelerating expansion of the universe by dark energy. Quantum theory predicts that the strength of this mysterious force should be about 10^{120} times larger than the value we observe.

This discrepancy seems extraordinarily fortuitous. According to Nobel prizewinner Steven Weinberg, if dark energy were not so tiny, galaxies could never have formed and we would not be here. The explanation Weinberg grudgingly accepts is that we must live in a universe with a "just right" value for dark energy. "The dark energy is still the only quantity that appears to require a multiverse explanation," admits Weinberg. "I don't see much evidence of fine-tuning of any other physical constants." **Marcus Chown** ■

"The existence of elements other than hydrogen, helium and lithium depends on a coincidence"

A GOLDILOCKS UNIVERSE

The values of many fundamental constants appear to lie within narrow boundaries that allow life to exist. In 2000, the UK's Astronomer Royal Martin Rees boiled them down to six in his book *Just Six Numbers*

NUMBER
N, the ratio of the strengths of two fundamental forces, electromagnetism and gravity
VALUE
about 10^{36}
IN WHAT WAY IS IT FINE-TUNED?
N determines the minimum size of sun-like stars. It tells us how big an object must be before its gravity can overcome the repulsive electromagnetic forces that keep atomic nuclei apart, igniting nuclear fusion. A larger value would not matter very much, but if N were lower, stars would be smaller and burn through their fuel more quickly, making the evolution of life unlikely.

NUMBER
ε, the proportion of the mass of a hydrogen atom that is released as energy when it is fused into helium inside a star
VALUE
0.007
IN WHAT WAY IS IT FINE-TUNED?
The fusion of hydrogen into helium is the first step in forming heavier elements and thus makes complex chemistry, and life, possible. If ε were slightly smaller, nuclear fusion would be impossible and the universe would consist only of hydrogen. If it were slightly larger, all the universe's hydrogen would have been consumed during the big bang and stars would not exist.

NUMBER
Ω, the ratio of the actual density of matter in the universe to the theoretical "critical density" which would cause the universe to collapse eventually under its own gravity
VALUE
about 0.3
IN WHAT WAY IS IT FINE-TUNED?
Ω is one of the factors that determines how fast the universe expands. If it were higher, the universe would have collapsed long ago; if it were lower, expansion would have been too rapid to allow stars and galaxies to form.

NUMBER
λ, the cosmological constant, or the energy that arises from quantum fluctuations of the vacuum
VALUE
about 0.7
IN WHAT WAY IS IT FINE-TUNED?
λ is the leading contender for the mysterious force that is accelerating the expansion of the universe. A smaller value would not be a problem, but if it were much larger the universe would have expanded so rapidly that stars or galaxies would not have had time to form.

NUMBER
Q, the amount of energy it would take to break up a galactic supercluster as a proportion of the total energy stored in all of its matter
VALUE
about 10^{-5}
IN WHAT WAY IS IT FINE-TUNED?
Q is a proxy measure of the size of the tiny fluctuations in the early universe that were eventually amplified into stars and galaxies. If it were smaller the universe would be inert and structureless; larger and the universe would be dominated by black holes by now. Neither case would support life.

NUMBER
D, the number of spatial dimensions
VALUE
3
IN WHAT WAY IS IT FINE-TUNED?
With four spatial dimensions the orbits of planets would be unstable, while life would be impossible with just two.

How do I know I exist?

IN A nutshell, you don't.

Philosopher René Descartes hit the nail on the head when he wrote "cogito ergo sum". The only evidence you have that you exist as a self-aware being is your conscious experience of thinking about your existence. Beyond that you're on your own. You cannot access anyone else's conscious thoughts, so you will never know if they are self-aware.

That was in 1644 and little progress has been made since. If anything, we are even less sure about the reality of our own existence.

It is not so long ago that computers became powerful enough to let us create alternative worlds. We have countless games and simulations that are, effectively, worlds within our world. As technology improves, these simulated worlds will become ever more sophisticated. The "original" universe will eventually be populated by a near-infinite number of advanced, virtual civilisations. It is hard to imagine that they will not contain autonomous, conscious beings. Beings like you and me.

According to Nick Bostrom, a philosopher at the University of Oxford who first made this argument, this simple fact makes it entirely plausible that our reality is in fact a simulation run by entities from a more advanced civilisation.

How would we know? Bostrom points out that the only way we could be sure is if a message popped up in front of our eyes saying: "You are living in a computer simulation." Or, he says, if the operators transported you to their reality (which, of course, may itself be a simulation).

Although we are unlikely to get proof, we might find some hints about our reality. "I think it might be feasible to get evidence that would at least give weak clues," says Bostrom.

Economist Robin Hanson of George Mason University in Fairfax, Virginia, is not so sure. If we did find anything out, the operators could just rewind everything back to a point where the clue could be erased. "We won't ever notice if they don't want us to," Hanson says. Anyway, seeking the truth might even be asking for trouble. We could be accused of ruining our creators' fun and cause them to pull the plug.

Zombie invasion

Hanson has a slightly different take on the argument. "Small simulations should be far more numerous than large ones," he says. That's why he thinks it is far more likely that he lives in a simulation where he is the only conscious, interesting being. In other words, everyone else is an extra: a zombie, if you will. However, he would have no way of knowing, which brings us back to Descartes.

Of course, we do have access to a technology that would have looked like sorcery in Descartes's day: the ability to peer inside someone's head and read their thoughts. Unfortunately, that doesn't take us any nearer to knowing whether they are sentient. "Even if you measure brainwaves, you can never know exactly what experience they represent," says psychologist Bruce Hood at the University of Bristol, UK.

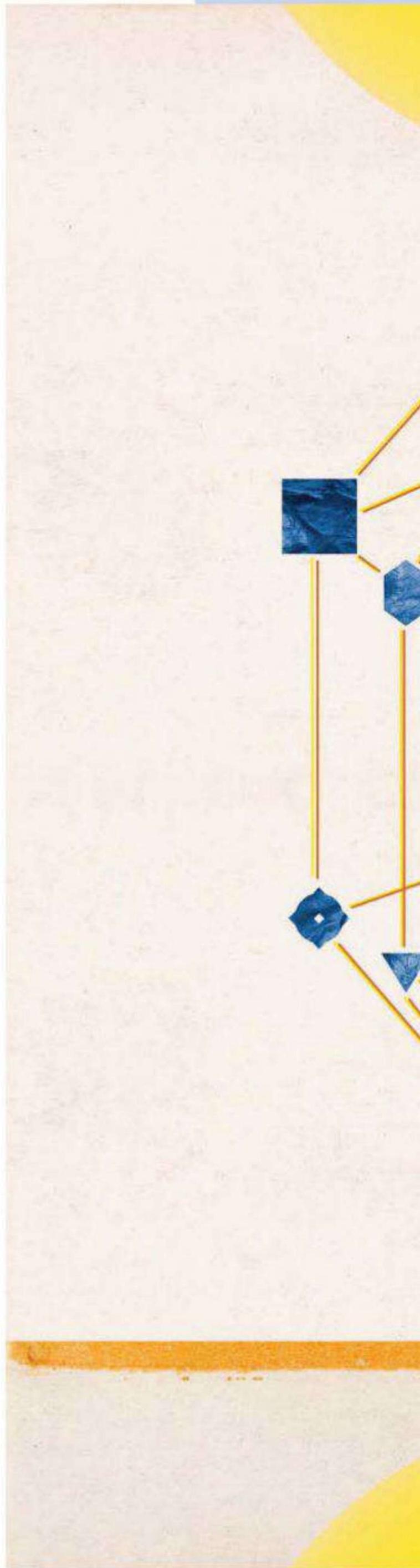
If anything, brain scanning has undermined Descartes's maxim. You, too, might be a zombie. "I happen to be one myself," says Stanford University philosopher Paul Skokowski. "And so, even if you don't realise it, are you."

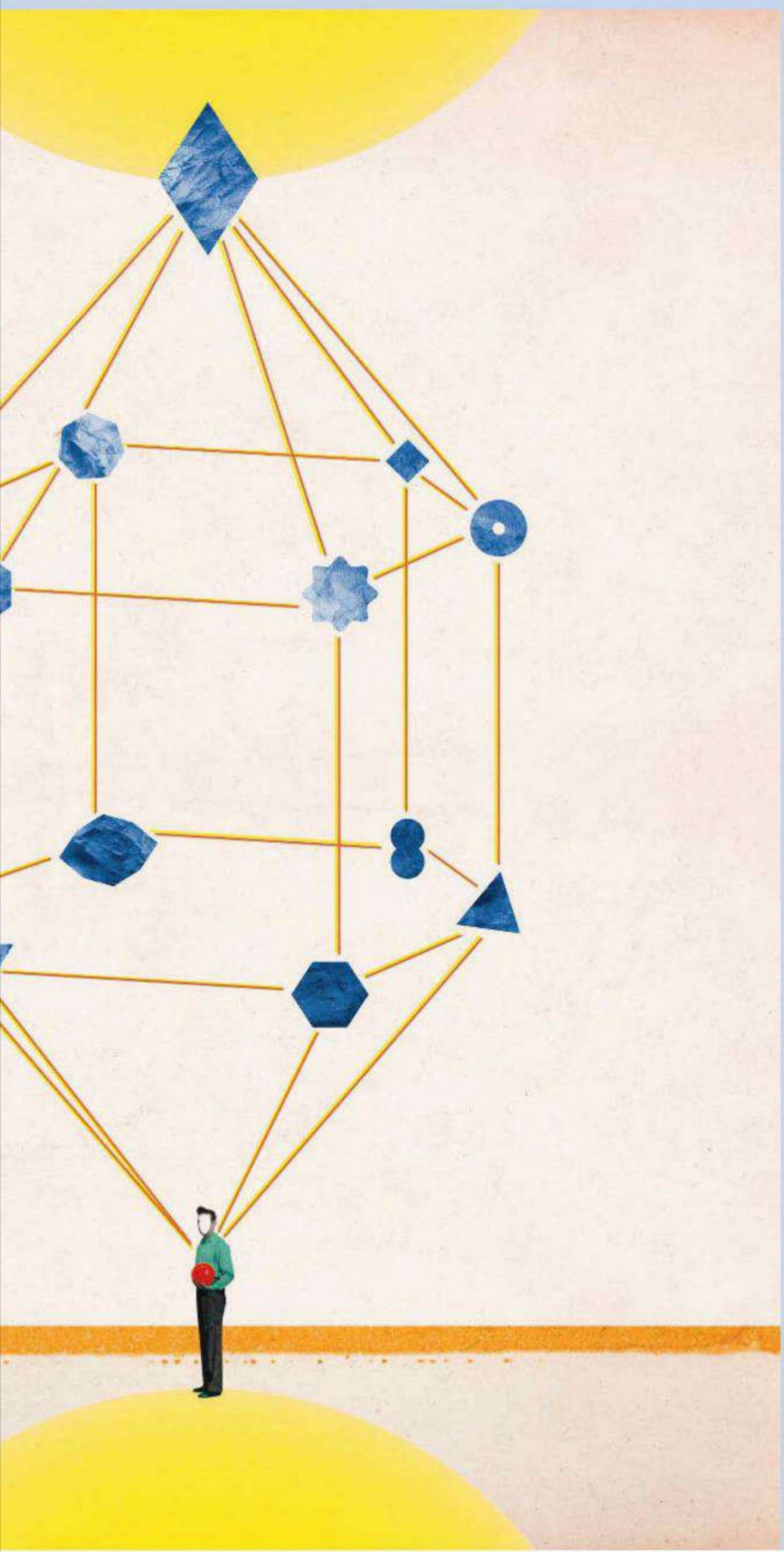
Skokowski's assertion is based on the belief, particularly common among neuroscientists who study brain scans, that we do not have free will. There is no ghost in the machine; our actions are driven by brain states that lie entirely beyond our control. "I think, therefore I am" might be an illusion.

So, it may well be that you live in a computer simulation in which you are the only self-aware creature. I could well be a zombie and so could you. Have an interesting day.

Michael Brooks ■

"I happen to be a zombie myself and even if you don't realise it, so are you"





Is there more than one me?

FAR, far away, in a galaxy with a remarkable resemblance to the Milky Way, is a star that looks remarkably like the sun. And on the star's third planet, which looks like a twin of the Earth, lives someonewho, for all the world, is you. Not only do they look the same as you and lead an identical life, they are reading this exact same article – in fact, they are focused on this very line.

Weird? I've hardly started. In fact, there are an infinite number of galaxies that look just like our own, containing infinite copies of you and your loved ones leading lives, up until this moment, that are absolutely identical to yours.

The existence of these parallel worlds is not just idle speculation. It does not depend on exotic theories such as the multiverse or the "many worlds" interpretation of quantum mechanics, in which the universe constantly bifurcates. It is an unavoidable consequence of the standard theory of our universe.

"Parallel worlds are an unavoidable consequence of our standard theory"

All this needs some explanation. The furthest we can see is the distance light has been able to travel since the universe was born 13.7 billion years ago. Light from objects further away has not arrived yet. They are beyond our cosmic horizon.

Yet we know there is more to the universe. Radiation left over from the big bang appears to confirm that the cosmos went through a fleeting phase of superfast expansion known as inflation. And, according to inflation, there is effectively an infinite amount of universe out there.

So our observable universe is akin to a bubble and beyond it lies an infinite number of other bubbles that have a similarly restricted view. Each one experienced the same big bang we did and has the same laws of physics. Yet the initial conditions were slightly different, so different stars and galaxies congealed out of the cooling debris.

Despite this, finding another universe just like ours seems unlikely. Yet quantum mechanics tells a different story. Zoom in and you'll find that the universe is grainy, with space resembling a chessboard. ›

JIRAYU KOO

"If you could travel far enough you would come across a universe identical to ours"

Immediately after the big bang, our observable universe – our bubble – contained only a few "squares". So there were only a few places for the matter that seeded the formation of today's galaxies.

The neighbouring bubbles contained a slightly different arrangement of matter. So did their neighbours. And so on. But eventually you run out of possible ways to arrange the matter in the bubbles. Eventually you come across an identical bubble to ours. As a result, there are a finite number of ways history can play out. Given that the universe is infinite, there must be a infinite number of histories just like ours, plus an infinite number of different ones.

If you could travel far enough in any direction today, you would come across a universe identical to our observable universe right down to the last detail, including you. Max Tegmark at the Massachusetts Institute of Technology has worked out that to find your closest identical copy you would have to travel $10^{10^{28}}$ metres. That corresponds to 1 followed by 10 billion billion billion zeroes.

Sadly that means you will never be able to meet your other you. With each passing moment, more of the universe appears over the horizon. Yet by the time our observable universe had expanded to encompass your nearest doppelganger, all the stars will have long burned out.

Remarkably, the only way to evade this bizarre conclusion is if our standard pictures of cosmology and quantum theory are wrong. Unsettled? You're not alone. Cosmologist Alexander Vilenkin of Tufts University in Medford, Massachusetts, has been working on such ideas for more than 25 years. "I have never been happy with the idea that there are an infinite number of Alexander Vilenkins out there," he says. "Unfortunately, I think it is likely to be true."

It is worth reiterating that this is the most basic and uncontroversial of all conceptions of multiple universes. There are many other "multiverse" theories. For instance, string theory, which views the fundamental building blocks of matter as ultra-tiny, vibrating strings of mass-energy, predicts the existence of other universes. The fact that the universe is apparently fine-tuned for us may be telling us of the existence of other universes with different laws of physics (see page 34). And then there is the many worlds interpretation of quantum mechanics in which all possible histories and futures – including yours – play out in separate universes. Many worlds is a minority view but if it is true there is a universe somewhere where you are Wimbledon champion.

Tegmark has classified such multiverses into a hierarchy of ever bigger versions (arxiv.org/abs/astro-ph/0302131), but nobody yet knows if or how all these versions mesh together. The multiverse is an emerging idea; science in the making. The dust has yet to settle and give us – and our infinite doppelgangers – a consistent and clear picture. Marcus Chown ■

Will we die out?

WRESTLING with mortality is difficult. But it is not just the prospect of personal annihilation that we have the dubious luxury of contemplating. One day, humanity itself will cease to exist. Like all species, we will either become extinct or evolve into something else. From a purely existential perspective the latter sounds infinitely preferable. So what are our chances?

First the good news: time is on our side. The average mammalian species lasts around 1 million years before it evolves into something else or dies out. By that reckoning, *Homo sapiens* has some 800,000 years to play with.

But that's assuming we are just another mammal. It is tempting to think that we have changed the game so drastically that the normal rules do not apply. Have we?

Let's deal with evolution first. There are two key ingredients: variation and selection. The key generator of variation is genetic mutation, and we certainly haven't broken free of that. "If anything, we are probably increasing the rate of mutational change," says Christopher Wills at the University of California, San Diego, noting that our world is awash with human-made mutagens.

But it is conceivable that we have changed the rules of natural selection. In general, individuals who are better adapted to their environment are more likely to survive and pass on their genes. Is that still true for humans when modern medicine and technology have increased everybody's ability to survive?

It seems that it is. Advances in genomic analysis make it clear that natural selection is still alive and kicking. One study found that around 1800 gene variations have become common in the past 50,000 years (*Nature*, vol 437, p 1299). Another study found that selection actually accelerated over this time, perhaps because by colonising the world and creating complex cultures we have subjected ourselves to a wide variety of new selection pressures (*Proceedings of the National Academy of Sciences*, vol 104, p 20753).

"There is no reason to think that humans will stop evolving," says Stephen Stearns at Yale University, whose research reveals continuing evolution in modern populations. "The only question is in what ways will we change as we continue to evolve."

"The only question is in what ways we will change as we continue to evolve"

Without strong, universal forces shaping our entire species, we could evolve aimlessly, but even then the cumulative effects would be significant. Palaeoanthropologist Chris Stringer from the Natural History Museum in London foresees a distant future hundreds of thousands of years from now when our descendents have accrued so many genetic and physical changes that they could no longer interbreed with today's humans, and would therefore be a new species.

Presumably it would be recognisable as a hominin, but what exactly it might look like is anybody's guess.

Dramatic events

Dramatic events would speed things up. "A pandemic could swiftly reduce the human population by 90 per cent or more," says philosopher Dan Dennett from Tufts University in Medford, Massachusetts. Depending on who was able to survive, the humans that passed through this bottleneck could emerge as a new species.

Extreme climate change could have the same effect. And if some people left Earth and set up home elsewhere, speciation seems inevitable, says Wills.

Advances in reproductive technology might allow us to direct our own evolution by picking the characteristics we most desire for our offspring. We could even choose to become superhuman as advances in computing, robotics, biotechnology and nanotechnology enable us to rebuild and extend our bodies and brains. "Very few people will opt out completely," predicts futurologist Ray Kurzweil. "Kind of like the Amish today."

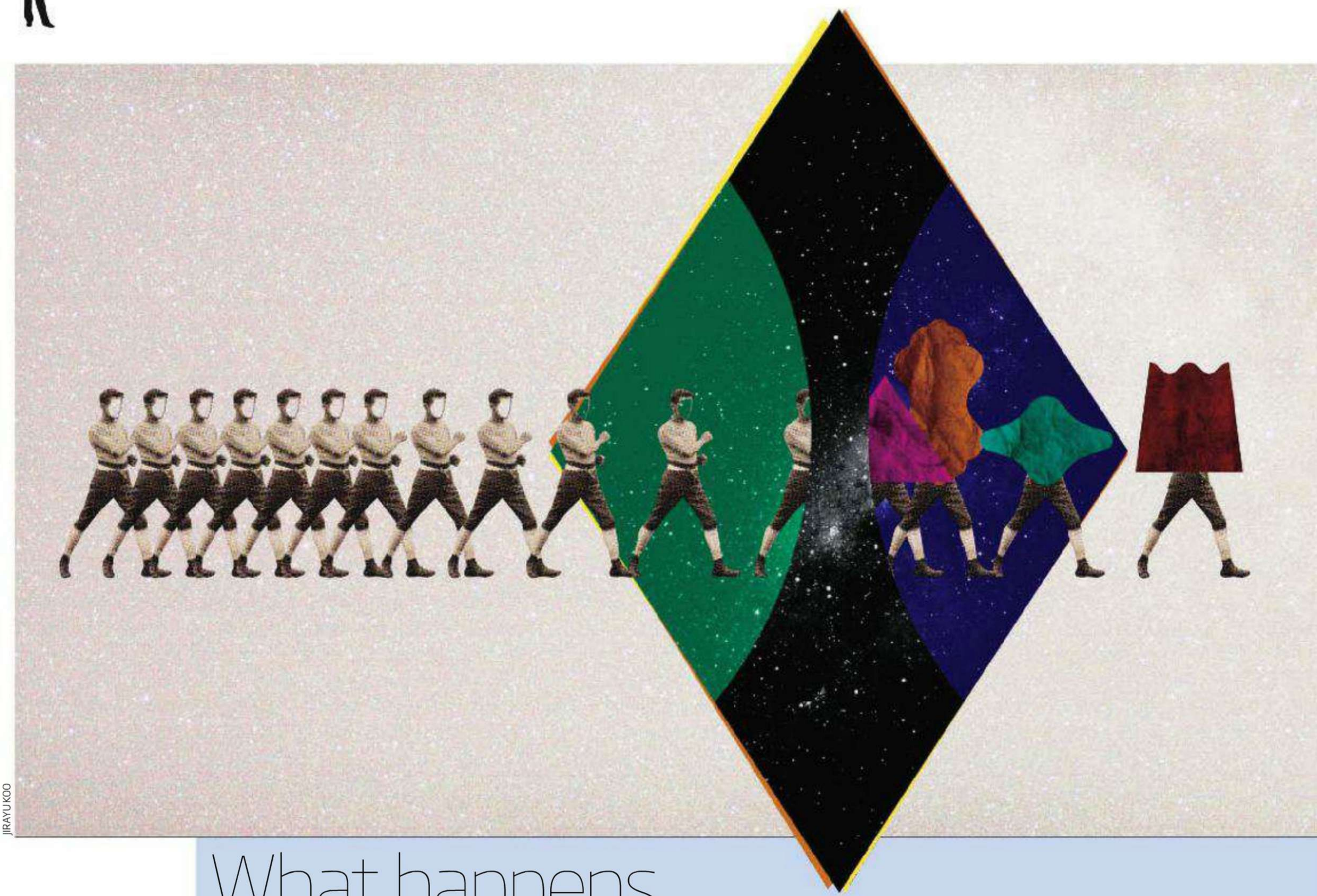
Of course extinction is also a possibility. In the wild, extinctions occur for a variety of reasons, with competition from other species, predation and loss of genetic diversity among the leading causes. Given our huge population and our dominance over other species none of these seem to be a threat.

But we may well do unto ourselves what we have done to so many other species and cause enough environmental destruction to drive ourselves to extinction. We also have no control over phenomena that have wreaked havoc in the past, such as asteroids, supervolcanoes and the like.

Meanwhile, our species' indomitable curiosity may lead us to create a new form of annihilation – perhaps with atomic particles, "grey goo" or a lethal bioengineered life form.

Although we can't predict our future, we can say one thing for certain: our existence is just a passing whim. **Kate Douglas** ■

LARS HANSEN/GALLERY STOCK



JIRAYU KOO

What happens when we become obsolete?

OUR brains are incredible. They are the most complicated things in the universe that we know of. And yet there is no reason to think that they are anything other than flesh-and-blood machines – which means we should able be build machines that can emulate them.

Artificial intelligences on a human level would probably not remain at that level for long. AIs are expected to become smarter than us before 2050 (*Technological Forecasting and Social Change*, vol 78, p 185). A few researchers even think it could happen in the next decade.

For the first time, we would no longer be the most intelligent beings on the planet. The consequences could be stupendous. In 1993, the mathematician and sci-fi author Vernor Vinge dubbed this point "the singularity", because he saw it as a turning point that would transform the world. So what will happen to us? Nobody really knows. "It's like cockroaches and dogs trying to predict the future of human technology," says Ben Goertzel, leader of OpenCog, an open source project to create AIs with general intelligence.

That hasn't stopped people from considering various scenarios (*Artificial Intelligence*, vol 171, p 1161). One distinct possibility is that AIs will exterminate us, which seems especially likely if the first are robots spawned in military labs.

Physicist and author David Deutsch of the University of Oxford has suggested that the way to avoid "a rogue AI apocalypse" is to welcome AIs into our existing institutions. But even if that were feasible, how could we compete with smarter and faster beings capable of working tirelessly 24/7 without ever getting tired or ill? They are likely to rapidly surpass all our scientific, technological and artistic achievements. Our precocious creations would soon end up owning the place.

One way or another, then, AIs look set to take over. One cause for optimism is that they will not be stuck on the planet like us fragile humans. A 1000-year trip to Epsilon Eridani is not so daunting if you can just turn yourself off until you get there. In fact, AIs may prefer to leave Earth. "They will probably work better in space, where it's supercool," says Goertzel.

So we are not necessarily doomed to compete with AIs for energy and resources – a battle we are not likely win. With a galaxy to colonise, they may be content to let us keep our damp little planet. They might be as indifferent to us as we are to ants, or

"Artificial intelligences might be as indifferent to us as we are to ants"

manage Earth as a kind of nature reserve.

That might seem like a futile existence. But most people won't be too bothered by the knowledge that they are inferior, Goertzel thinks – not as long as there's sex, drugs and rock'n'roll. Some people will continue to do science and art for the sheer joy of it, regardless of how poor their work is in comparison to the machines'.

For Goertzel, the best case scenario would be that the AIs provide a "human reserve" for those who want to stay as they are, while offering those who want it the chance to slowly transform themselves into something more than humans. "You would want it to be a gradual change, so at each step of the way you still feel yourself."

Stay human and die, or transform into a near-immortal superintelligence – what a choice. Michael Le Page ■

Am I the same person I was yesterday?

IT'S THERE when we wake up and slips away when we fall asleep, maybe to reappear in our dreams. It's that feeling we have of being anchored in a body we own and control and perceive the world from within. It's the feeling of personal identity that stretches across time, from our first memories, via the here and now, to some imagined future. It's all of these tied into a coherent whole. It's our sense of self.

Humans have pondered the nature of the self for millennia. Is it real or an illusion? And if real, what is it, and where do we find it?

Different philosophical traditions have reached radically different conclusions. At one extreme is the Buddhist concept of "no self", in which you are merely a fleeting collection of thoughts and sensations. At the other are dualist ideas, most recently associated with the philosopher Karl Popper and Nobel laureate and neuroscientist John Eccles. They argued that the self exists as a separate "field" which interacts with and controls the brain.

Modern science, if anything, is leaning towards Buddhism. Our sense of self is not an entity in its own right, but emerges from general purpose processes in the brain.

Seth Gillihan and Martha Farah of the University of Pennsylvania in Philadelphia have proposed a view of the self that has three strands: the physical self (which arises from our sense of embodiment); the psychological self (which comprises our subjective point-of-view, our autobiographical memories and the ability to differentiate between self and others); and a higher level sense of agency, which attributes the actions of the physical self to the psychological self (*Psychological Bulletin*, vol 131, p 76).

We are now uncovering some of the brain processes underlying these strands. For instance, Olaf Blanke of the Swiss Federal Institute of Technology in Lausanne and colleagues have shown that the physical sense of self is centred on the temporo-parietal cortex. It integrates information from your senses to create a sense of embodiment, a feeling of being located in a particular body in a particular place. That feeling can be spectacularly disrupted if the temporo-parietal cortex receives contradictory inputs, causing it to generate out-of-body experiences (*New Scientist*, 10 October 2009, p 34).

Being in charge

It is proving harder to find the site of our sense of agency – that feeling of being in charge of our actions. In one functional MRI study volunteers with joysticks moved images around on a computer screen. When the volunteer felt he had initiated the action, the brain's anterior insula was activated but the right inferior parietal cortex lit up when the volunteer attributed the action to the experimenter (*Neuroimage*, vol 15, p 596).

But other researchers, using different experiments, have identified many more brain regions that seem to be responsible for the sense of agency.

Within the brain, it seems, the self is both everywhere and nowhere. "If you make a list [for what's needed for a sense of self], there is hardly a brain region untouched," says cognitive philosopher Thomas Metzinger of Johannes Gutenberg University in Mainz, Germany. Metzinger interprets this as meaning the self is an illusion. We are, he says, fooled by our brains into believing that we are substantial and unchanging.

Mental disorders also make it abundantly clear that this entity that we regard as inviolate is not so. For example, those suffering from schizophrenia harbour delusions that experiences and thoughts are being implanted in their brain by someone or something else. "In some sense, it's a disorder of the self, because these ›

people are doing things, but they are not feeling as if they themselves are doing them," says Anil Seth of the University of Sussex in the UK. "That's a disorder of agency."

Another striking condition is depersonalisation disorder, in which people feel a persistent sense of detachment from their body and thoughts. Even the narrative we have of ourselves as children growing up, becoming adults and growing old, which is carefully constructed from our bank of autobiographical memories, is error prone. Studies have shown that each time we recall an episode from our past, we remember the details differently, thus altering ourselves (*Physics of Life Reviews*, vol 7, p 88).

"Even the narrative we have of ourselves growing up is error prone"

So the self, despite its seeming constancy and solidity, is constantly changing. We are not the same person we were a year ago and we will be different tomorrow or a year from now. And the only reason we believe otherwise is because the brain does such a stellar job of pulling the wool over our eyes.
Anil Ananthaswamy ■

How will it all end?

YOUR TEMPORARY BODY

YOUR lifelong sense of self is intimately tied to your body, but how much of that body stays with you for life? The answer is surprisingly little. If you live to be, say, 75 years old, the vast majority of your body will be younger than "you" are.

The cells lining your gut, for example, are replaced about every five days. The outer layer of your skin turns over every two weeks and you get a new set of red blood cells every four months. That is not so surprising given that these cells are on the frontline of wear and tear. But the rest of your body also needs a refit from time to time.

Using a variant of carbon dating, a team led by Jonas Frisén at the Karolinska Institute in Stockholm, Sweden, have discovered that the average age of a bone cell is 10 years, a muscle cell 15 years and a fat cell about 9.5 years. Your heart cells are on average six years younger than you; if you live beyond 50 about half of the cells in your heart will have been replaced.

The exception is your brain, most of which stays with you for life. But renewal happens here too. There are cells in your cerebellum and hippocampus that are younger than you.

All of which puts the idea of lifelong personal identity into perspective. Imagine being given a car on the day you are born. Over the next 70 years you gradually replace almost every part, from the tail pipe to the headlights. A few bits and pieces remain, but is it really the same car? Think about it. Graham Lawton ■

IT IS three weeks after the end of time, and at the Post-Universe Conference of Cosmology and Other Loose Ends, Professor Adams is standing in front of a restless audience telling them in smug tones what they already know. The universe ended in precisely the way that his own theory predicted, in a rather uncomfortable event known as the "Big Slurp".

Of course, by definition there can be no such meeting and no way to prove or disprove a theory about the end of all things. But this untestable question tugs at our morbid curiosity. In recent years physicists have been peering deep into the tea leaves of time to try to foretell our ultimate fate. Will the universe be finished off by a big freeze, a big rip, a big crunch… or a big something else?

"The foundations would be yanked from under us, we would cease to exist"

To make a first attempt at this long-range forecast, we can just extrapolate current trends. Today's universe is expanding, and the expansion is accelerating as the repulsive agent called dark energy takes hold. Projecting our ballooning universe into the future, we seem to be doomed to a dingy end. Most of known space will fly off into the darkness, isolating our local group of galaxies in its own lonely pocket universe. The stars will fade and eventually matter itself may fall apart as protons decay, leaving behind nothing but a wispy gas of fundamental particles, ever-more tenuous and ever colder.

Or it could be worse. We don't know what dark energy is, so we don't know whether it will remain constant into the distant future. The repulsion might get stronger as space expands. If this growing "phantom energy" really gets going, the eventual end will come in a split second of cosmic violence called the big rip, as planets, molecules and finally subatomic particles are shredded. Then again, some form of attractive cosmic force could arise to overpower today's repulsion and pull the galaxies back together again, crushing everything to a point of infinite density – a big crunch.

Fortunately, neither of these violent ends will happen any time soon. Observations show that dark energy is changing slowly if at all, implying that a big rip or big crunch is probably tens of billions of years away at least.

An even more disquieting possibility could be just around the corner, however. The very nature of space-time may be unstable. According to string theory, for example, the vacuum of space seems to be free to adopt any of a bewildering variety of different states, which would support different kinds of forces and particles, even different numbers of dimensions. Our apparently firm reality might suddenly decay into a state with lower energy. The foundations of our existence would suddenly be yanked from under us and we, along with any familiar forms of matter, would cease to exist.

Transmogrification

If the vacuum does decay, it will happen at some point in space first, and then race outwards in a spherical shock-front of grisly transmogrification travelling at just a tiny fraction less than the speed of light. In theory we would get some warning of approaching doom, but not a lot. "Much less than a microsecond," says cosmologist Alexander Vilenkin of Tufts University in Medford, Massachusetts. At this very moment a wave of ultimate weirdness might be turning the moon into ectoplasm and bearing down on Earth.

Vilenkin thinks that such an end is almost inevitable; that unless a big rip gets us first, the vacuum will eventually drop into a negative energy state. After the transformation, space would then exert strong gravity of its own, pulling what's left of the universe into a big crunch.

That, however, need not be the end of everything. If our own universe is merely one within an ever-branching and growing multiverse, as some theories predict, then the cosmos as a whole will endure even if each of its branches has a limited lifespan. And for our local universe there remains the hope of resurrection. Today's physical theories break down at a big crunch or a big rip, allowing the possibility that a new universe could rise from the ashes (in a big bounce, or some other big as-yet-unnamed thing). And in the case of a big freeze, there will be so much time to play with that a random quantum fluctuation might spark a whole new big bang. Perhaps that impossible cosmology conference could happen after all. Perhaps existence will never end. Stephen Battersby ■

MILO NEWMAN/MILLENNIUM IMAGES, UK

Pushing the body's boundaries

Performance artist **Stelarc** talks to **Tiffany O'Callaghan** about humanity in the age of technology

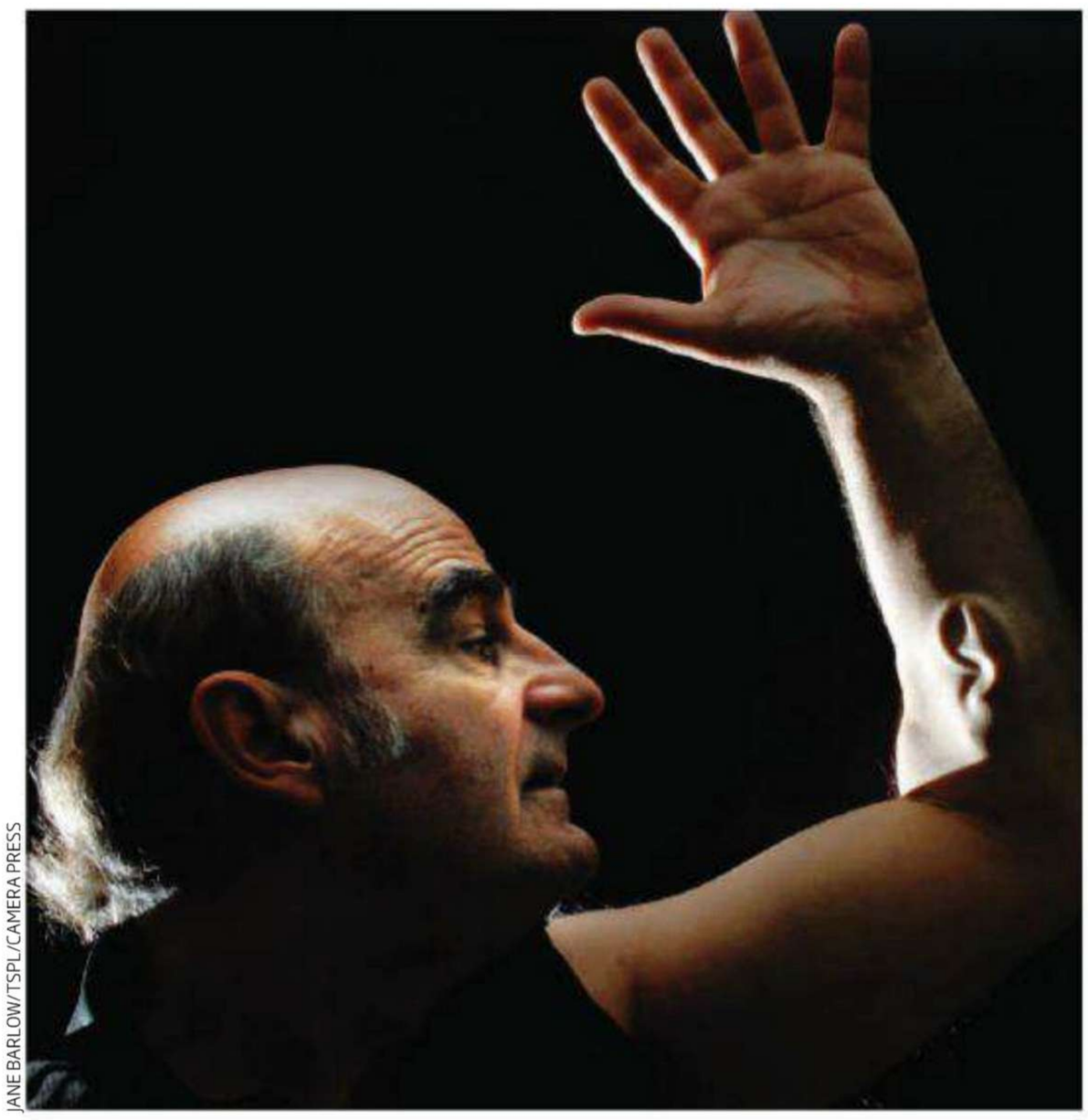
As an artist, what is your role in shaping technology?
It's a very modest one. Each new technology generates novel information and unexpected images of the body and the world, which often destabilises our paradigms of what a body is and how it operates. Technology generates uncertainty, it constructs the unexpected. That's what makes it exciting to incorporate as part of artistic expression.

What is it about the boundaries of the body that fascinates you?
All of my projects explore alternate anatomical architectures – a body with a third hand, or an extra ear, or an artwork inside a bodily space instead of a public space.

We are biological bodies, but we are often accelerated, augmented and enhanced by technology. There may be a time soon when bodies become portals of sensory experience. I might be able to see with your eyes when you are in New York, for example, or listen with someone's ears from London. We can no longer think of the body as simplistically bound by its skin and containing a single self.

Will it become harder to tell where we end and technology begins?
That's beginning to be the case. In 1000 years' time, perhaps technology will be invisible because it will be inside our bodies. We will be able to recolonise the human body with micromachines, nanosensors and nanobots that augment our bacterial and viral population.

Will the body become obsolete?
I think that the body is obsolete. From the standpoint that it's increasingly inadequate to cope with the technological terrain it inhabits. That doesn't mean we can do without a body; there has to be some kind of embodiment. But I think the possibilities are there for unexpected hybrids of biology, technology and computer code. We are very much a meat, metal and software system now.


JANE BARLOW/TSPL/CAMERA PRESS

Talk to the arm: Stelarc wants to add a microphone to his implanted ear

> **"Bodies could become portals. I might be able to see with your eyes when you are in New York"**

Do you worry that your work combining technology and the body might jeopardise your health?
There's been no deliberate attempt to endanger the body, but to do anything physically difficult or technically complicated, yes, those actions might be risky. You do things with a positive attitude and a sense that you need to do this if you are to achieve anything.

Is physical discomfort part of exploring the body's boundaries?
Only in a very general sense. If you are going to suspend your body with 18 hooks in the skin, and you are going to be hoisted 60 metres high by a large crane, there may be all sorts of possible problems. You anticipate those and try to take appropriate precautions. Those performances were not done to have a painful experience.

Why do you have an ear on your left arm?
At the moment this is only a relief of an ear. It's partly surgically constructed and partly cell grown. We need to surgically lift the helix to create an ear flap, and then we will grow a soft earlobe using my adult stem cells. When the ear is more of a three dimensional structure we will reinsert the microphone and connect it to a wireless transmitter. Then any Wi-Fi hotspot will internet-enable the ear.

We are replicating a bodily structure, relocating and then rewiring it for additional capabilities.

So you had a microphone in your arm before?
We had a microphone in there for a couple of weeks. At the end of the surgery the sound was picked up and wirelessly transmitted. So the project is plausible. This ear is effectively an internet organ for people in other places to access, a mobile acoustical organ that anyone online could access and hear what the ear is listening to.

What future projects do you have up your sleeve?
One project is to engineer an insect-like microrobot that can climb up my tongue and into my mouth. It will have a webcam and an LED on-board so we will be able to stream the images live on the internet. I will just have to be careful not to swallow the robot. We will have to make multiples just in case that happens. ■

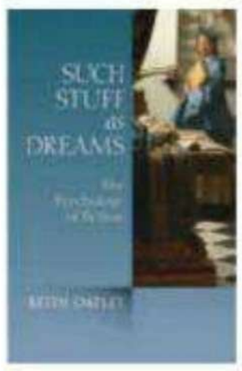
PROFILE
Stelarc is a performance artist who explores the capabilities of the human body. His work is featured in Art & Science at the GV Art gallery in London until 24 September

Stories I tell myself

Fiction fuels the imagination, but does it also serve a grander psychological purpose?

Such Stuff As Dreams: The psychology of fiction by Keith Oatley, Wiley-Blackwell, £16.99

Reviewed by Michael Bond



IF YOU'VE ever been in a book club or enjoy discussing books with friends, you will know that people often interpret stories in different ways, reflecting their own experiences, inclinations and views of the world. Take Jane Austen's *Pride and Prejudice*. While some readers may have little trouble forgiving Mr Darcy's conceit once he starts to show affection for Elizabeth, others might question whether he is really capable of change.

This is one of the ways fiction seduces us: no matter how tight the narrative structure, or how well-defined the characters, we can always follow our own imaginings. In the technological era, this idea is evident in the nonlinear plot sequences of video games that let players decide for themselves how a storyline progresses. A similar device was used in the *Choose Your Own Adventure* series of books, hugely popular with adolescents in the 1980s and 1990s.

The idea that fiction is not just the writer's creation, but a co-conspiracy between writer and reader, is a central theme in *Such Stuff As Dreams*. Written by novelist and cognitive psychologist Keith Oatley, the book covers a lot of ground, from the evolution of language and the origins of creativity to the mechanics of empathy and theory of mind. Oatley goes to great lengths to build a psychological theory of fiction – delving into the effects of fiction on the minds of readers and authors, how we identify with characters, the way that stories move us, how they can change the way we see ourselves and how they might even improve our social skills.

Unfortunately for Oatley's theory, *Such Stuff As Dreams* reads less like a work of psychology than one of literary criticism. It is no less impressive for that. Much of the discussion is compelling, and this book could well change the way you read. The psychology, however, sometimes feels a little flat, largely because there is a lack of convincing evidence to back his main hypothesis – that reading novels significantly improves people's capacity to navigate their social world, and that fiction is therefore "good for you".

"Fiction is not just the writer's creation, but a co-conspiracy between writer and reader"

Still, his writing is entertaining and he's tapping into a rich vein, and I hope he will explore the subject further. It would be interesting to know, for example, how recent psychological findings about the slipperiness of personality might find their way into fiction or affect the way we understand the concept of character – up to now considered an immutable quality in both the real and imagined world.

Spare a thought for Mr Darcy's immaculate friend Mr Bingley, described in Austen's novel (which Oatley extensively mines) as "sensible, good humoured, lively... handsome... with such perfect good-breeding... His character is thereby complete". Today's social psychologists may beg to differ.

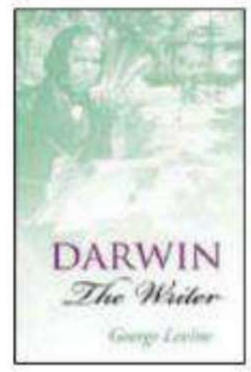
BERNARD FAUCON/AGENCE VU/CAMERA PRESS

Mind expanding: reading fiction can shape our personalities

Natural prose

Darwin the Writer by George Levine, Oxford University Press, £19.99/$35

Reviewed by Jonathon Keats



MIDWAY through *On the Origin of Species*, Charles Darwin describes how he scooped mud from a local pond into a breakfast cup. An impressive 537 weeds sprouted over the next six months, suggesting to him how much life can be transported on the feet of water birds. According to literary scholar George Levine, we should be equally impressed that an object as homely as a breakfast cup appears in the most revolutionary text of the 19th century.

In Levine's view, Darwin's references to domestic life help to make him a character with whom the reader can identify as he finds "startling" explanations for natural phenomena that readers – at least in the 1800s – attributed to God. Equally essential, mundane domesticity serves to ground a theory in which nothing is as it seems: the intricate design of life has no designer and natural wonders arise from commonplace blunders. Levine is correct to identify paradox as Darwin's characteristic expression, and convincing when he shows the influence of Darwinian paradox on modernist authors, beginning with Oscar Wilde.

Levine is most provocative when he contrasts Darwin's articulation of natural selection with accounts that have followed, notably Daniel Dennett's idea of evolution as an "algorithm". Though Levine doesn't explore the idea sufficiently, he suggests that a shift in the rhetoric of Darwinism may have fostered the current outbreak of creationism – and that those seeking to popularise evolution today would do well to start by replenishing Darwin's breakfast cup.

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Benaroya Research Institute
WA - Washington
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Translational Science Strategist

AstraZeneca US
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Dow Chemical (US)
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St. Jude Children's Research Hospital
TN - Tennessee
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IA - Iowa
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PAUL MCDEVITT

FEEDBACK is indebted to James Newton-Thomas for his assistance in elucidating the "bearish Dark Cloud Cover candlestick pattern" that so puzzled us when we read of it in the "Forex analyst picks" column of a free newspaper aimed at London's financial folk (14 May and 25 June). James sends us to "The Top 10 Best Candlestick Patterns" (bit.ly/candlestickpatterns) on a website that promises we can "learn a unique trading strategy!"

It seems that the bearish Dark Cloud Cover pattern is just one of many candlestick patterns – others are named "engulfing", "hammer", "harami", "piercing", "doji" and "kicker", and they may come in "bullish" or "bearish" flavours. Apparently, the basic idea is to plot the high and low prices of a stock or currency on a graph, join them with a vertical line, and then over that draw a rectangle with the opening and closing prices at the top and bottom (or vice versa). Typically, you end up with an image that looks like a candle that can be burned at both ends.

Then you compare the candlesticks for succeeding days, or hours if you're a twitchy trader. For example, when you see the "harami" pattern, the site suggests, "the first thing that comes to mind is that the momentum preceding it has stopped". It is?

Our first thought is: that's an interesting way of predicting where a graph goes next. Has anyone tried it with any other chaotic-seeming data, such as daily temperatures? Then we remember that the point of trading is to divine other traders' perceptions of your perceptions of what the price will be in a day or an hour. So if they're looking at candlesticks too... our head hurts again.

Would the candlestick technhique be worth trying as an aid to betting on something else that depends on feelings of confidence, such as cricket or baseball batting averages? Possibly – but on the whole, we're still backing the chimps (25 June).

SINCE we wondered what is being polished in the "Didn't I do well" gesture that involves blowing on the knuckles of the right hand and then rubbing them on the left lapel (2 July), we have been inundated with answers.

They all fall into one of two categories. In the first, readers assert that what is being polished is the medals that the performer of the gesture has been awarded for "doing well". Proponents of this theory say the gesture was commonly used in the years following the second world war.

In the second and much more popular category, readers have been telling us that we got the gesture wrong. It is not the knuckles that are being breathed on and polished, they say – it is the fingernails. Several readers also point out that there is another beat to the gesture that we missed. After polishing, the hand is held out with the fingers spread and the palm facing away so that the polisher can admire those exquisitely shiny nails.

"The gesture represents nonchalance," says Andy Green. "It indicates that the difficult task was completed with such ease that you didn't give it a second thought and moved on to buff your nails out of boredom."

We're not alone in contemplating this. Liz Whitehouse alerts us to a discussion of the gesture on the Straight Dope bulletin board at bit.ly/donewell.

REACHING gingerly into the Feedback piling system, we discover a report from Peter Wheelhouse of a sign on a door at the UK's University of Bath declaring firmly: "No exit – violators will be removed from the building."

How does that work, then? Peter envisages security operatives dragging the violator back inside the building in order to remove them; and in the event that they used the same door themselves becoming violators and having to be removed, ad infinitum. And what about emergencies?

Does this sign still grace the sports centre, or have the mathematical sciences people had a word with them?

READERS have pointed out that the worrying restaurant sign saying "Come in. We're Closed" that Paul Brown came across on Flickr (18 June) is actually a work of art created by the Australian artist and poet Richard Tipping (bit.ly/richardtipping). You can order the sign from online outlets such as Viper Records (bit.ly/closedsign), along with a companion sign saying "Sorry. We're open".

FINALLY, Maggie O'Hanlon was disconcerted to learn that the eco-friendly boots she bought from Earth Spirit have biodegradable soles. "Good for you – good for the planet," proclaims the label.

That all seems fine, except for one caveat: Maggie can't help wondering how long the biodegrading takes.

Someone in the Dubai government hasn't got the hang of the internet. Saeed Al Mutawaa sends us a photo of a sign saying: "To collect online documents pls. contact Delivery Counter"

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.

For your ice only

To save mixing my gin or vodka martinis with ice and over-diluting them I pre-mix them and put them in my freezer. When I take them out they are a sludgy mixture of randomly aligned ice sheets which melt quite quickly once in a glass. How do these sheets form? I tend to make my martinis about 8 parts vodka or gin to 1 part dry vermouth.

■ Practically all ice is crystalline; the crystals grow as cold molecules packing onto their outer surfaces, rather like infinitesimal Lego blocks.

When water molecules fit together, certain joints are stronger than others, so the crystals grow faster in some directions than others. Molecules of pure water pack easily in almost any direction, so ice forms nondescript blocks unless freezing is slow. But foreign molecules, such as sugar or ethanol, interfere strongly with packing in certain directions, so needles and plates result.

Such crystals also interfere with each other's growth and create temperature and concentration gradients that favour alignment, leading to the packed crystals found in ice lollies for instance, which grow from the lolly stick that acts as a nucleation site.

Ice crystals tend to dissolve in the surrounding liquid, with melting happening largely at the crystal surface; arrays of thin crystals present a large surface, and consequently melt rapidly. This explains why the sheets in the martini melt quickly. The surrounding solution also lost water when the ice froze, increasing its concentration, and that accelerates melting, much as salt melts snow on roads. The result is a very cold martini, but drink it quickly; it will take up heat correspondingly rapidly.

Jon Richfield
Somerset West, South Africa

Grrrr

How long can you keep a tiger cub as a pet? I have read of people doing so, but surely, for very obvious reasons, there is a time limit to how long you can keep a carnivore in your living room?

■ You can keep a tiger cub as a pet until it grows up and gets hungry or loses patience with you.

Doug Grigg
Cannonvale, Queensland, Australia

■ If there is an upper age limit then one is assuming that tigers are suitable for a domestic environment below that age. The flaw with this is that they would need their mother at this stage and, if one has qualms about keeping an adult tiger, then one would not even contemplate a maternal tigress.

As for the implication that there is a stage in a juvenile tiger's physical development which would mark a watershed in pet/owner relations, then it is a case of "take your pick". Cubs become fully mobile at about eight weeks, when they are still endowed with cuteness, but you wouldn't want one to bite or scratch you. At 18 months, young tigers become independent in terms of being capable of fending for themselves. Fending for themselves in this context generally means hunting. That does not mean they have left home, however. In the wild, cubs stay with mothers for up to two and a half years, and removing one may have emotional repercussions for an animal that is already a dangerous predator.

"You can keep a tiger cub as a pet until it grows up and gets hungry or loses patience with you"

Even if you and your family avoid featuring on the tiger's menu, there are the minor social, and, probably, legal difficulties arising out of the disappearance of your neighbours' pets. Tigers do not only kill to eat; they will also, in the wild, suppress local populations of any rival carnivores in their territory. These include wolves – and next-door's labrador. And, if it's a male tiger, there's the particularly noxious spray-marking of personal space to consider – tiger pee makes fox urine smell like Chanel No. 5.

Clearly it is not impossible to keep a tiger as a pet. According to the most recent statistics from the US Association of Zoos and Aquariums, some 12,000 are kept as pets in the US alone, ironically more than the world population of wild tigers, and largely as consequence of overbreeding by zoos in the 1980s and 1990s. How many are kept as domestic pets in the accepted sense, rather than wildlife parks or private enclosures, isn't known.

However, in a sad commentary on US animal welfare legislation, a large number of these big cats must be living in people's homes, as if they were large dogs. For instance, the American Society for the Prevention of Cruelty to Animals estimates there are 500 lions and tigers in metropolitan Houston alone. While 19 states have banned private ownership of big cats, only 15 of the others require an owner's licence, and 16 have no relevant legislation at all, despite the US's indigenous population of cougars being on the endangered species list.

These animals are all adults, so strictly speaking there is no upper age limit for keeping a tiger as a pet because it has grown too large, or its behaviour makes it unsuitable. The correct answer to the question is, of course, that no tiger of any age should live socially alongside people. Their proper place is in the wild.

Hadrian Jeffs
Norwich, UK

This week's question

BLACKSMITH'S DILEMMA

Why did American cowboys need to shoe their horses, but the native Americans did not?

Larry Curley
Huntingdon, Cambridgeshire, UK

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

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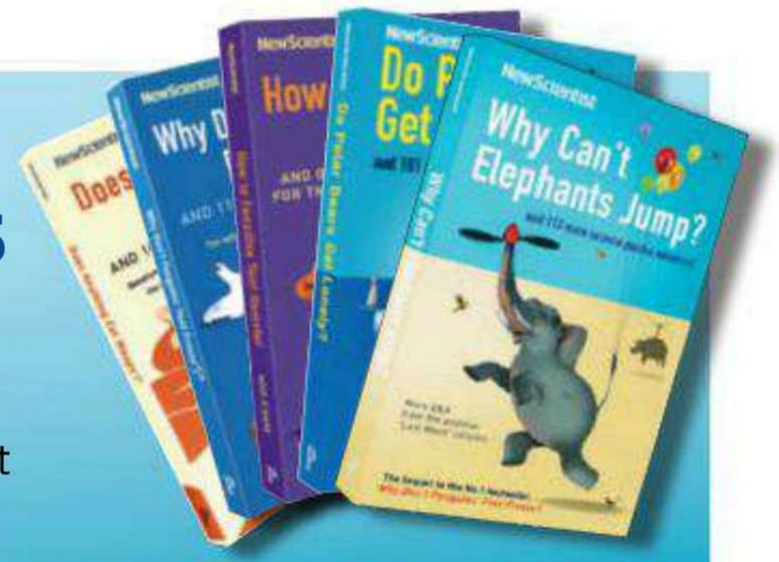

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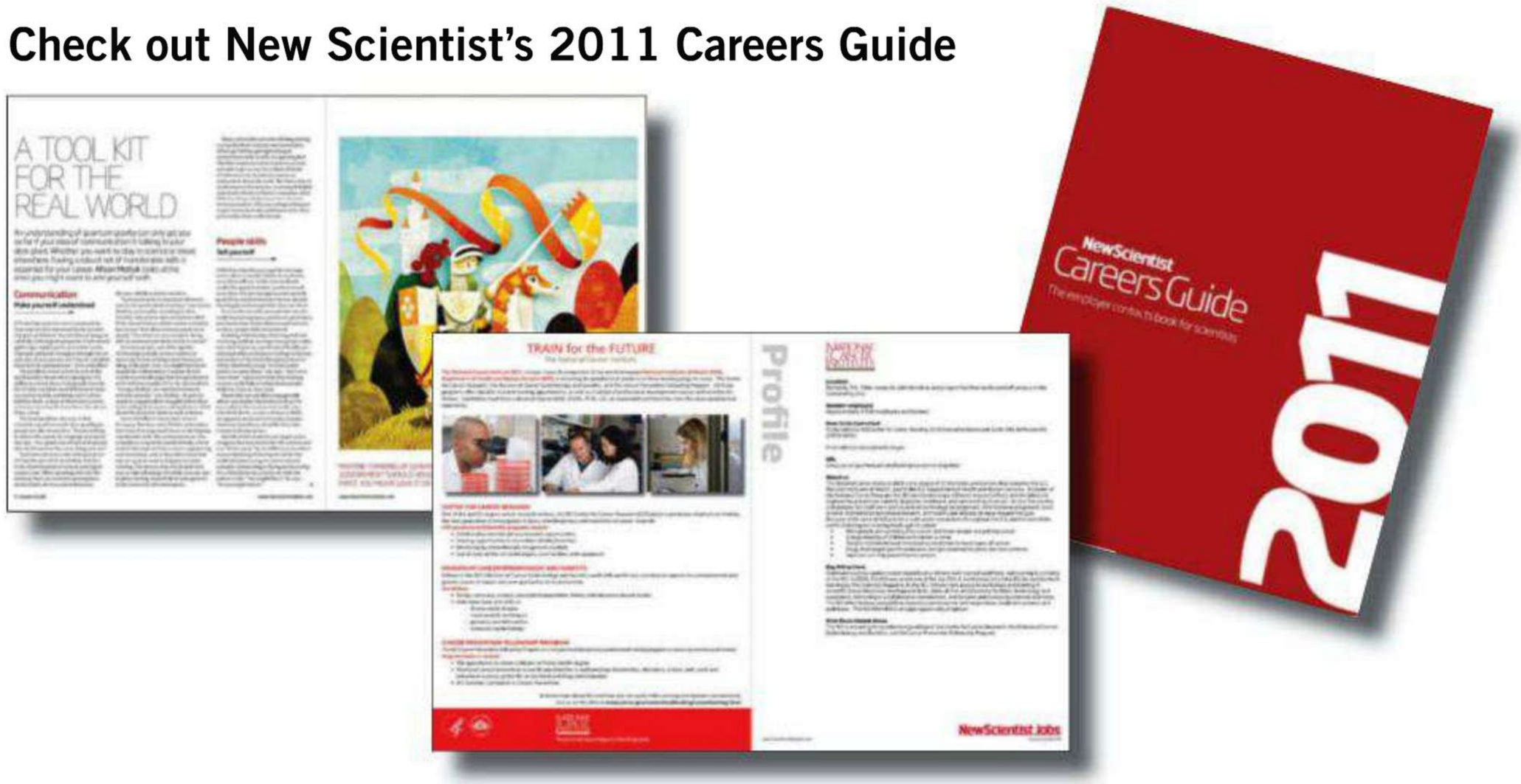

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